

DRAFT

**Treatability Study in Support of
Intrinsic Remediation
for POL Site SS-36**



**Eglin Air Force Base
Florida**

Prepared For

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

and

**Eglin Air Force Base
Florida**

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TREATABILITY STUDY IN SUPPORT OF

INTRINSIC REMEDIATION

for

POL SITE SS-36

EGLIN AIR FORCE BASE

FORT WALTON BEACH, FLORIDA

July 1995

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

TECHNOLOGY TRANSFER DIVISION

BROOKS AIR FORCE BASE

SAN ANTONIO, TEXAS

AND

EGLIN AIR FORCE BASE

FORT WALTON BEACH, FLORIDA

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EXECUTIVE SUMMARY

This report presents the results of a treatability study (TS) performed by Parsons Engineering Science, Inc. (Parsons ES) in conjunction with the Air Force Center for Environmental Excellence (AFCEE) and the United States Environmental Protection Agency (USEPA) Robert S. Kerr Environmental Research Laboratory (RSKERL) at Eglin Air Force Base (AFB), Florida. The purpose of this study was to evaluate the use of intrinsic remediation with long-term monitoring (LTM) as a remedial option for dissolved fuel-hydrocarbon contamination in the shallow saturated zone related to a 1988 motor gasoline (MOGAS) spill near Site SS-36. The main focus of this study was to assess the potential for petroleum hydrocarbon contamination in groundwater to migrate from Site SS-36 to potential receptors. Soil and groundwater contamination is known to be present at the site, with aqueous (i.e., dissolved), gaseous, and residual light nonaqueous phase liquid (LNAPL) contamination. This study evaluated the impact of the dissolved and residual LNAPL on the shallow groundwater system at the site. Site history and the results of soil and groundwater investigations conducted previously also are summarized in this report.

Three lines of evidence can be used to document the occurrence of intrinsic remediation: 1) geochemical evidence; 2) documented loss of contaminant mass at the field scale; and 3) laboratory microcosm studies. All three lines of evidence are presented herein to define the effects of natural attenuation.

Comparison of benzene, toluene, ethylbenzene, and xylenes (BTEX), electron acceptor, and biodegradation byproduct isopleth maps for the Eglin AFB study site provides strong qualitative evidence of biodegradation of BTEX compounds. BTEX concentrations at monitoring wells decreased significantly between 1993 and 1994 sampling events. Geochemical data strongly suggest that biodegradation of fuel hydrocarbons is occurring at the site via the anaerobic processes of iron reduction and methanogenesis, as well as by aerobic respiration (in the vicinity of a nearby creek). It appears that aerobic respiration near the creek is rapidly consuming hydrocarbons that migrate to that area, preventing detectable concentrations of BTEX compounds from entering the surface water. This is evidenced by patterns of BTEX and dissolved oxygen distribution, and by the nondetection of BTEX compounds in surface water samples.

USEPA RSKERL researchers also performed a microcosm study using site soils. This study provided evidence of microbial degradation of BTEX compounds and a lower bound on degradation rates. BTEX and trimethylbenzene (TMB) data also were used to calculate degradation rates. In addition, partitioning calculations using residual soil BTEX and total petroleum hydrocarbon (TPH) concentrations provided evidence of significant weathering of the remaining residual LNAPL.

A contaminant fate and transport model (using the groundwater flow model code MODFLOW and the transport model code MT3D[®]) was used to estimate the rate and direction of dissolved BTEX movement through the shallow saturated zone under the influence of advection, dispersion, sorption, and biodegradation. Input parameters used for the model were obtained from existing site characterization data, supplemented with data collected by Parsons ES in conjunction with personnel from the RSKERL and EA Engineering, Science, and Technology. Chemical analysis of residual LNAPL indicates that residual LNAPL contamination at the site consists of significantly weathered MOGAS. Extensive site-specific data were used for model implementation. Model parameters that could not be obtained from existing site data were estimated using widely accepted literature values for sediments similar to those found at the site. Simulation results suggest that the plume will persist for about 10 more years before natural attenuation reduces concentrations below levels of concern.

The results of this study suggest that natural attenuation of BTEX compounds is occurring at the Eglin AFB site to the extent that the dissolved concentrations of these compounds in groundwater will continue to decrease, reaching levels below current regulatory guidelines in about 10 years. The study results also indicate that the creek, which is a potential downgradient exposure point for dissolved contamination at this site, has not been impacted by contamination resulting from the 1988 MOGAS release. Given the rates of BTEX plume migration and degradation predicted by the model scenario PREDICT2, and given that there are no identifiable impacts to downgradient surface water, intrinsic remediation with LTM and institutional controls is recommended as the remedial option for BTEX-impacted groundwater at the site. Construction activities in the plume area and groundwater use in and downgradient from the plume area should be restricted for a period of approximately 10 years.

To verify the results of the modeling effort, and to ensure that natural attenuation rates are sufficient to protect potential downgradient receptors, the Air Force recommends sampling groundwater from four LTM wells and three point-of-compliance monitoring wells, as well as surface water from two locations within the creek adjacent to the study site. Water samples should be analyzed for the analytes described in Section 7 of this report. Samples should be collected on an annual basis for 10 years to verify that natural attenuation continues to reduce plume mass and toxicity, and to ensure that concentrations of BTEX (as well as other parameters specified in Chapter 62-770 of the Florida Administrative Code) exceeding state target levels are not present in the surface water. If BTEX (or other target analyte) concentrations in water samples are found to exceed target levels, additional corrective actions may be required.

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SECTION 1

INTRODUCTION

This report was prepared by Parsons Engineering-Science, Inc. [Parsons ES (formerly Engineering-Science, Inc.)] and presents the results of a treatability study (TS) conducted to evaluate the use of intrinsic remediation with long-term monitoring (LTM) for remediation of fuel-hydrocarbon-contaminated groundwater at a petroleum, oils, and lubricants (POL) tank farm known as Site SS-36, located at Eglin Air Force Base (AFB), Florida. Previous investigations determined that unleaded motor gasoline (MOGAS) had been released into the soil and shallow groundwater in the vicinity of Building 763 at the site. The main emphasis of the work described herein was to evaluate the potential for naturally occurring degradation mechanisms to reduce dissolved benzene, toluene, ethylbenzene, and xylenes (BTEX) concentrations in groundwater to levels that are protective of human health and the environment. This study is not intended to be a contamination assessment report or a remedial action plan; rather, it is provided for the use of the Base and its prime environmental contractors as information to be used for future decision making regarding this site.

As used throughout this report, the term "intrinsic remediation" refers to a management strategy that relies on natural attenuation mechanisms to control exposure to risks associated with contaminants in the subsurface. "Natural attenuation" refers to the actual processes (e.g., sorption, dispersion, and biodegradation) that facilitate intrinsic remediation.

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 groundwater modeling in support of intrinsic remediation with LTM. EA Engineering, Science and Technology, Inc. (EA) provided field support during field operations.

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 the program and this specific Eglin AFB study is to provide solid evidence of intrinsic remediation of dissolved fuel hydrocarbons in groundwater so that this information can be used by the Base and its prime environmental contractor(s) to develop an effective groundwater remediation strategy. As a result, these studies are not necessarily intended to fulfill specific federal or state requirements regarding site assessments, remedial action plans, or other such mandated investigations and reports. A secondary goal of this multi-site initiative is to provide a database from multiple sites that demonstrates that natural processes of contaminant degradation often can reduce contaminant concentrations in groundwater to below acceptable cleanup standards before completion of potential receptor exposure pathways.

The scope of work for this project involved the following tasks:

- Reviewing existing hydrogeologic and soil and groundwater quality data for the site;
- Conducting supplemental site characterization activities to determine the nature and extent of soil and groundwater contamination and to collect geochemical data in support of intrinsic remediation;
- Developing a conceptual hydrogeologic model of the shallow saturated zone, including the current distribution of contaminants;
- Determining if natural processes of contaminant destruction are occurring in groundwater at the site;
- Performing contaminant fate and transport modeling based on site hydrogeologic conditions using the groundwater flow model code MODFLOW and the contaminant transport code MT3D[®];
- Evaluating a range of model input parameters to determine the sensitivity of the model to those parameters and to consider several contaminant fate and transport scenarios;
- Determining if natural processes are sufficient to minimize BTEX plume expansion so that groundwater quality standards can be met at a downgradient point of compliance (POC);
- Developing preliminary remedial action objectives (RAOs) and reviewing available remedial technologies;
- Using the results of modeling to recommend the most appropriate remedial option based on specific effectiveness, implementability, and cost criteria; and

- Provide an LTM plan which includes LTM and POC well locations and a sampling and analysis plan.

Site characterization activities in support of intrinsic remediation conducted under this program included Geoprobe[®] sampling of groundwater, soil borehole drilling and soil sample collection and analysis, monitoring well installation, and sampling and analysis of groundwater from newly installed monitoring wells.

Site-specific data were used to develop a fate and transport model for the site, and to conduct a preliminary exposure pathways analysis. The model was used to simulate the movement of dissolved BTEX in the shallow saturated zone under the influence of advection, dispersion, sorption, and biodegradation. As part of the TS, this modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible threat to potential downgradient receptors by conducting a preliminary exposure assessment; and 3) to provide technical support for the intrinsic remediation with LTM remedial option during regulatory negotiations, as appropriate.

Several remedial options were evaluated during this TS, including groundwater extraction and treatment (i.e., pump and treat); institutional controls; and natural contaminant attenuation with LTM. All hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options were collected under this program; however, the field work conducted under this program was oriented toward the collection of hydrogeologic data to be used as input into a groundwater flow and contaminant transport model. Model results are used to evaluate the effectiveness of intrinsic remediation with LTM for restoration of fuel-hydrocarbon-contaminated groundwater.

This report contains nine sections, including this introduction, and five 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 groundwater contamination and the geochemistry of soil and groundwater at the site. Section 5 describes the flow and transport model and design of the conceptual model for the site, lists fate and transport model assumptions and input parameters, and describes sensitivity analysis, model output, and the results of the modeling. Section 6 presents a comparative analysis of remedial alternatives. Section 7 presents a long-term monitoring

plan for the site. Section 8 presents the conclusions of this work and provides recommendations for further work at the site. Section 9 lists the references used to develop this document. Appendix A contains boring logs, well completion diagrams, and hydraulic conductivity test results. Appendix B contains soil and groundwater analytical data. Appendix C presents details of calculations used to help quantify intrinsic remediation. Appendix D contains model input and output, along with model-specific calculations. Appendix E contains calculations used for remedial alternative design and costing.

1.2 FACILITY BACKGROUND

Site SS-36 is located in the main portion of Eglin AFB (the Base), which is located north of Fort Walton Beach in the south-central portion of Okaloosa County, Florida. Figure 1.1 is a location map showing the position of the site relative to the main portion of the Base and the surrounding area. Site SS-36 is located on the northeastern corner of Eglin Boulevard and 8th Street, and is bounded on the east by Dock Road and Weekly Bayou.

Site SS-36 has been in operation since 1960, and is a major POL distribution and storage area. Fuel shipments are brought by barge to the docks at the southern end of the site. The fuel is offloaded at the docks and pumped to several aboveground storage tanks (ASTs) in the northern portion of the site. The primary petroleum product stored at Site SS-36 is JP-4 jet fuel, but JP-5 fuel, JP-8 fuel, diesel fuel, and motor gasoline (MOGAS) also are stored here.

Several documented fuel releases have resulted in soil and groundwater contamination at Site SS-36, including some near the ASTs in the northwestern half of the site. Several site investigations have been conducted by various consultants in response to this contamination. The results of these investigations are covered in several reports, including:

- Response to Fuel in Ground at POL Area (Roy F. Weston Inc., 1984);
- Enhanced Bioreclamation Study (EA, 1989);
- Remedial Action Plan for Clean-up of Hydrocarbons in the Subsurface, POL Facility, Eglin AFB (Geraghty & Miller Inc., 1985);
- Site Characterization of the POL Area, Floating Fuel Recovery and Residual Cleanup Site, Eglin AFB, Florida (EA, 1987)
- Cone Penetrometer Logs (Rice University, 1993); and
- Draft Preliminary Contamination Assessment Report (EA, 1993).

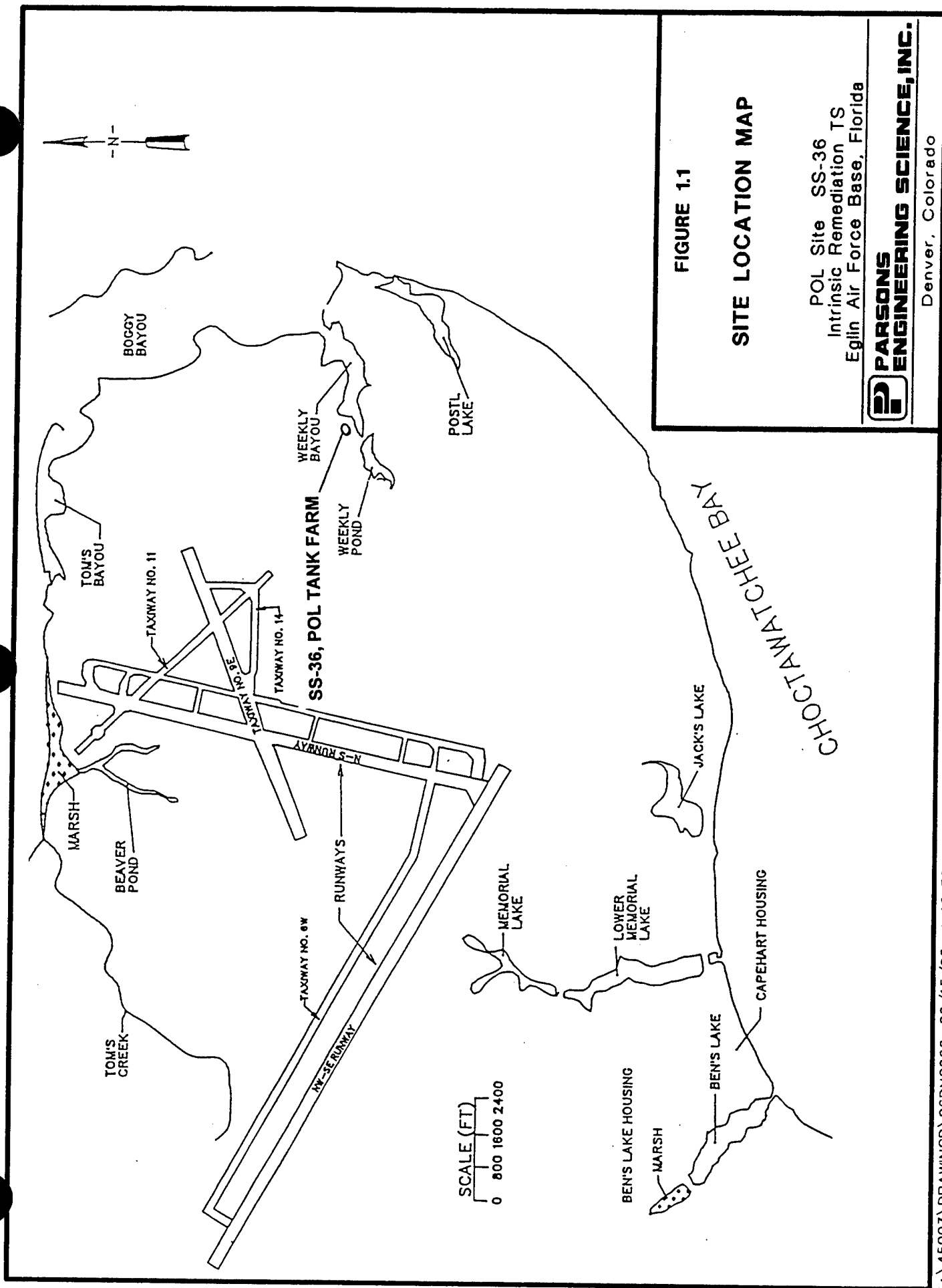


FIGURE 1.1

SITE LOCATION MAP

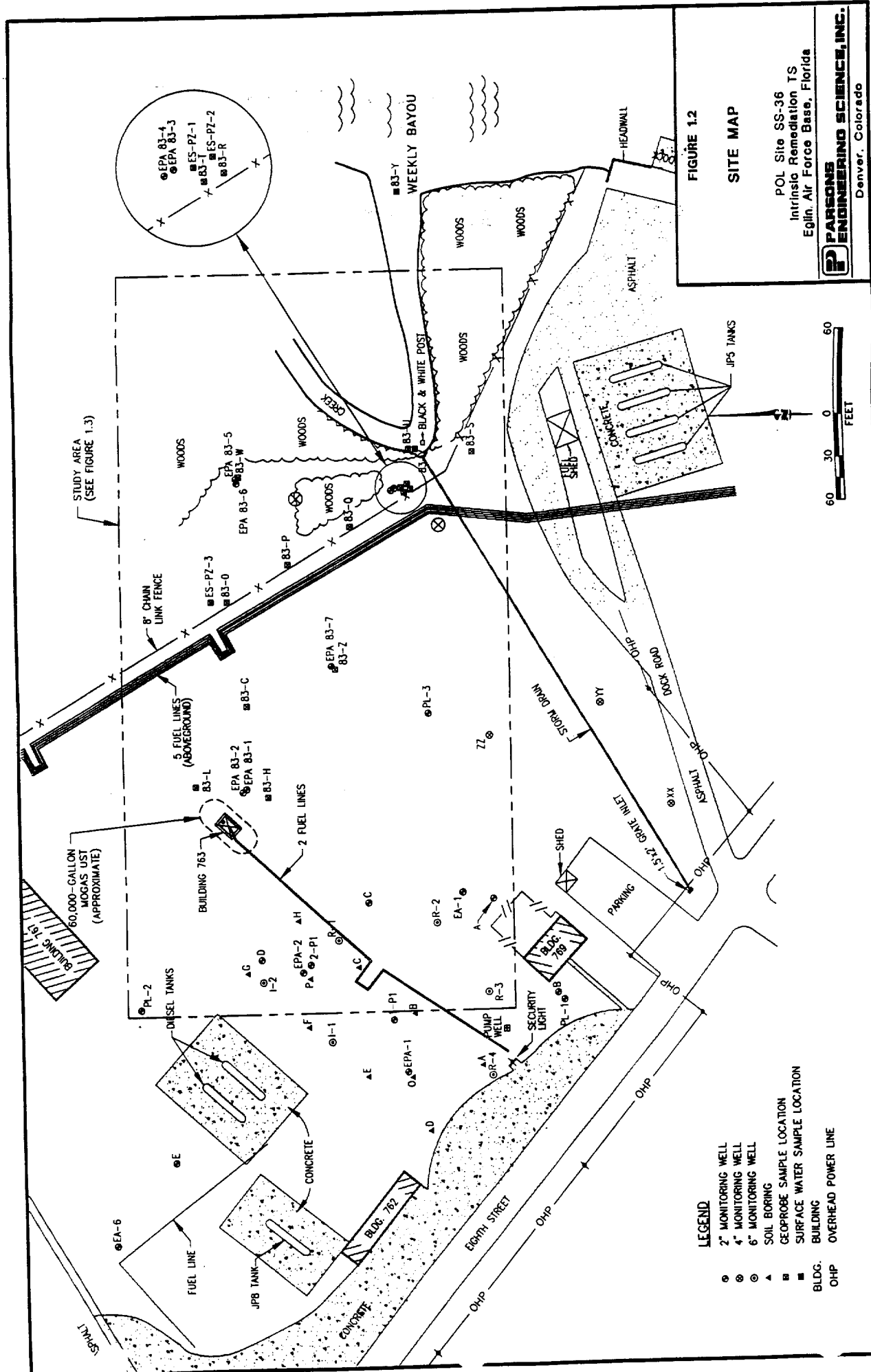
POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

The site-specific data presented in Sections 3, 4, and 5 are based on a review of these documents and on data collected by Parson ES and researchers from the RSKERL under this program.

Figure 1.2 is a site map showing the southeastern one-third of Site SS-36 and the adjacent area in detail. For the purposes of the work described herein, the area outlined on Figure 1.2 and shown on Figure 1.3 will be referred to as the study site. This area includes a portion of the POL facility which consists of a 60,000-gallon underground storage tank (UST) beneath Building 763 used to store MOGAS. This study focuses only on groundwater contamination resulting from a 1988 spill associated with the MOGAS UST. Contamination from other sources throughout Site SS-36 is not addressed in this TS.

The MOGAS UST is an oval, brass- or copper-lined concrete vault approximately 12 feet deep. Before it was used to hold MOGAS, the tank was used to store diesel fuel. Base personnel reported that small volumes of diesel fuel (less than 5 gallons) were occasionally spilled during operation of a sump pump. The spill of concern for this study occurred in early 1988, when the sump pump was left on overnight and approximately 1,200 gallons of MOGAS were discharged to the ground surface (Burdett, pers. comm., September 17, 1993). Some of the MOGAS apparently flowed some distance overland from the spill area toward the creek that discharges into Weekly Bayou (Figure 1.2) before infiltrating into the subsurface. It does not appear that there were any leaks from the UST, as it was empty and dry during the field effort for this study. If the UST had any holes or other leaks, it would have contained several feet of water, because the water table is only a few feet below ground surface (bgs) at this site. The tank has not been used since June 1988, when the power supply to Building 763 was disconnected.



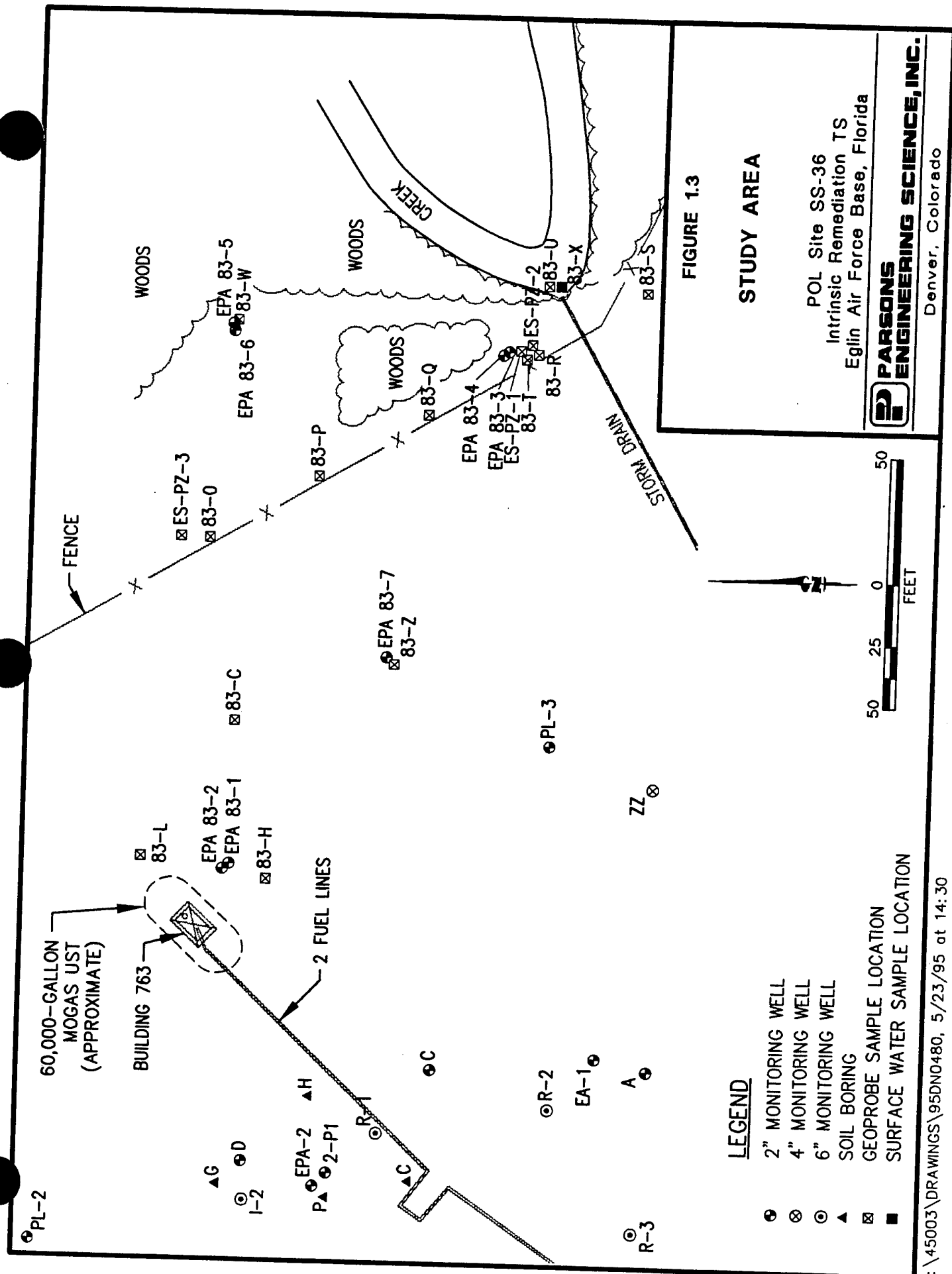


FIGURE 1.3

STUDY AREA

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

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Denver, Colorado

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

To meet the requirements of the intrinsic remediation demonstration, several investigative techniques, including soil and groundwater sampling and aquifer testing, were utilized. Soil sampling was accomplished during this investigation using hollow-stem auger (HSA) drilling in conjunction with continuous split-barrel sampling. Previous investigations conducted at the site utilized standard HSA drilling and soil sampling as well as cone penetrometer testing (CPT). Geoprobe[®] sampling apparatus and monitoring wells (including newly installed wells) were used to collect groundwater samples during this investigation. Previous investigations utilized monitoring wells installed in HSA boreholes and CPT grab sampling to sample groundwater. Aquifer tests conducted at the site included single-well pumping and recovery tests.

This section presents the methods used by ES and researchers from the RSKERL to collect site-specific data at the site in September 1993. In addition, RSKERL researchers collected groundwater data in the vicinity of the site in February 1993. Rice University (1993) studied the area in March 1993, using a CPT for soil testing and groundwater sample collection. Data collected under this program and data collected by Rice and the RSKERL were integrated to develop the conceptual site model and to aid interpretation of the physical setting (Section 3) and contaminant distribution (Section 4).

The physical and chemical hydrogeologic data listed below were collected during the field work phase of the TS:

- Depth from measurement datum to the water table or potentiometric surface in monitoring wells;
- Location of potential groundwater recharge and discharge areas;
- Hydraulic conductivity as determined from pumping test data;
- Detailed stratigraphic analysis of subsurface media;
- Estimation of extent and thickness of mobile-phase LNAPL;

- Dissolved oxygen (DO), nitrate, ferrous iron, sulfate, methane, chloride, ammonia, and total organic carbon (TOC) concentrations in groundwater;
- Temperature, specific conductance, reduction/oxidation (redox) potential, total alkalinity, and pH of groundwater;
- BTEX and trimethylbenzene (TMB) concentrations in groundwater; and
- BTEX, TMB, and TPH concentrations in soil.

The following sections describe the procedures followed when collecting site-specific data. The applied drilling, soil sampling, lithologic logging, and monitoring well development procedures are described in Section 2.1. Groundwater sampling procedures are described in Section 2.2. Aquifer testing procedures are described in Section 2.3.

2.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

At the end of September 1993, drilling, soil sampling, and monitoring well installation was conducted at seven new locations (Figure 2.1). Drilling, soil sampling, and monitoring well installation were accomplished by EA. Parsons ES personnel were present during these activities.

2.1.1 Well Locations and Completion Intervals

Seven new groundwater monitoring wells were installed to help characterize the shallow groundwater flow system at the study site. These wells are identified as EPA 83-1, EPA 83-2, EPA 83-3, EPA 83-4, EPA 83-5, EPA 83-6, and EPA 83-7. The new monitoring wells were installed in the locations shown on Figure 2.1. The well locations were selected to provide the hydrogeologic data necessary for evaluation of intrinsic remediation. Table 2.1 presents well completion details for all site wells. Six of the wells (EPA 83-1 through EPA 83-6) were installed as nested pairs, with one well screened across the water table and the top of the other well screen placed 14 to 18 feet below the bottom of the first well. All wells had 5-foot screens.

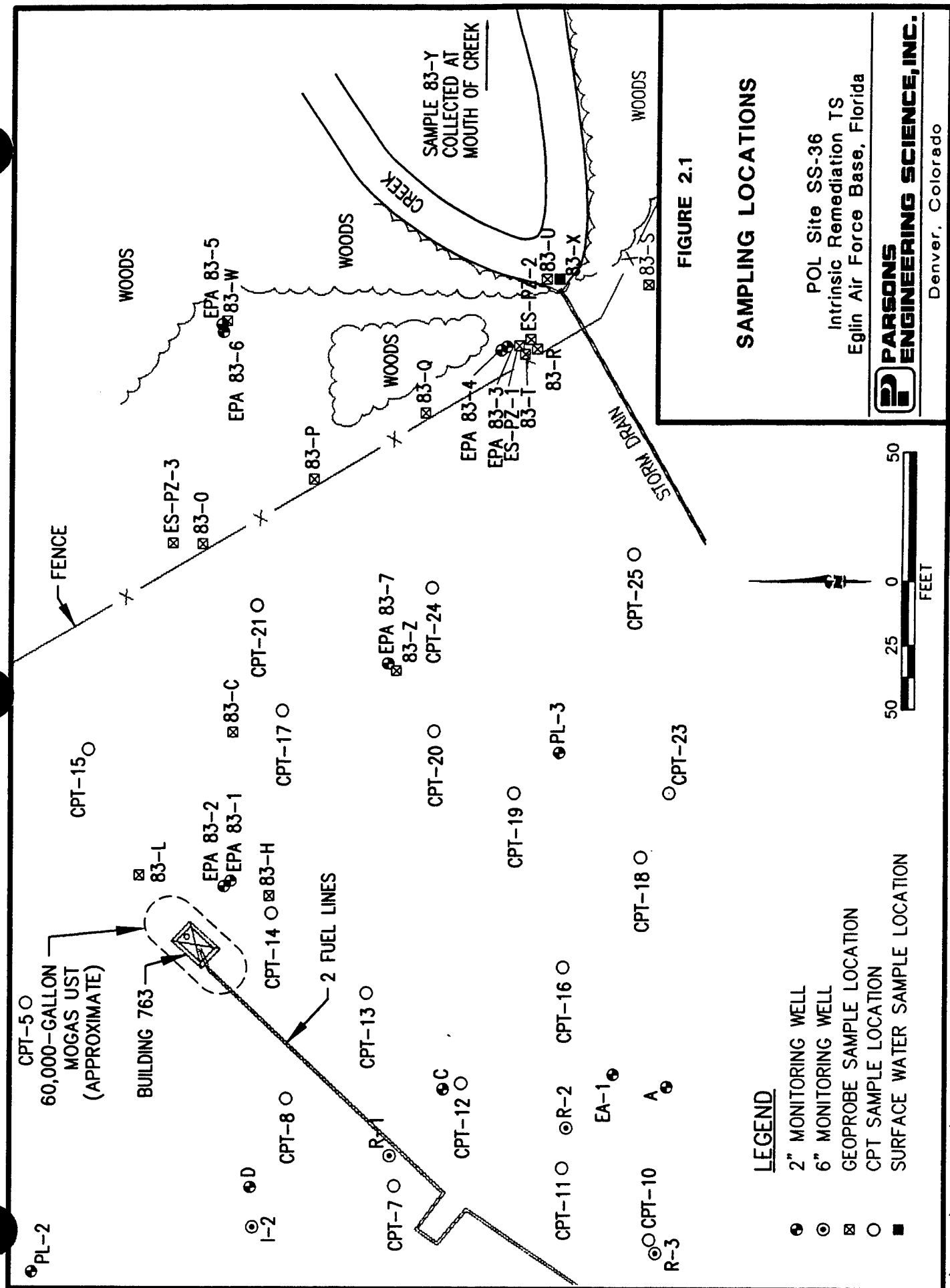


TABLE 2.1

WELL COMPLETION INFORMATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Location	Easting	Northing	Datum Elevation (ft msl) ^a	Ground Elevation (ft msl)	Total Depth (ft bgs) ^b	Total Depth (ft bto c) ^c	Well Diameter (inches)	Screen Length (feet)	Depth to Screen Top (ft bgs)	Screen Elevation Top (ft msl)	Screen Elevation Bottom (ft msl)
MONITORING WELLS											
A	10067	9859	10.60	8.74	14.68	12.82	2	ND ^d	ND	ND	ND
C	10066	9945	13.76	11.54	16.86	14.64	2	ND	ND	ND	ND
D	10027	10020	15.47	13.16	16.78	14.47	2	ND	ND	ND	ND
EPA 83-1	10147	10028	12.84	10.35	28.45	25.96	2	5	20.21	25.21	-14.86
EPA 83-2	10145	10031	12.77	10.46	10.34	8.03	2	5	2.28	7.28	3.18
EPA 83-3	10354	9922	5.77	3.93	22.00	20.16	2	5	14.41	19.41	-15.48
EPA 83-4	10353	9924	5.89	4.03	8.60	6.74	2	5	0.99	5.99	-1.96
EPA 83-5	10363	10032	6.98	5.11	22.35	20.48	2	5	14.73	19.73	-14.62
EPA 83-6	10361	10032	7.02	5.15	8.60	6.73	2	5	0.98	5.98	-0.83
EPA 83-7	10231	9967	10.68	8.72	11.10	9.14	2	5	3.39	8.39	0.33
I-1	9969	9972	16.52	13.00	20.82	17.30	6	8	8.55	16.55	-3.55
I-2	10012	10019	16.91	13.38	20.75	17.22	6	8	8.47	16.47	-3.09
PL-1	9995	9810	12.51	10.51	52.00	50.00	2	10	39.25	49.25	-38.74
PL-2	9994	10105	15.49	13.35	51.24	49.10	2	5	43.35	48.35	-35
PL-3	10197	9901	8.94	6.83	41.34	39.23	2	5	33.48	38.48	-31.65
R-1	10040	9966	13.41	12.47	19.50	18.56	6	5	12.81	17.81	-5.34
R-2	10051	9898	10.40	9.78	19.10	18.48	6	5	12.73	17.73	-7.95
R-3	10002	9863	10.90	10.23	19.08	18.41	6	5	12.66	17.66	-7.43
ZZ	10180	9859	8.91	6.65	5.88	3.62	4	ND	ND	ND	ND
GEOPROBE SAMPLING LOCATIONS											
Geoprobe 83 C-1	10205	10027	ND	10.03	30	ND	0.5	1.5	7.25	8.75	1.28
Geoprobe 83 C-2	10205	10027	ND	10.03	30	ND	0.5	1.5	13.25	14.75	-4.72
Geoprobe 83 H-1	10141	10013	ND	10.40	30	ND	0.5	1.5	4.25	5.75	4.65
Geoprobe 83 H-2	10141	10013	ND	10.40	30	ND	0.5	1.5	25.25	26.75	-16.35
Geoprobe 83 L-1	10149	10063	ND	10.92	24	ND	0.5	1.5	4.25	5.75	5.17
Geoprobe 83 L-2	10149	10063	ND	10.92	24	ND	0.5	1.5	16.25	17.75	-6.83
Geoprobe 83 O-1	10278	10039	ND	10.19	30	ND	0.5	1.5	10.25	11.75	-1.56
Geoprobe 83 O-2	10278	10039	ND	10.19	30	ND	0.5	1.5	22.25	23.75	-13.56
Geoprobe 83 P-1	10303	9997	ND	6.64	33	ND	0.5	1.5	4.25	5.75	0.89

TABLE 2.1 (Continued)

WELL COMPLETION INFORMATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Location	Easting	Northing	Datum Elevation (ft msl) ^a	Ground Elevation (ft msl)	Total Depth (ft bgs) ^b	Total Depth (ft btoe) ^c	Well Diameter (inches)	Screen Length (feet)	Depth to Screen		Screen Elevation	
									Top (ft bgs)	Bottom (ft bgs)	Top (ft msl)	Bottom (ft msl)
Geoprobe 83 P-2	10303	9997	ND	6.64	33	ND	0.5	1.5	25.25	26.75	-18.61	-20.11
Geoprobe 83 Q-1	10329	9953	ND	5.19	36	ND	0.5	1.5	4.25	5.75	0.94	-0.56
Geoprobe 83 Q-2	10329	9953	ND	5.19	36	ND	0.5	1.5	25.25	26.75	-20.06	-21.56
Geoprobe 83 R-1	10354	9910	ND	4.10	33	ND	0.5	1.5	4.25	5.75	-0.15	-1.65
Geoprobe 83 R-2	10354	9910	ND	4.10	33	ND	0.5	1.5	5.75	7.25	-1.65	-3.15
Geoprobe 83 R-3	10354	9910	ND	4.10	33	ND	0.5	1.5	20.25	21.75	-16.15	-17.65
Geoprobe 83 R-4	10354	9910	ND	4.10	33	ND	0.5	1.5	33.25	34.75	-29.15	-30.65
Geoprobe 83 S-1	10379	9867	ND	4.91	39	ND	0.5	1.5	4.25	5.75	0.66	-0.84
Geoprobe 83 S-2	10379	9867	ND	4.91	39	ND	0.5	1.5	16.25	17.75	-11.34	-12.84
Geoprobe 83 S-3	10379	9867	ND	4.91	39	ND	0.5	1.5	25.25	26.75	-20.34	-21.84
Geoprobe 83 U-1	ND	ND	ND	ND	10 ^d	ND	0.5	1.5	0.3	1.8	ND	ND
Geoprobe 83 U-2	ND	ND	ND	ND	10	ND	0.5	1.5	3.3	4.8	ND	ND
Geoprobe 83 U-3	ND	ND	ND	ND	10	ND	0.5	1.5	5.9	10	ND	ND
Geoprobe 83 W-1	10365	10031	ND	5.08	32	ND	0.5	1.5	4.25	5.75	0.83	-0.67
Geoprobe 83 W-2	10365	10031	ND	5.08	32	ND	0.5	1.5	22.25	23.75	-17.17	-18.67
Geoprobe 83 Z-1	10231	9967	ND	8.72	24	ND	0.5	1.5	5.25	6.75	3.47	1.97
Geoprobe 83 Z-2	10231	9967	ND	8.72	24	ND	0.5	1.5	13.25	14.75	-4.53	-6.03
Geoprobe 83 Z-3	10231	9967	ND	8.72	24	ND	0.5	1.5	22.25	23.75	-13.53	-15.03
Geoprobe Mouth Ctk.	10561	9918	ND	0.07	ND	ND	0.5	1.5	ND	ND	ND	ND

CONE PENETROMETER TEST LOCATIONS												
CPT-5	10100	10107	NA ^e	12.44	17.22	NA	NA	4.5	5.18	9.68	7.26	2.76
CPT-7	10029	9964	NA	12.29	13.12	NA	NA	4.5	2.04	6.54	10.25	5.75
CPT-8-4	10063	10006	NA	12.55	17.22	NA	NA	0.5	4	4.5	8.55	8.05
CPT-8-6	10063	10006	NA	12.73	17.22	NA	NA	0.5	6	6.5	6.73	6.23
CPT-8-8	10063	10006	NA	12.63	17.22	NA	NA	0.5	8	8.5	4.63	4.13
CPT-8-10	10063	10006	NA	12.64	17.22	NA	NA	0.5	10	10.5	2.64	2.14
CPT-8-12	10063	10006	NA	12.63	17.22	NA	NA	0.5	12	12.5	0.63	0.13
CPT-10	10008	9865	NA	10.17	19.69	NA	NA	4.5	0.95	5.45	9.22	4.72
CPT-11	10036	9899	NA	9.93	19.69	NA	NA	4.5	-0.4	4.1	10.33	5.83
CPT-12	10069	9938	NA	11.00	13.12	NA	NA	4.5	2.25	6.75	8.75	4.25

TABLE 2.1 (Concluded)

WELL COMPLETION INFORMATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Location	Easting	Northing	Datum Elevation (ft msl) ^{a/}	Ground Elevation (ft msl)	Total Depth (ft bgs) ^{b/}	Total Depth (ft bioc) ^{c/}	Well Diameter (inches)	Screen Length (feet)	Depth to Screen Top (ft bgs)	Depth to Screen Bottom (ft bgs)	Screen Elevation Top (ft msl)	Screen Elevation Bottom (ft msl)
CPT-13	10104	9975	NA	11.48	16.40	NA	NA	4.5	1.13	5.63	10.35	5.85
CPT-14	10135	10012	NA	10.58	37.73	NA	NA	4.5	2.42	6.92	8.16	3.66
CPT-15	10199	10083	NA	10.60	19.69	NA	NA	4.5	2.14	6.64	8.46	3.96
CPT-16	10114	9899	NA	9.08	13.12	NA	NA	4.5	1.7	6.2	7.38	2.88
CPT-17-3	10214	10008	NA	9.58	16.40	NA	NA	0.5	3	3.5	6.58	6.08
CPT-17-5	10214	10008	NA	9.51	16.40	NA	NA	0.5	5	5.5	4.51	4.01
CPT-17-7	10214	10008	NA	9.56	16.40	NA	NA	0.5	7	7.5	2.56	2.06
CPT-17-9	10214	10008	NA	9.47	16.40	NA	NA	0.5	9	9.5	0.47	-0.03
CPT-18	10157	9869	NA	6.86	13.12	NA	NA	4.5	-0.35	4.15	7.21	2.71
CPT-19-3	10182	9918	NA	7.03	16.40	NA	NA	0.5	3	3.5	4.03	3.53
CPT-19-5	10182	9918	NA	6.98	16.40	NA	NA	0.5	5	5.5	1.98	1.48
CPT-19-7	10182	9918	NA	6.94	16.40	NA	NA	0.5	7	7.5	-0.06	-0.56
CPT-19-9	10182	9918	NA	6.92	16.40	NA	NA	0.5	9	9.5	-2.08	-2.58
CPT-20	10206	9949	NA	7.95	19.69	NA	NA	4.5	1.94	6.44	6.01	1.51
CPT-21	10255	10018	NA	9.51	19.69	NA	NA	4.5	3.23	7.73	6.28	1.78
CPT-23	10182	9858	NA	6.35	13.12	NA	NA	4.5	0.82	5.32	5.53	1.03
CPT-24	10262	9950	NA	6.95	19.69	NA	NA	4.5	2.21	6.71	4.74	0.24
CPT-25	10275	9872	NA	5.65	16.40	NA	NA	4.5	2.54	7.04	3.11	-1.39
TEMPORARY PIEZOMETERS												
ES-PZ-1	10355	9917	NA	3.79	10.69	NA	2	5	5.69	10.69	-1.9	-6.9
ES-PZ-2	10357	9913	NA	3.74	14.94	NA	2	5	9.94	14.94	-6.2	-11.2
ES-PZ-3	10278	10051	NA	9.83	8.40	NA	1.25	1.5	6.9	8.4	2.93	1.43

^{a/} ft msl = feet above mean sea level.^{b/} ft bgs = feet below ground surface.^{c/} ft bioc = feet below top of casing^{d/} ND = data not available.^{e/} Depths for 83-U are in feet below the sediment surface at the bottom of the creek.^{f/} NA = not applicable.

2.1.2 Well Drilling and Installation Procedures

This section describes the procedures used for drilling and installation of new monitoring wells. All new monitoring wells were installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (USEPA, 1987).

2.1.2.1 Drilling and Soil Sampling

Drilling was accomplished by using the HSA method. The borings were drilled and continuously sampled to the total depth of the borehole, or until sand heave prevented additional sampling. The boreholes for monitoring wells EPA 83-4 and EPA 83-6 were not logged because they were drilled immediately adjacent to wells EPA 83-3 and 83-6, respectively. A final borehole diameter of at least 8 inches was used for the installation of wells with a 2-inch inside-diameter (ID) casing.

Continuous soil samples were obtained using a 2.5-inch-ID split-barrel sampling device (also known as a split spoon). Where possible, samples were collected continuously over the full depth of the soil borehole. The soil samples collected were removed from the continuous sampler in 1-foot intervals and placed in clean glass jars for laboratory analysis. In addition, a portion of the soil sample was placed in a clean glass jar for flame ionization detector (FID) headspace measurements for volatile organic compounds (VOCs) and lithologic logging. Jars containing soil samples collected for the headspace procedure were quickly 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 FID probe and reading the concentration of the headspace gases. The FID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The FID was also used to monitor the worker breathing zone.

The Parsons ES field hydrogeologist observed drilling and well installation activities, maintained a detailed descriptive log of subsurface materials recovered, and photographed representative samples. Final geologic boring logs are presented in Appendix A. These logs contain:

- Sample interval (top and bottom depth);
- Presence or absence of contamination based on odor, staining, and/or PID readings;

- Soil description, including color, major textural constituents, minor constituents, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Lithologic contacts with the depth of lithologic contacts and/or significant textural changes recorded to the nearest 0.1 foot (1 inch).

Soils exhibiting petroleum hydrocarbon contamination based on FID screening were drummed and stored onsite during the drilling operations. Eglin AFB personnel were responsible for the final disposition of these soils.

2.1.2.2 Monitoring Well Installation

Groundwater monitoring wells were installed in seven soil borings under this program. Detailed well installation procedures are described in the following paragraphs. Well completion diagrams are included in Appendix A.

2.1.2.2.1 Well Materials Decontamination

Well completion materials were inspected by the field hydrogeologist and determined to be clean and acceptable prior to use. All well completion materials were factory sealed. Pre-packaged sand, bentonite, and Portland[®] cement were used in well construction, and the bags were inspected for possible external contamination before use. Materials that could not be cleaned to the satisfaction of the field hydrogeologist were not used.

2.1.2.2.2 Well Casing

Upon completion of drilling, a monitoring well casing was installed. Well construction details were noted on a Monitoring Well Installation Record form. This information became part of the permanent field record for the site and is included in Appendix A.

Blank well casing was constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections were flush-threaded, and glued joints were not used. The casing at each well was fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing.

The field hydrogeologist verified and recorded the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus

between the casing and borehole wall. All lengths and depths were measured to the nearest 0.1 foot.

2.1.2.2.3 Well Screen

Well screens were constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. The screens were factory slotted with 0.010-inch openings. Each shallow well was screened so that seasonal fluctuations of the water table can be measured. Screen positions were selected by the field hydrogeologist after consideration was given to the geometry and hydraulic characteristics of the stratum in which the wells were screened.

2.1.2.2.4 Sand Filter Pack

A graded sand filter was placed around the screened interval from the bottom of the casing to approximately 0.2 to 2.7 feet above the top of the screen. Where the top of the well screen was relatively close to the ground surface, the filter pack interval above the screen was minimized to allow placement of an annular space seal. Number 20-30 silica sand was used for the sand filter pack.

2.1.2.2.5 Annular Sealant

An annular seal of sodium bentonite pellets was placed above the sand pack. For deeper wells, the pellet seal was approximately 2 feet thick. In shallow wells, the thickness of the bentonite seal was reduced to allow placement of sufficient grout or concrete. In all wells, the pellet seal was overlaid with a Portland[®] cement/sodium bentonite grout to a depth of 0.5 to 1 foot bgs. The Portland[®] cement/sodium bentonite grout mix consisted of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the grout did not exceed 8 percent by dry weight. The grout or bentonite chips were overlaid with concrete that extends to the ground surface.

2.1.2.2.6 Protective Cover

Each monitoring well was completed with a steel protective cover. The covers were placed so that the top of each cover was 2.0 to 2.5 feet above grade. The protective casing was set into the upper portion of the annular seal and concreted into place. All wells were

completed with concrete pads that slope gently away from the protective casing to facilitate runoff during precipitation events.

2.1.2.5 Well Development

Before being sampled, newly installed monitoring wells were developed. Well development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen.

Personnel from EA developed the wells using a submersible pump. The pump also was used to surge the well so that fines were agitated and removed from the well in the development water. Development was continued until at least 10 casing volumes of water were removed from the well, or until the water became clear. All well development waters were run through a portable carbon filtration unit prior to discharge. In addition to this initial purging, a large volume of water was purged from each well during the single well pumping and recovery tests. These tests were conducted before the wells were sampled. EA well development records are included in Appendix A.

2.1.2.6 Water Level Measurements

Water levels at all sampled monitoring wells were measured. Measurements were made using an electric water level probe capable of recording to the nearest 1/8 inch (0.01 foot). In addition, water level measurements were made in other selected monitoring wells in the vicinity of the site.

2.1.2.7 Well Location and Datum Survey

The location and elevation of the new wells were surveyed by a registered surveyor soon after well completion. The horizontal locations were measured relative to established Eglin AFB coordinates. 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 (msl) 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.

2.2 GROUNDWATER AND SURFACE WATER SAMPLING

This section describes the procedures used for collecting groundwater and surface water quality samples. In order to maintain a high degree of quality control during this sampling event, the procedures described in the following sections were followed.

Groundwater samples were collected in three phases under this program. Phase one, during the period 14 - 17 September 1993, consisted of collecting groundwater samples using the RSKERL's Geoprobe®. This groundwater sampling process is described in Section 2.2.3.1. The second phase of groundwater sampling took place on 30 September and 1 October 1993, and consisted of collecting groundwater samples from newly installed monitoring wells. The procedures used to sample groundwater monitoring wells are described in Section 2.2.3.2. The third phase of groundwater sampling took place on 18 October 1994, and consisted of sampling the groundwater monitoring wells that were installed in September 1993. In addition to the sampling events conducted under this program, groundwater samples also have been collected in the vicinity of the study site by RSKERL and Rice University. Surface water samples were collected from the creek east-southeast of the site on 17 September 1993.

Groundwater and surface water sampling activities are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity (for monitoring well sampling), including
 - Protective cover, cap and lock,
 - External surface seal and pad,
 - Datum reference, and
 - Internal surface seal;
- Groundwater or surface water sampling, including
 - Water level measurements,
 - Visual inspection of water,
 - Well casing or Geoprobe® point evacuation, and
 - Sampling;
- Sample preservation and shipment, including
 - Sample preparation,
 - Onsite measurement of physical parameters, and

- Sample labeling and packing;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample disposition.

Detailed groundwater and surface water sampling and sample handling procedures that were used are presented in following sections.

2.2.1 Groundwater and Surface Water Sampling Locations

Groundwater samples were collected from newly installed monitoring wells and from Geoprobe® groundwater sampling equipment. Surface water samples were collected from two locations in the creek.

2.2.1.1 Geoprobe® Sampling Locations

Groundwater samples were collected using the Geoprobe® sampling apparatus at 11 locations (83-C, 83-H, 83-L, 83-O, 83-P, 83-Q, 83-R, 83-S, 83-U, 83-W, and 83-Z) during the period 13 - 17 September 1993. At each location, samples were collected from multiple depths. Geoprobe® sampling locations are shown in Figure 2.1.

2.2.1.2 Monitoring Well Sampling Locations

Seven new monitoring wells were installed in the locations shown on Figure 2.1. After completion of well installation and development activities, these wells were sampled using a peristaltic pump with dedicated polyethylene tubing.

2.2.1.3 Surface Water Sampling Locations

Water samples were collected from two locations in the creek shown on Figure 1.2. These samples are labeled 83-X and 83-Y. At each location, samples were collected from above and below the freshwater - salt water interface, and at the water - sediment interface.

2.2.2 Preparation for Sampling

All equipment used for sampling was assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record keeping materials were gathered prior to leaving the office.

2.2.2.1 Equipment Cleaning

All portions of sampling and test equipment that contacted the sample were thoroughly cleaned before use. This equipment included water level probe and cable, lifting line, test equipment for onsite use, and other equipment that contacted the samples. The following cleaning protocol was used:

- Wash with potable water and phosphate-free laboratory detergent;
- Rinse with potable water;
- Rinse with reagent-grade acetone;
- Rinse with distilled or deionized water; and
- Air dry prior to use.

2.2.2.2 Equipment Calibration

As required, field analytical equipment were calibrated according to the manufacturer's specifications prior to field use. This applied to equipment used for onsite chemical measurements of DO, redox potential, pH, specific conductivity, and temperature.

2.2.3 Sampling Procedures

Special care was taken to prevent contamination of the groundwater and extracted samples through cross-contamination from improperly cleaned equipment. Water level probes and cable used to determine static water levels and well total depths were thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 2.2.2.1. In addition, a clean pair of new, disposable nitrile gloves was worn each time a different well was sampled.

2.2.3.1 Geoprobe® Groundwater Sampling

The Geoprobe® system used by the RSKERL is a hydraulically powered percussion/probing machine used to advance sampling tools through unconsolidated soils. This system provides for the rapid collection of groundwater (and soil and soil gas, if necessary) samples at shallow depths while minimizing the generation of investigation-derived waste materials. Where needed, the apparatus can be dismounted from the hydraulic unit, carried by hand to the sampling location, and manually driven to depth. This allows collection of samples from locations that would otherwise be inaccessible to a truck-mounted Geoprobe®. The following sections describe the groundwater sample collection methods and decontamination methods using the Geoprobe® system.

2.2.3.1.1 Sampling Interval and Method

Based on the anticipated groundwater elevation, the sampling depth and interval were estimated prior to driving the Geoprobe® sampling rods into the ground. The Parsons ES field hydrogeologist verified the sampling depth by measuring the length of each Geoprobe® sampling rod prior to insertion into the ground. An 18-inch-long rod with 0.020-inch slots was placed at the tip of the Geoprobe® sampling rods. Groundwater samples were then acquired using a peristaltic pump, as described in Section 2.2.3.1.4.

2.2.3.1.2 Preparation of Location

Prior to sampling, the area around the well was cleared of foreign materials, such as brush, rocks, and debris. This prevented sampling equipment from inadvertently contacting foreign materials near the sampling point.

2.2.3.1.3 Sample Extraction

A peristaltic pump was used to extract groundwater samples from the Geoprobe® sampling point. Prior to sample collection, groundwater was purged until DO and temperature readings stabilized. The samples were transferred directly to the appropriate sample container. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

2.2.3.1.4 Geoprobe® Equipment Decontamination

All probe rids, tips, or other downhole equipment were decontaminated with a high-pressure, steam/hot water wash. Only potable water was used for decontamination. Collection of waters and decontamination of sampling tools was as described in Section 2.1.2.2.

2.2.3.2 Groundwater Monitoring Well Sampling

2.2.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well was cleared of foreign materials, such as brush, rocks, and debris. These procedures prevented sampling equipment from inadvertently contacting debris around the monitoring well.

2.2.3.2.2 Water Level and Total Depth Measurements

Prior to removing any water from the well the static water level was measured. An electric water level probe was used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measurement of the static water level, the water level probe was lowered to the bottom of the well for measurement of total well depth (recorded to the nearest 0.01 foot). Based on these measurements, the volume of water purged from the wells was calculated.

2.2.3.2.3 Well Bore Purging

Three to five times the calculated casing volume was removed from each well prior to sampling. All purge water was run through a portable carbon filtration unit (provided by EA) before discharge. A peristaltic pump with dedicated polyethylene tubing was used for well evacuation.

2.2.3.2.4 Sample Extraction

A peristaltic pump with dedicated polyethylene tubing was used to extract groundwater samples from the well. The sample was transferred directly to the appropriate sample container. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

2.2.3.3 Surface Water Sampling

Surface water samples were collected by opening the appropriate sample containers at the desired depth, allowing the container to fill, and capping the container. Preservatives were added to the sampling containers after they were filled. For parameters measured with direct-reading meters, the meter probe was held at the appropriate sample depth until the meter readings stabilized.

2.2.4 Onsite Chemical Parameter Measurement

2.2.4.1 Dissolved Oxygen Measurements

DO measurements were taken using an Orion® model 840 DO meter. Groundwater was continuously extracted with a peristaltic pump and circulated through an Erlenmeyer flask. The probe of the DO meter was submerged in the Erlenmeyer flask to monitor DO concentrations. For surface water, the probe was merely lowered to the sample location. DO concentrations were recorded after DO readings stabilized; these readings represent the lowest DO concentration observed.

2.2.4.2 Reduction/Oxidation Potential Measurements

Redox potential measurements were taken in the same fashion as DO measurements, except that using an Orion® model 290A redox potential meter. Groundwater was continuously extracted with a peristaltic pump and collected in an Erlenmeyer flask. The redox probe was submerged in the Erlenmeyer flask to take continuous redox measurements. Redox potential measurements were recorded after the readings stabilized, and the recorded readings represent the lowest redox potential observed.

2.2.4.3 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of the groundwater change significantly within a short time following sample acquisition, these parameters were measured in the field. The measurements were made in a clean glass container separate from

those intended for laboratory analysis, and the measured values were recorded in the groundwater sampling record.

2.2.5 Sample Handling

2.2.5.1 Sample Preservation

The USEPA Mobile Laboratory added any necessary chemical preservatives to sample containers prior to sampling. Soil samples collected for VOC analysis were stored in 40-milliliter (mL) volatile organic analysis (VOA) vials and preserved with 5 mL of acidified water ($\text{pH} < 2$) and 5 mL of methylene chloride. Soil samples collected for TOC measurements were stored at 4 degrees Celsius ($^{\circ}\text{C}$) in coolers. Groundwater samples collected for VOC analysis were stored in 40-mL VOA vials with lead-lined septa and preserved with 4 grams of trisodium phosphate. Groundwater samples for all oxidized inorganic compounds, with the exception of nitrate, were stored in 200-mL HDPE sample containers and stored at or below 4°C . Groundwater samples collected for nitrate analysis were stored in 200-mL HDPE sample containers and acidified ($\text{pH} < 2$) with sulfuric acid. All analyses for reduced inorganic species (e.g., ferrous iron, nitrite, and methane) were performed immediately in the field.

2.2.5.2 Sample Container and Labels

Sample containers and appropriate container lids were provided by the USEPA Mobile Laboratory. The sample containers were filled as described in Sections 2.2.3.1.4, 2.2.3.2.4, and 2.2.3.3, and the container lids were tightly closed. Samples to be analyzed for VOCs were collected into containers with zero headspace. The sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (groundwater);
- Sampling date;
- Sampling time;

- Preservatives added; and,
- Sample collector's initials.

2.2.5.3 Sample Shipment

After the samples were sealed and labeled, they were packaged for immediate transport to the onsite USEPA Mobile Laboratory shortly after sample acquisition.

2.3 AQUIFER TESTING

Single-well pumping and recovery tests were performed at this site to determine the hydraulic conductivity of the shallow aquifer. Tests were performed on wells EPA 83-1, EPA 83-2, EPA 83-3, EPA 83-4, EPA 83-5, and EPA 83-6. To minimize the amount of water requiring treatment, these tests also were short term (less than 1 hour in duration). This method of testing, while not as thorough as a full-scale, multiple-well pumping and recovery test, generally yields suitable information on the hydraulic properties of the aquifer in the vicinity of the well that is tested. All tests were performed after well development.

To perform the tests, a Grundfos Redi-Flo[®] submersible pump was lowered to a depth near the bottom of the well screen. A pressure transducer (attached to a data logger) was then lowered to about 1 foot above the pump. After water levels stabilized, the pump was started and flow rates were measured while the pumping continued. Pumping continued until water levels in the well were not changing significantly. Because of the relatively high hydraulic conductivity of the aquifer materials, water level stabilization only took 15 to 20 minutes. After the water level began to stabilize, the pump was shut off, and the well was allowed to recovery. Recovery was monitored until water levels were within 0.1 foot of the level measured before the test. Water generated during the pumping portions of the test was run through EA's portable carbon filtration prior to discharge.

Data obtained during well testing were analyzed using AQTESOLV software and the drawdown methods of Theis (1935), Cooper and Jacob (1946), and Neuman (1974), and the recovery method of Theis (1935). Testing results are presented in Section 3.3.2.2.

2.4 SURVEYING

All site monitoring wells, Geoprobe[®] locations, and selected site reference points were surveyed by George, Nielsen & Tooke, P.A. of Crestview, Florida on 24 September 1993, following well installation. All horizontal coordinates were measured to the nearest 0.1 foot relative to a base datum. Top of casing elevation (measurement datum) for wells was surveyed to the nearest 0.01 foot relative to a USGS msl datum. Ground surface elevations were measured to the nearest 0.1 foot relative to the same USGS datum.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section incorporates data collected by Parson ES in September 1993, with data documented in previous reports on Eglin AFB and Site SS-36. Investigative techniques used to determine the physical characteristics of the site are reviewed in Section 2.

3.1 SURFACE FEATURES

3.1.1 Topography and Surface Water Hydrology

Eglin AFB is located in the Gulf Coastal Plain Physiographic Province of the Interior Plains, a region characterized by low topographic relief, generally sandy soils, and a gradual slope toward the Gulf of Mexico. Within the Base, there are two further physiographic divisions, the Western Highlands and the Coastal Lowlands. Site SS-36 is within the Coastal Lowlands, which includes coastal areas, flood plains of larger rivers, and coastal barrier islands. The topography in the Coastal Lowlands is generally flat, with land surface elevations between 0 and 25 feet above msl. The land surface at Site SS-36 is relatively flat, sloping gently to the southeast toward Weekly Bayou (Figure 1.2).

The main surface water feature in the area is Weekly Bayou, approximately 270 feet southeast of Building 763. Weekly Bayou opens into Boggy Bayou, which opens into Choctawhatchee Bay. Choctawhatchee Bay is open to the Gulf of Mexico. Surface water runoff from the site is minimal (EA, 1993). Surficial sediments in unpaved areas are mostly sand with some packed oyster shells, allowing rapid infiltration of precipitation.

3.1.2 Manmade Features

Much of the land surface at the site is grassy, with some areas paved or covered with buildings. Figure 1.2 shows the locations of buildings and some of the paved areas. Precipitation either infiltrates directly into the ground or runs off covered or paved areas to

unpaved areas where it can then infiltrate. It is not known if the buried storm drain or the product piping (Figure 1.2) influence groundwater movement. However, the relatively high permeability of the sediments in the vicinity of the water table should prevent or minimize such preferential migration.

3.2 REGIONAL GEOLOGY AND HYDROGEOLOGY

Eglin AFB lies within a basin that has been receiving sediments since the Jurassic Period (about 200 million years ago). In the vicinity of the Base, these sediments are about 12,000 feet thick, with individual formations dipping and thickening to the southwest. Older sedimentary units consist of evaporites, carbonates, sandstones, and shales of Jurassic to early Tertiary (Eocene) age. The Eocene units are overlain by the low-permeability shales and limestones of the Claiborne Group. The Claiborne Group is the lower bounding unit of the Floridan Aquifer, which, from bottom to top, consists of fossiliferous limestones of the Ocala Group, the Bucchunna Clay, and the carbonates of the Chickasawhay and Tampa Formations. The upper carbonate formations are highly porous due to dissolution along fractures and other voids (Barr *et al.*, 1981). Immediately above the Tampa Formation is the Pensacola Clay, which is the upper confining unit of the Floridan aquifer. The Pensacola Clay hydraulically isolates the Floridan Aquifer from the overlying units (Barr *et al.*, 1981).

Surficial sediments overlying the Pensacola Clay in the vicinity of Eglin AFB include the Plio-Pleistocene Citronelle Formation and Pleistocene terrace deposits. The terrace deposits, which generally consist of fine- to coarse-grained, well-sorted, white to tan sand, overlie the Citronelle Formation. The Citronelle Formation consists of white to tan sand with discontinuous units of clay, clayey sand, and gravel. The thicknesses of these units vary considerably due to erosion, but together the units are generally 50 to 200 feet thick. Figure 3.1 is a generalized stratigraphic column showing the relations between the geologic units.

Shallow groundwater (i.e., in the surficial sediments) in the area is derived from precipitation. Some rainfall flows to surface streams as direct runoff, some returns to the atmosphere through evapotranspiration, and some percolates into the groundwater system. Infiltration in the area is promoted by flat topography, permeable soils, and groundwater levels below the root zone (Trapp *et al.*, 1977). Average annual precipitation in the area is reported to be 64 inches (Barr *et al.*, 1985).

AGE	LITHOLOGY			GEOLOGIC UNIT
LATE MIOCENE TO RECENT	SAND, LIGHT BROWN TO LIGHT GRAY, FINE TO VERY COARSE GRAINED, LITTLE INTERBEDDED GRAVEL, CLAYEY SAND, AND CLAY		SURFICIAL AQUIFER	TERRACE DEPOSITS & CITRONELLE FORMATION
MIOCENE	CLAY, GRAY, SANDY MICACEOUS		PENSACOLA CLAY CONFINING UNIT	PENSACOLA CLAY
LATE OGGIOCENE AND EARLY MIOCENE	LIMESTONE AND DOLOMITE, LIGHT GRAY		UPPER FLORIDAN AQUIFER	TAMPA FORMATION & CHICKASAWHAY FORMATION
MIDDLE OGGIOCENE	CLAY, GRAY, SOFT, SILTY TO SANDY, FOSSILIFEROUS		BUCATUNNA CLAY CONFINING UNIT	BACATUNNA CLAY
LATE EOCENE	LIMESTONE, WHITE, VERY FOSSILIFEROUS		LOWER FLORIDAN AQUIFER	OCALA GROUP
MIDDLE EOCENE	CALCAREOUS SHALE AND SHALY LIMESTONE			CLAIBORNE GROUP

FIGURE 3.1

**GENERALIZED
STRATIGRAPHIC COLUMN**

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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SOURCE: EA, 1993.

The Floridan aquifer is recharged in the uplands of northwest Florida where the Pensacola Clay is thinner or absent. Regional flow in this aquifer is to the south, eventually discharging to the Gulf of Mexico. The potentiometric surface of the Floridan aquifer may be as much as 100 feet lower than the water levels in the shallow aquifer. The Floridan aquifer is the principal source of drinking water at Eglin AFB and for the surrounding communities.

3.3 SITE GEOLOGY AND HYDROGEOLOGY

3.3.1 Lithology and Stratigraphic Relationships

During the course of previous investigations in the SS-36 area (Geraghty and Miller, 1985; EA, 1987; EA, 1993, Rice University, 1993), many soil boreholes, monitoring wells, and CPT holes have been installed. In general, subsurface soil observed at the site consists of white to gray, very fine to medium sand with local silty intervals. In some locations, intervals of interbedded sand and thin clay lenses were encountered, generally below 10 feet bgs. Some of the sand just below the ground surface may be fill that was used during Base construction. In many locations, black peat and/or organic-rich clay intervals from 2 to 5 feet thick are present at depths of up to 25 feet bgs. On the CPT logs provided by Rice University (1993), this peat and clay unit shows up as an undefined soil type, allowing for easy identification. In addition, brown to gray clay units have been encountered in some boreholes. The clay is sometimes silty, and may be up to 10 feet thick. All of these units are part of the shallow sand and gravel aquifer. The lower confining unit of the shallow aquifer, the Pensacola Clay, was reportedly observed at 43 feet bgs in the borehole for monitoring well PL-3 (EA, 1987).

Soil stratigraphy encountered during monitoring well installation activities conducted by Parsons ES in September 1993, was similar to that encountered by the previous investigators. The upper 10 to 15 feet of the soil column generally consisted of white to gray, fine to medium sand with some coarse sand intervals. Below this upper sand interval, black organic-rich clay and peat was encountered in several boreholes at depths of 9 to 17 feet bgs. This material was typically 2 to 5 feet thick. At one location (EPA 83-3), the dark clay and organic material was thinly interbedded within the sand.

These stratigraphic relationships are illustrated by hydrogeologic sections A - A' and B - B', which include CPT data and data from previously installed wells. Figure 3.2 shows the locations of these sections. Figure 3.3 presents hydrogeologic section A - A', which is approximately

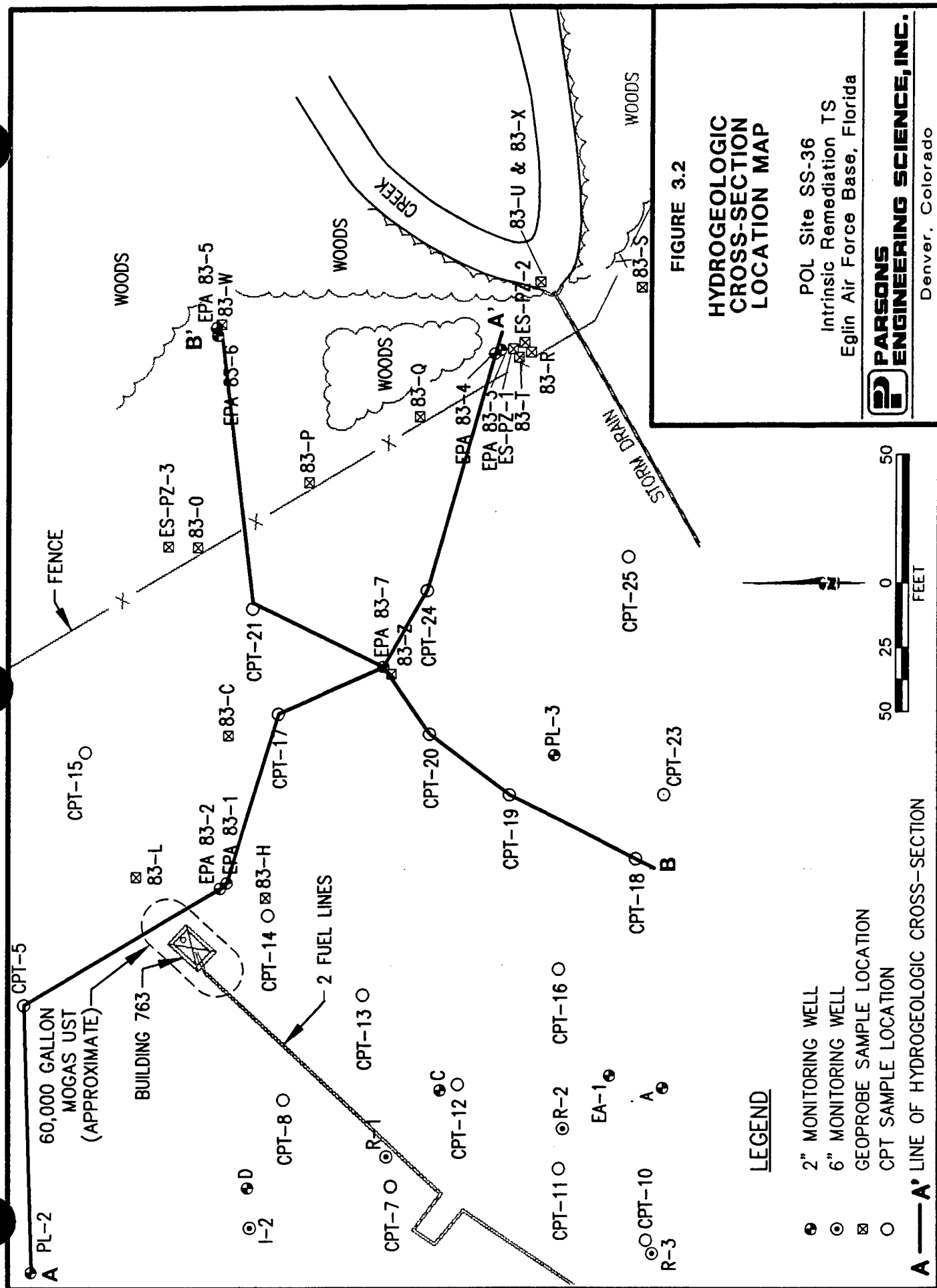


FIGURE 3.2

HYDROGEOLOGIC CROSS-SECTION LOCATION MAP

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

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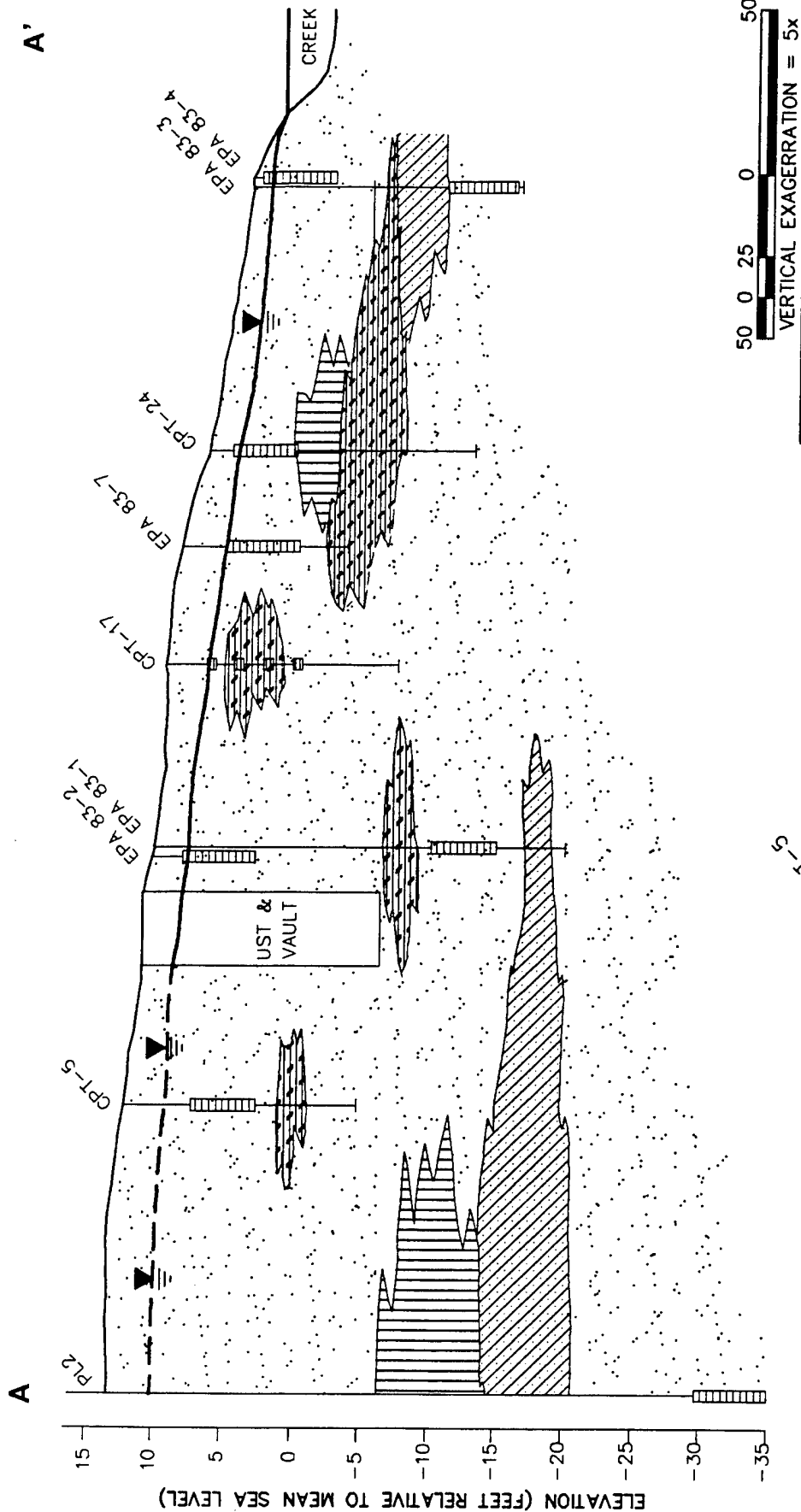


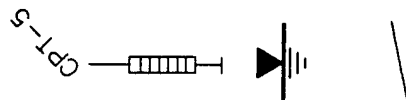
FIGURE 3.3

HYDROGEOLOGIC CROSS-SECTION A-A'

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

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Borehole name
Borehole
Well screen or sampling interval
Bottom of borehole
Approximate water table surface
(Dashed where inferred)
Geologic contact
(Dashed where inferred)



Black PEAT or organic-rich CLAY with silt. Locally sandy; much root material.

CLAY—brown to gray, locally silty.

Brown to gray or black SAND with thin interbedded CLAY lenses; silty in places.

Fine to coarse SAND; white to gray, with local silty intervals. Organic material sometimes observed.



parallel to the direction of groundwater flow. Figure 3.4 presents hydrogeologic section B - B', which is approximately perpendicular to the direction of groundwater flow.

3.3.2 Groundwater Hydraulics

3.3.2.1 Flow Direction and Gradient

Groundwater is present at about 3 to 4 feet bgs at the site. The water table is present in the sand unit, which may locally include fill. Previous groundwater elevation data (Geraghty & Miller, 1985; EA, 1987) generally indicated that flow in the SS-36 area is to the east-southeast, toward the small creek that feeds into Weekly Bayou. Groundwater elevations measured at the site in September 1993 indicated flow was to the east-southeast, with a horizontal gradient ranging from 0.02 to 0.03 foot per foot (ft/ft) (Figure 3.5). For the purposes of this study, the average gradient was assumed to be 0.025 ft/ft. Table 3.1 presents groundwater elevation data collected in September 1993. Significant vertical flow gradients within the shallow aquifer were observed at this site. In the vicinity of the source area, the vertical gradient measured between wells EPA 83-1 and EPA 83-2 was 0.14 ft/ft (downward). A downward vertical gradient of 0.05 ft/ft was measured between wells EPA 83-5 and EPA 83-6. Although flow may be downward away from the creek, it appears that shallow groundwater in the vicinity of the site eventually discharges into the creek. An upward vertical gradient of -0.06 ft/ft was measured between wells EPA 83-3 and EPA 83-4, which are located near the creek. No information is available regarding tidal influences on groundwater levels.

3.3.2.2 Hydraulic Conductivity

Slug tests and pumping tests have previously been performed within the shallow aquifer at Site SS-36 by Geraghty & Miller (1985) and EA (1987 and 1993). Results of the tests performed in 1985 and 1987 were relatively consistent, indicating hydraulic conductivities in the range of 4×10^{-3} to 2×10^{-1} foot per minute (ft/min). However, EA (1993) reported slug test results indicating hydraulic conductivities of about 1×10^{-5} to 6×10^{-5} ft/min. It is not clear why these results were so much lower than those previously obtained at the site. Other pumping tests (Hayes and Barr, 1983) performed in the sand and gravel aquifer indicated transmissivities of 400 to 6,200 square feet per day (0.28 to 4.3 square feet per minute). Transmissivity is equal to the product of hydraulic conductivity and the saturated thickness of the aquifer. Therefore, if a

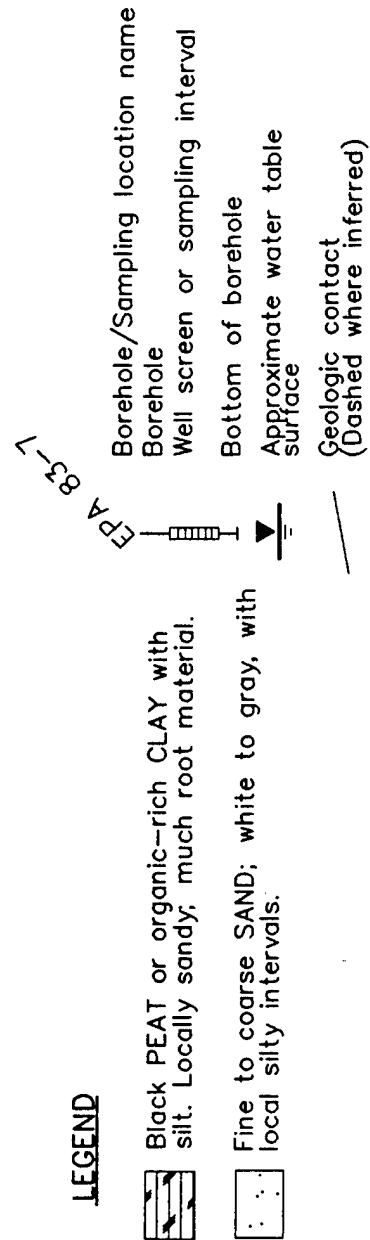
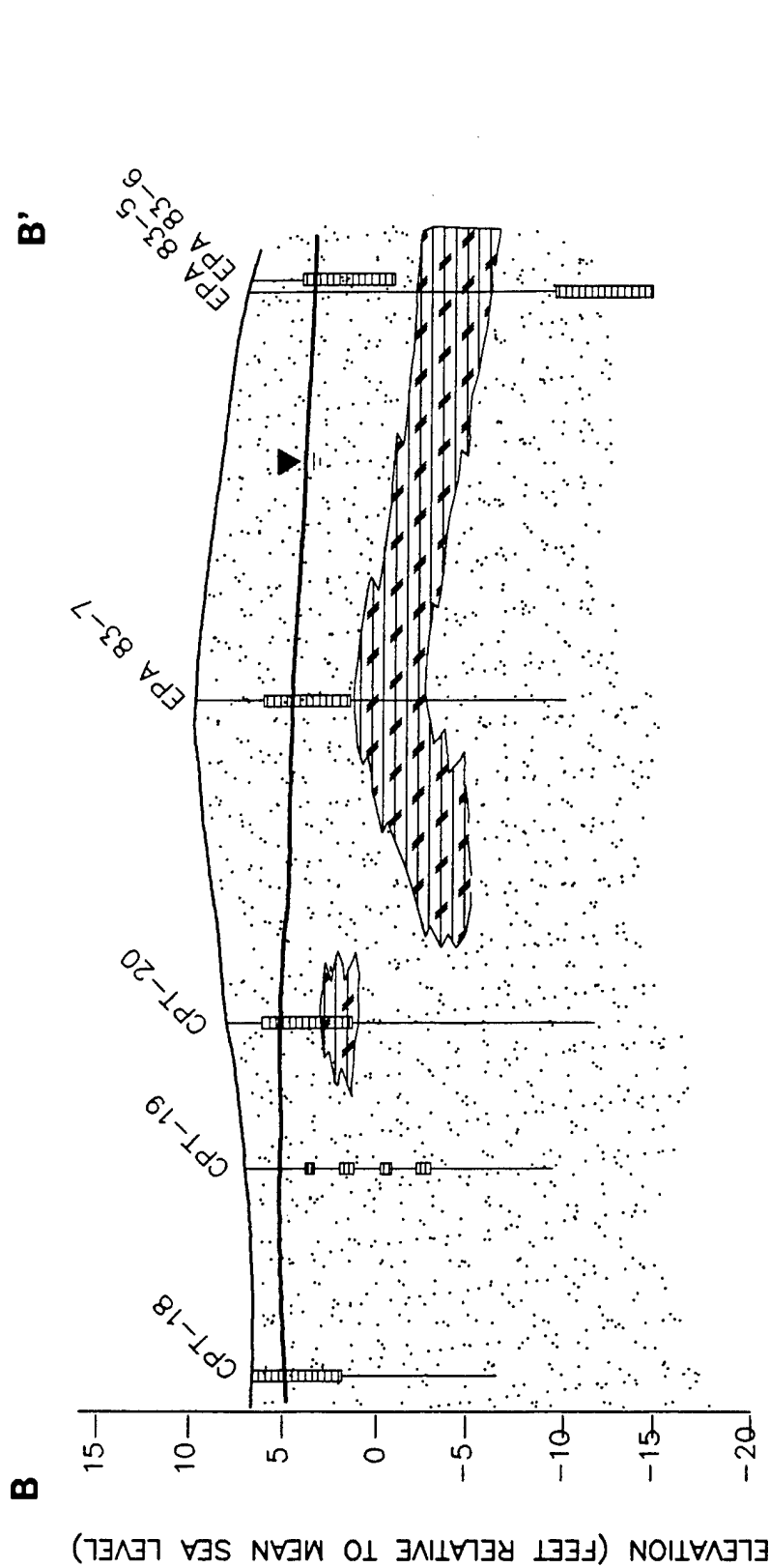


FIGURE 3.4

HYDROGEOLOGIC CROSS-SECTION B-B'

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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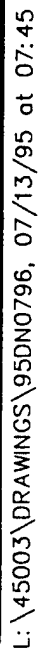


TABLE 3.1
WATER LEVEL DATA
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

WELL NUMBER	DATE AND TIME	EASTING	NORTHING	DATUM ^{a/} ELEVATION (ft msl) ^{b/}	DEPTH TO WATER (ft btoc) ^{c/}	GROUNDWATER ELEVATION (ft msl)
EPA-83-1	9/23/93 0807	10146.70	10028.15	12.84	7.86	4.98
	9/23/93 1841	10146.70	10028.15	12.84	7.93	4.91
	9/24/93 0842	10146.70	10028.15	12.84	7.92	4.92
EPA-83-2	9/23/93 0809	10144.57	10030.72	12.77	4.91	7.86
	9/23/93 1840	10144.57	10030.72	12.77	4.99	7.78
	9/24/93 0840	10144.57	10030.72	12.77	4.94	7.83
EPA-83-3	9/23/93 0729	10354.49	9922.04	5.77	3.05	2.72
	9/23/93 1743	10354.49	9922.04	5.77	3.13	2.64
	9/24/93 0858	10354.49	9922.04	5.77	3.15	2.62
EPA-83-4	9/23/93 0733	10353.09	9924.25	5.89	4.06	1.83
	9/23/93 1744	10353.09	9924.25	5.89	4.25	1.64
	9/24/93 0855	10353.09	9924.25	5.89	4.13	1.76
EPA-83-5	9/23/93 0723	10363.49	10032.47	6.98	4.51	2.47
	9/23/93 1813	10363.49	10032.47	6.98	4.74	2.24
	9/24/93 0830	10363.49	10032.47	6.98	4.62	2.36
EPA-83-6	9/23/93 0715	10360.56	10032.00	7.02	3.77	3.25
	9/23/93 1816	10360.56	10032.00	7.02	3.82	3.20
	9/24/93 0835	10360.56	10032.00	7.02	3.82	3.20
EPA-83-7	9/23/93 1843	10231.39	9967.36	10.68	6.46	4.22
	9/24/93 0845	10231.39	9967.36	10.68	6.49	4.19
EA-1	9/13/93 1420	10071.37	9879.49	9.59	2.85	6.74
	9/14/93 0728	10071.37	9879.49	9.59	2.86	6.73
	9/14/93 1553	10071.37	9879.49	9.59	2.92	6.67
	9/23/93 0744	10071.37	9879.49	9.59	3.15	6.44
	9/23/93 1836	10071.37	9879.49	9.59	3.18	6.41
	9/24/93 0920	10071.37	9879.49	9.59	3.18	6.41
EA-6	9/14/93 0810	9831.09	10125.11	16.42	6.98	9.44
	9/14/93 1437	9831.09	10125.11	16.42	7.00	9.42
	9/23/93 0749	9831.09	10125.11	16.42	7.35	9.07
	9/23/93 1820	9831.09	10125.11	16.42	7.35	9.07
	9/24/93 0937	9831.09	10125.11	16.42	7.36	9.06
EPA-2	9/13/93 1443	10018.00	9991.08	14.80	6.10	8.70
	9/14/93 0757	10018.00	9991.08	14.80	6.14	8.66
	9/14/93 1500	10018.00	9991.08	14.80	6.16	8.64
	9/23/93 0754	10018.00	9991.08	14.80	6.50	8.30
	9/23/93 1825	10018.00	9991.08	14.80	6.53	8.27
	9/24/93 0941	10018.00	9991.08	14.80	6.53	8.27
I-1	9/13/93 1440	9969.32	9971.93	16.52	7.73	8.79
	9/14/93 0754	9969.32	9971.93	16.52	7.78	8.74
	9/14/93 1510	9969.32	9971.93	16.52	7.80	8.72

TABLE 3.1 (Continued)
WATER LEVEL DATA
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

WELL NUMBER	DATE AND TIME	EASTING	NORTHING	DATUM ^{a/} ELEVATION (ft msl) ^{b/}	DEPTH TO WATER (ft btoc) ^{c/}	GROUNDWATER ELEVATION (ft msl)
	9/23/93 0755	9969.32	9971.93	16.52	8.15	8.37
	9/23/93 1826	9969.32	9971.93	16.52	8.16	8.36
	9/24/93 0940	9969.32	9971.93	16.52	8.18	8.34
I-2	9/13/93 1447	10011.78	10019.23	16.91	8.16	8.75
	9/14/93 0803	10011.78	10019.23	16.91	8.22	8.69
	9/14/93 1450	10011.78	10019.23	16.91	8.23	8.68
	9/23/93 0753	10011.78	10019.23	16.91	8.59	8.32
	9/23/93 1824	10011.78	10019.23	16.91	8.55	8.36
	9/24/93 0942	10011.78	10019.23	16.91	8.61	8.30
PL-1	9/23/93 0758	9994.79	9809.95	12.51	5.46	7.05
	9/23/93 1830	9994.79	9809.95	12.51	5.47	7.04
	9/24/93 0926	9994.79	9809.95	12.51	5.49	7.02
PL-2	9/14/93 0806	9994.18	10104.58	15.49	6.87	8.62
	9/14/93 1443	9994.18	10104.58	15.49	6.90	8.59
	9/23/93 0751	9994.18	10104.58	15.49	7.21	8.28
	9/23/93 1822	9994.18	10104.58	15.49	7.23	8.26
	9/24/93 0945	9994.18	10104.58	15.49	7.23	8.26
PL-3	9/13/93 1405	10196.61	9901.14	8.94	4.22	4.72
	9/14/93 0721	10196.61	9901.14	8.94	4.26	4.68
	9/14/93 1526	10196.61	9901.14	8.94	4.24	4.70
	9/23/93 0736	10196.61	9901.14	8.94	4.45	4.49
	9/23/93 1846	10196.61	9901.14	8.94	4.48	4.46
	9/24/93 0935	10196.61	9901.14	8.94	4.50	4.44
R-2	9/13/93 1423	10050.57	9897.69	10.40	2.22	8.18
	9/14/93 0736	10050.57	9897.69	10.40	2.26	8.14
	9/14/93 1559	10050.57	9897.69	10.40	2.28	8.12
	9/23/93 0747	10050.57	9897.69	10.40	2.60	7.80
	9/23/93 1835	10050.57	9897.69	10.40	2.62	7.78
	9/24/93 0922	10050.57	9897.69	10.40	2.62	7.78
R-3	9/13/93 1430	10001.70	9862.86	10.90	3.35	7.55
	9/14/93 0740	10001.70	9862.86	10.90	3.42	7.48
	9/14/93 1520	10001.70	9862.86	10.90	3.42	7.48
	9/23/93 0759	10001.70	9862.86	10.90	3.73	7.17
	9/23/93 1834	10001.70	9862.86	10.90	3.74	7.16
	9/24/93 0930	10001.70	9862.86	10.90	3.74	7.16
ZZ	9/13/93 1400	10180.12	9859.28	8.91	3.58	5.33
	9/14/93 0716	10180.12	9859.28	8.91	3.59	5.32
	9/14/93 1532	10180.12	9859.28	8.91	3.66	5.25
	9/23/93 0740	10180.12	9859.28	8.91	3.74	5.17
	9/23/93 1848	10180.12	9859.28	8.91	3.94	4.97

TABLE 3.1 (Concluded)
WATER LEVEL DATA
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

WELL NUMBER	DATE AND TIME	EASTING	NORTHING	DATUM ^{a/} ELEVATION (ft msl) ^{b/}	DEPTH TO WATER (ft btoc) ^{c/}	GROUNDWATER ELEVATION (ft msl)
	9/24/93 0910	10180.12	9859.28	8.91	3.90	5.01
A	9/13/93 1427	10066.58	9858.69	10.60	3.62	6.98
	9/14/93 0733	10066.58	9858.69	10.60	3.65	6.95
	9/14/93 1547	10066.58	9858.69	10.60	3.68	6.92
	9/23/93 0746	10066.58	9858.69	10.60	3.92	6.68
	9/23/93 1838	10066.58	9858.69	10.60	3.95	6.65
	9/24/93 0918	10066.58	9858.69	10.60	3.94	6.66
C	9/14/93 1604	10065.66	9945.23	13.76	5.25	8.51
	9/23/93 0748	10065.66	9945.23	13.76	5.59	8.17
	9/24/93 0932	10065.66	9945.23	13.76	5.60	8.16
D	9/13/93 1445	10027.38	10020.12	15.47	6.76	8.71
	9/14/93 0800	10027.38	10020.12	15.47	6.80	8.67
	9/14/93 1455	10027.38	10020.12	15.47	6.83	8.64
	9/23/93 0752	10027.38	10020.12	15.47	7.19	8.28
	9/23/93 1823	10027.38	10020.12	15.47	7.20	8.27
	9/24/93 0943	10027.38	10020.12	15.47	7.21	8.26
ES-PZ-1	9/14/93 1344	10354.95	9917.38	3.79	4.77	-0.98
ES-PZ-2	9/14/93 1348	10357.47	9912.95	3.74	1.27	2.47
ES-PZ-3	9/23/93 1809	10278.24	10050.84	9.83	5.65	4.18
	9/24/93 0900	10278.24	10050.84	9.83	5.80	4.03

^{a/} Datum is top of PVC.

^{b/} ft msl = feet above mean sea level.

Source: EA, 1993

^{c/} ft btoc = feet below top of casing.

^{d/} ND = data not available.

saturated thickness of 45 feet is assumed, these results convert to hydraulic conductivities ranging from 6×10^{-3} to 1×10^{-1} ft/min.

Hydraulic conductivity was estimated at wells installed by Parsons ES using short-term single-well pumping and recovery tests as described in Section 2. Pumping and recovery tests were performed in monitoring wells EPA 83-1 through EPA 83-6. The results of these tests are summarized in Table 3.2. The average hydraulic conductivity of the sands in the shallow saturated zone as determined from these tests is 1.5×10^{-2} ft/min, or 21.6 feet per day (ft/day). This is consistent with tests performed by Geraghty & Miller (1985), EA (1987), and Hayes and Barr (1983).

3.3.2.3 Effective Porosity

Because of the difficulty involved in accurately determining effective porosity, accepted literature values for the type of sediment in the shallow saturated zone were used. Freeze and Cherry (1979) give ranges of effective porosity for sand of 0.25 to 0.50. The effective porosity for sediments of the shallow saturated zone was assumed to be 0.30 for this study. This estimate is the same as those made during other studies at POL Site SS-36 (e.g., Geraghty and Miller, 1985; EA, 1987 and 1993).

3.3.2.4 Advective Groundwater Velocity

The advective velocity of groundwater in the direction parallel to groundwater flow is given by:

$$\bar{v} = \frac{K}{n_e} \frac{dH}{dL}$$

Where: $\bar{v}$ = Average advective groundwater velocity (seepage velocity) [L/T]

K = Hydraulic conductivity [L/T] (1.5×10^{-2} ft/min)

dH/dL = Gradient [L/L] (0.025 ft/ft)

n_e = Effective porosity (0.3).

Using this relationship in conjunction with site-specific data, the average advective groundwater velocity at the site is 1.8 ft/day, or approximately 657 feet per year.

TABLE 3.2
RESULTS OF AQUIFER PUMPING AND RECOVERY TESTS
INTRINSIC REMEDIATION TS
POL SITE SS-36
EGLIN AIR FORCE BASE, FLORIDA

WELL	TEST NUMBER	DATE TESTED	AQUIFER	WELL DEPTH (feet bgs)	STATIC WATER LEVEL (feet bgs)	SATURATED THICKNESS (feet) ^a	PUMPING RATE (ft ³ /min)	TRANSMISSIVITY (ft ² /min)				HYDRAULIC CONDUCTIVITY (ft/min)			
								THEIS DRAWDOWN	COOPER-JACOB DRAWDOWN	NEUMAN DRAWDOWN	THEIS RECOVERY	THEIS DRAWDOWN	COOPER-JACOB DRAWDOWN	NEUMAN DRAWDOWN	THEIS RECOVERY
EPA-83-1	1	9/22/93	confined	25.75	5.93	28	0.53	1.37E-01	1.37E-01	NA ^b	1.85E-01	4.88E-03	4.88E-03	NA	6.59E-03
	2	9/22/93				28	0.82	2.36E-01	2.36E-01	NA	1.86E-01	8.42E-03	8.42E-03	NA	6.66E-03
EPA-83-2	1	9/22/93	unconfined	7.75	2.91	6.25	0.39	8.23E-02	7.10E-02	2.38E-02	9.53E-02	1.32E-02	1.14E-02	3.80E-03	1.52E-02
	2	9/22/93				6.25	0.39	3.54E-01	3.12E-01	1.80E-01	1.07E-01	5.66E-02	5.00E-02	2.87E-02	1.72E-02
EPA-83-3	1	9/22/93	confined	20.75	1.05	27	0.578	6.64E-01	6.64E-01	NA	5.24E-01	2.46E-02	2.46E-02	NA	1.94E-02
	2	9/23/93	unconfined	7.25	2.06	7.8	0.356	-- ^c	--	--	1.22E-01	--	--	--	1.57E-02
EPA-83-5	1	9/24/93	confined	19.75	2.51	26	0.587	3.74E-01	5.06E-01	NA	5.23E-01	1.44E-02	1.95E-02	NA	2.01E-02
	1	9/24/93	unconfined	9.25	1.77	11.2	0.379	4.07E-02	3.97E-02	2.73E-02	7.71E-02	3.63E-03	3.54E-03	2.44E-03	6.88E-03
AVERAGE							2.70E-01	2.81E-01	2.81E-01	7.69E-02	2.27E-01	1.80E-02	1.75E-02	1.17E-02	1.35E-02
OVERALL AVERAGE							2.14E-01								

^a Saturated thickness = 1.5 x (static water level - well depth)

^b NA = not applicable.

^c Drawdown data were not available for the second pumping test of well EPA-83-4.

3.3.2.5 Preferential Flow Paths

No preferential contaminant migration pathways were identified during the field work phase of this project. The relatively high hydraulic conductivity of the aquifer materials may prevent manmade features such as utility trenches or storm drains from providing preferential flow paths.

3.3.3 Groundwater Use

Groundwater from the shallow aquifer is only used for irrigation water within the Base, although some domestic wells off the Base tap the shallow aquifer. The Floridan aquifer is the principal source of drinking water for Eglin AFB and the surrounding communities. Contamination from this site is unlikely to affect the Floridan aquifer because the Pensacola Clay should act as an effective barrier to contaminant migration from the shallow aquifer to the Floridan aquifer. In addition, the groundwater flow gradients observed at the site indicate that dissolved petroleum hydrocarbons introduced to the shallow aquifer by the 1988 MOGAS spill should eventually migrate upward, towards Weekly Bayou.

SECTION 4

NATURE AND EXTENT OF CONTAMINATION AND SOIL AND GROUNDWATER GEOCHEMISTRY

4.1 SOURCES OF CONTAMINATION

The contaminant source of concern for this study is the spill that happened in early 1988, when the sump pump for the UST vault was left on overnight and approximately 1,200 gallons of MOGAS were discharged to the ground surface. It does not appear that there were any leaks from the UST, as it was empty and dry during the field effort for this study. If the UST had any holes or other leaks, it would have contained several feet of water because the water table is only a few feet bgs at this site. The tank has not been used since June 1988, when the power supply to Building 763 was disconnected.

Several other releases at the POL Yard have been documented in addition to the 1988 MOGAS release. Most of these releases are upgradient of the study site. In 1984, free product (LNAPL) was discovered in the subsurface in the area southwest of Building 763 and the study area for this site. Roy F. Weston, Inc. was retained by the Air Force to identify the source of contamination and the extent of contamination. Storage tanks and piping lines were tested, and four piping leaks were discovered. The LNAPL was identified as JP-4 jet fuel, and the product plume was delineated with borings and wells. The plume of free product was located in an area between Building 769 and well PL-2 (Roy F. Weston, 1984) (see Figure 1.2). Fluid level measurements indicated that this plume was migrating very slowly, if at all, to the east toward Weekly Bayou. A passive recovery system was installed, and by October 1984, approximately 7,400 gallons of fuel had been collected (Roy F. Weston, 1984).

In 1987, an *in situ* enhanced biodegradation system was installed to treat contaminated soil and groundwater in the vicinity of the LNAPL plume (EA, 1989). Inorganic nutrients and hydrogen peroxide were injected into the subsurface, and EA (1993) estimated that 5,000 pounds of hydrocarbons were removed due to biodegradation and volatilization. In addition, about 150 gallons of free product were bailed from wells.

Later investigations by EA (1987 and 1993) used soil gas surveys to delineate additional areas of contamination. Several small areas of contamination were detected in the vicinity of the large storage tanks northwest of the study area, and a large area of contamination was discovered near the loading dock southeast of the study area.

4.2 SOIL CHEMISTRY

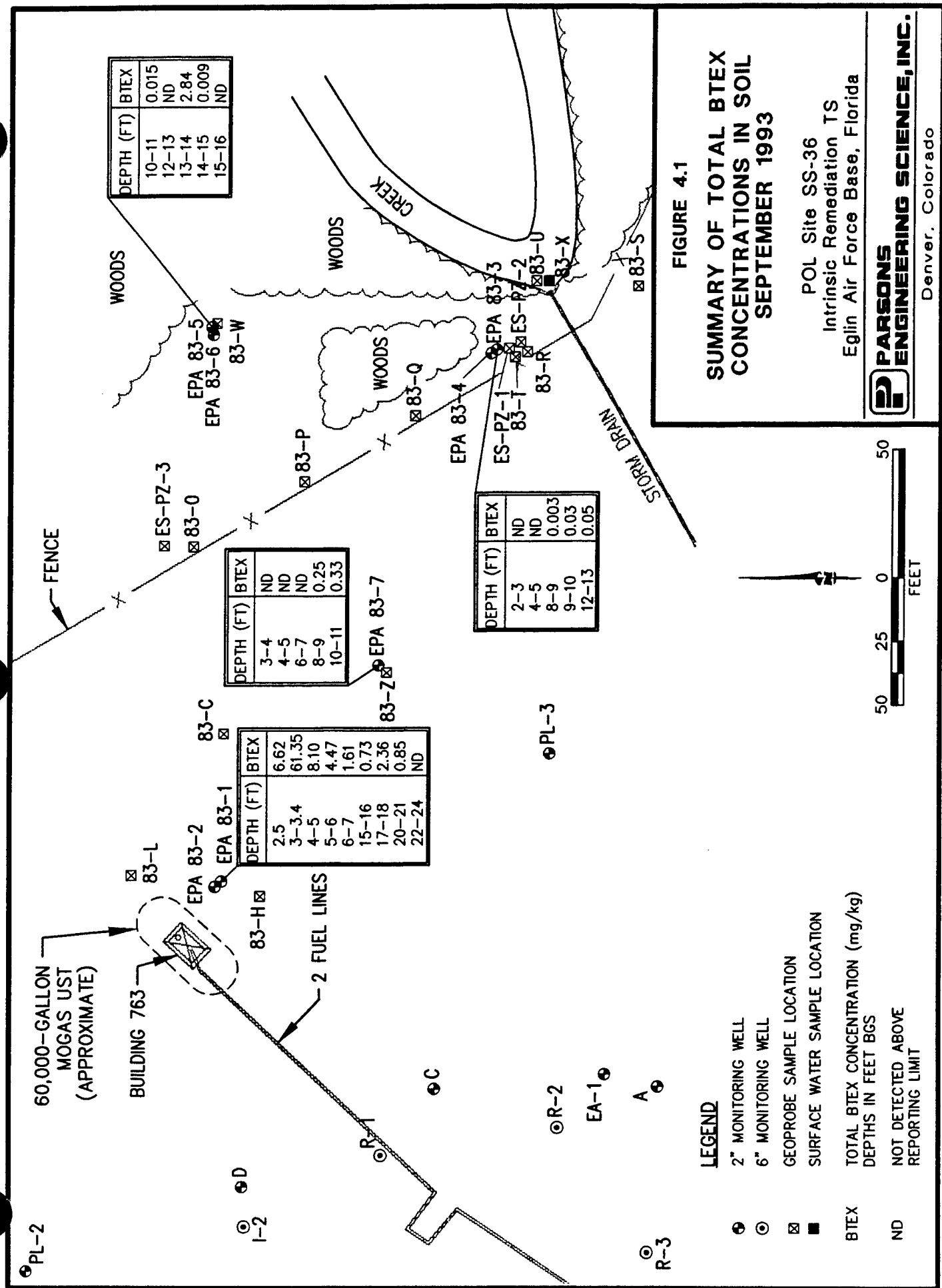
4.2.1 Residual Contamination

Residual LNAPL is defined as the LNAPL that is trapped in the aquifer or vadose zone by the processes of cohesion and capillarity, and therefore will not flow within the aquifer and will not flow from the aquifer matrix into a well under the influence of gravity. Mobile LNAPL is defined as LNAPL that is free to flow in the aquifer and that will flow from the aquifer matrix into a well under the influence of gravity. At this study site, the LNAPL consists of fuel hydrocarbons, particularly MOGAS.

As noted in Section 4.1, mobile LNAPL was present immediately west and southwest of the study area, northwest of Building 769. However, much of this product has been captured by a passive recovery system, and the residual LNAPL was treated using *in situ* enhanced biodegradation. There is no previous evidence that mobile LNAPL was present on the groundwater or in the capillary fringe in the vicinity of Building 763, but it is likely that an LNAPL body was present for an indefinite period following the 1988 release. Mobile LNAPL was not detected in any site wells during this investigation.

For this study, soil samples were collected from the boreholes for wells EPA 83-1, EPA 83-2, EPA 83-3, EPA 83-5, and EPA 83-7. These samples were submitted for laboratory analysis of BTEX using RSKERL Standard Operating Procedure (RSKSOP) 122 and for total petroleum hydrocarbons (TPH) using RSKSOP-72. Table 4.1 presents soil analytical data, while soil BTEX and TPH concentrations are summarized on Figures 4.1 and 4.2, respectively. Laboratory data reports are presented in Appendix B.

Soil TPH concentrations ranged from 0.46 milligrams per kilogram (mg/kg) to 7,090 mg/kg. At EPA 83-5, TPH concentrations were no higher than 9.73 mg/kg. Significantly elevated concentrations of TPH were detected at shallow depths in boreholes EPA 83-1, EPA 83-7, and EPA 83-3, which lie along a path from the source area to the small creek at the eastern margin of the site. In general, TPH concentrations



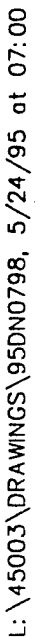


TABLE 4.1

FUEL HYDROCARBON ANALYTICAL RESULTS FOR SOIL SAMPLES
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Sample Location	Sample Date	Sample Interval Top (ft bgs) Bottom (ft bgs)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	P-Xylene (mg/kg)	M-Xylene (mg/kg)	O-Xylene (mg/kg)	Total Xylene (mg/kg)	Total BTEX (mg/kg)	1,3,5-TMB (mg/kg)	1,2,4-TMB (mg/kg)	1,2,3-TMB (mg/kg)	TPH ^a (mg/kg)
EPA 83-1	9/20/93	2 2.4	ND ^c	<0.01	<0.01	<0.01	0.00301	0.0347	0.03771	0.03771	0.0644	0.0031	0.017	33
EPA 83-1	9/20/93	2.5 2.5	ND	0.292	0.454	0.587	1.29	4	5.877	6.623	6.33	3.01	3.44	407
EPA 83-1	9/20/93	3 3.4	2.66	5.68	4.01	10.6	21.2	17.2	49	61.35	1.93	3.07	1.26	2140
EPA 83-1	9/20/93	4 5	0.194	0.712	0.242	1.48	2.46	3.23	7.17	8.1002	1.17	1.51	0.661	209
EPA 83-1	9/20/93	5 6	0.36	0.445	0.238	0.733	1.3	1.39	3.423	4.466	0.753	0.701	0.337	491
EPA 83-1	9/20/93	6 7	0.0255	0.0995	0.0327	0.302	0.501	0.644	1.447	1.6047	0.322	0.431	0.17	53.6
EPA 83-1	9/20/93	15 16	0.0138	0.0445	0.0303	0.127	0.28	0.239	0.646	0.7346	0.106	0.159	0.0639	21.3
EPA 83-1	9/20/93	16 17	0.00382	0.0134	0.011	0.0332	0.0649	0.0431	0.1412	0.16942	0.0161	0.0364	0.015	5.84
EPA 83-1	9/20/93	17 18	1.32	0.0157	0.0852	0.111	0.819	0.00476	0.93476	2.35566	0.0438	0.269	0.113	12
EPA 83-1	9/20/93	18 19	0.645	0.0268	0.03	0.0483	0.122	0.0179	0.1882	0.89	0.00817	0.014	0.011	8.4
EPA 83-1	9/20/93	19 20	<0.01	<0.01	0.00262	0.00285	0.00399	0.00389	0.01073	0.01335	0.0028	0.00572	0.00327	5.9
EPA 83-1	9/20/93	20 21	0.781	0.0159	0.00698	0.00772	0.0328	0.00483	0.04535	0.04923	<0.01	<0.01	<0.01	16.6
EPA 83-1	9/20/93	21 22	<0.01	<0.01	<0.01	<0.01	0.00214	<0.01	0.00214	0.00214	<0.01	0.00278	<0.01	1.18
EPA 83-1	9/20/93	22 24	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.37
EPA 83-2	9/21/93	3 3.5	0.165	18.2	2.05	41.7	69.1	59.2	170	190.415	21.9	47.6	13.1	1550
EPA 83-2	9/21/93	3.5 4	0.147	1.21	0.04	0.0633	0.141	0.11	0.3143	1.7113	0.245	0.118	0.0625	190
EPA 83-3	9/21/93	1.5 2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1210
EPA 83-3	9/21/93	2 2.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1970
EPA 83-3	9/21/93	2 3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	7090
EPA 83-3	9/21/93	4 5	ND	ND	ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	ND	<0.01	4.91
EPA 83-3	9/21/93	8 9	ND	<0.01	<0.01	<0.01	0.00318	<0.01	0.00318	0.00318	0.0106	0.0165	0.00968	6.02
EPA 83-3	9/21/93	9 10	0.0256	<0.01	<0.01	0.00329	0.00391	<0.01	0.0072	0.0328	0.00726	0.0157	0.326	4.96
EPA 83-3	9/21/93	12 13	0.0131	0.00286	0.00831	0.00675	0.0106	0.0111	0.02845	0.05272	0.017	0.0191	0.0256	3.61
EPA 83-5	9/22/93	10 11	<0.01	<0.01	<0.01	0.00505	0.00554	0.00492	0.01551	0.01551	0.00537	0.00604	0.00594	9.73
EPA 83-5	9/22/93	12 13	ND	ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	ND	<0.01	ND	1.02
EPA 83-5	9/22/93	13 14	<0.01	2.84	<0.01	<0.01	<0.01	<0.01	<0.01	2.84	<0.01	<0.01	<0.01	1.16
EPA 83-5	9/22/93	14 15	<0.01	ND	<0.01	0.00423	0.00495	<0.01	0.00918	0.00918	ND	<0.01	ND	2.37
EPA 83-5	9/22/93	15 16	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.27
EPA 83-7	9/23/93	3 4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.46
EPA 83-7	9/23/93	4 5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1170
EPA 83-7	9/23/93	6 7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.23	0.832	0.605	5310
EPA 83-7	9/23/93	8 9	0.00637	<0.01	0.0142	0.0345	0.124	0.0669	0.2254	0.24597	0.409	0.761	0.416	40.3
EPA 83-7	9/23/93	10 11	<0.01	<0.01	<0.01	0.0922	0.237	<0.01	0.3292	0.3292	0.656	1.19	0.692	16.2

a/ ft bgs = feet below ground surface.

b/ TPH quantified using RSKSOP-72 with a JP-4 standard.

c/ ND = not detected.

at these locations were highest in the vicinity of the water table and diminished with depth.

BTEX compounds were also detected at all four sampling locations (Figure 4.1). However, concentrations were much lower than TPH concentrations, ranging from 0.003 mg/kg to 61.35 mg/kg. All of the highest BTEX concentrations were detected in samples from different depths at EPA 83-1. With the exception of one sample from EPA 83-5, total BTEX concentrations away from EPA 83-1 all were below 0.33 mg/kg. At EPA 83-7 and EPA 83-3, BTEX compounds were not detected in samples from the vicinity of the water table, but were detected in samples 5 feet (or more) below the water table.

The low (or nondetectable) BTEX concentrations associated with the elevated TPH concentrations indicates that the remaining residual LNAPL is significantly weathered. As weathering of the residual LNAPL continues through the processes of volatilization, biodegradation, and dissolution, less BTEX will partition from the LNAPL into site groundwater.

4.3 GROUNDWATER AND SURFACE WATER CHEMISTRY

Three lines of evidence can be used to document the occurrence of natural attenuation: 1) geochemical evidence; 2) documented loss of contaminant mass at the field scale; and 3) laboratory microcosm studies. All three lines of evidence are presented herein to define the effects of natural attenuation. USEPA RSKERL researchers performed an anaerobic microcosm study on a soil sample collected from below the water table at the site; this evidence, along with the geochemical and contaminant data, is described in the following sections.

4.3.1 Dissolved Hydrocarbon Contamination

Laboratory analytical results for groundwater samples collected during previous site investigations indicated the presence of fuel hydrocarbon contamination in the shallow saturated zone. Groundwater samples collected in September 1993 and October 1994 by Parsons ES and EPA RSKERL personnel confirmed these results. Table 4.2 summarizes groundwater contaminant data for these samples, and laboratory reports are presented in Appendix B.

TABLE 4.2
FUEL HYDROCARBONS DETECTED IN
GROUNDWATER AND SURFACE WATER
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Sample Location	Sample Date	Depth to Screen Top (ft bgs)	Screen Elevation Top (ft msl)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	P-xylene (µg/L)	M-xylene (µg/L)	O-xylene (µg/L)	M&P-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Total BTEX ^a (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	TPH (mg/L)
SURFACE WATER																	
83-X Fresh	09/17/93	0.25 ^d	ND ^d	<1	<1	<1	<1	<1	<1	— ^b	<1	<1	<1	<1	<1	<1	—
83-X Salt	09/17/93	1.25 ^w	ND	<1	<1	<1	<1	<1	<1	—	<1	<1	<1	<1	<1	<1	—
83-X SW Sediment	09/17/93	1.83 ^w	ND	<1	<1	<1	<1	<1	<1	—	<1	<1	<1	<1	<1	<1	—
83-Y Fresh	09/17/93	0.15 ^d	ND	<1	<1	<1	<1	<1	<1	—	<1	<1	<1	<1	<1	<1	—
83-Y Salt	09/17/93	0.6 ^d	ND	<1	<1	<1	<1	<1	<1	—	<1	<1	<1	<1	<1	<1	—
83-Y SW Sediment	09/17/93	1 ^d	ND	<1	<1	<1	<1	<1	<1	—	<1	<1	<1	<1	<1	<1	—
CONE PENETROMETER SAMPLES																	
CPT-5	03/24/93	5.18	9.68	<1	<1	1.6	22.6	53.8	0.8	—	77.2	78.8	86	10.7	16.8	11.6	—
CPT-7	03/25/93	2.04	6.54	<1	20.3	6.9	20.2	32.7	36.6	—	89.5	116.7	—	190	257	185	—
CPT-8-6	03/26/93	6	6.5	0.6	8.7	5.4	21.9	34.1	22	—	78	92.7	84	71.8	124	101	—
CPT-8-8	03/26/93	8	8.5	4.63	19.50	28.7	64.8	66.7	1300	—	2615	4908.5	18100	364	1100	478	—
CPT-8-10	03/26/93	10	10.5	2.64	11.6	78.5	309	549	94.6	—	952.6	1150.7	1130	135	276	94.9	—
CPT-8-12	03/26/93	12	12.5	0.63	1.8	75.7	34.3	68.8	47.7	—	150.8	244.7	223	12.7	26.9	13	—
CPT-10	03/23/93	0.95	5.45	9.22	4.72	14.5	294	63.7	15.1	—	946.1	1107.2	1120	127	278	172	—
CPT-11	03/25/93	-0.4	4.1	10.33	5.83	9.7	158	163	0.8	—	321.8	419.5	477	108	290	94.7	—
CPT-12	03/25/93	2.25	6.75	8.75	4.25	9.2	284	625	624	—	1533	1678.7	1900	222	455	280	—
CPT-13	03/24/93	1.13	5.63	10.35	5.85	4.2	86.7	122	0.9	—	209.6	239.2	267	57.8	166	82.8	—
CPT-14	03/25/93	2.42	6.92	8.16	3.66	8.3	173	325	42.1	—	540.1	647.5	—	36.8	126	61.6	—
CPT-15	03/24/93	2.14	6.64	8.46	3.96	—	—	—	—	—	—	—	24	—	—	—	—
CPT-16	03/25/93	1.7	6.2	7.38	2.88	5.5	13.3	21.4	2.4	—	37.1	99.6	112	7.1	102	11.5	—
CPT-17-5	03/26/93	5	5.5	4.51	4.01	—	—	—	—	—	—	—	208	—	—	—	—
CPT-17-7	03/26/93	7	7.5	2.56	2.06	—	—	—	—	—	—	—	111	—	—	—	—
CPT-17-9	03/26/93	9	9.5	0.47	-0.03	—	—	—	—	—	—	—	205	—	—	—	—
CPT-18	03/22/93	-0.35	4.15	7.21	2.71	—	—	—	—	—	—	—	7	—	—	—	—
CPT-19-3	03/26/93	3	3.5	4.03	3.53	—	—	—	—	—	—	—	12	—	—	—	—
CPT-19-5	03/26/93	5	5.5	1.98	1.48	—	—	—	—	—	—	—	12	—	—	—	—
CPT-19-7	03/26/93	7	7.5	-0.06	-0.56	—	—	—	—	—	—	—	45	—	—	—	—
CPT-19-9	03/26/93	9	9.5	-2.08	-2.58	—	—	—	—	—	—	—	41	—	—	—	—
CPT-20	03/24/93	1.94	6.44	6.01	1.51	—	—	—	—	—	—	—	4030	—	—	—	—
CPT-21	03/25/93	3.23	7.73	6.28	1.78	—	—	—	—	—	—	—	1	—	—	—	—
CPT-24	03/24/93	2.21	6.71	4.74	0.24	—	—	—	—	—	—	—	228	—	—	—	—
CPT-25	03/24/93	2.54	7.04	3.11	-1.39	—	—	—	—	—	—	—	20	—	—	—	—
MONITORING WELLS																	
EPA 83-1	09/30/93	20.21	25.21	-9.86	-14.86	21	12	140	—	—	860	872	1045	—	—	—	2.2
EPA 83-1 d ^e	09/30/93	20.21	25.21	-9.86	-14.86	300	1300	51	—	—	580	1010	2661	—	—	—	7.8
EPA 83-1	10/18/94	20.21	25.21	-9.86	-14.86	2	1	3.1	24.7	12.9	1	38.6	44.7	—	20.5	115	24.5
EPA 83-2	09/30/93	2.28	7.28	8.18	3.18	240	740	62	—	—	430	750	1792	—	—	—	6.1
EPA 83-2	10/18/94	2.28	7.28	8.18	3.18	463	748	13.1	179	219	—	491.1	625.3	—	60.7	87.8	58
EPA 83-3	09/30/93	14.41	19.41	-10.48	-15.48	34	2.3	2.3	—	—	18	56.6	—	—	—	—	1.3
EPA 83-3	10/18/94	14.41	19.41	-10.48	-15.48	22.2	1.8	6.9	53.2	4.6	—	81.7	112.6	—	21.2	110	26.1
EPA 83-4	09/30/93	0.99	5.99	3.04	-1.96	<1	<1	1.2	<1	<1	<1	1.2	—	—	<1	<1	2.5
EPA 83-4	10/18/94	0.99	5.99	3.04	-1.96	<1	<1	1.4	<1	<1	<1	1.4	—	—	<1	<1	<0.6
EPA 83-5	10/01/93	14.73	19.73	-9.62	-14.62	<1	<1	<1	<1	<1	13	13	—	—	<1	<1	<0.6
EPA 83-5	10/18/94	14.73	19.73	-9.62	-14.62	<1	<1	<1	<1	<1	<1	<1	—	—	<1	<1	<0.6
EPA 83-6	10/01/93	0.98	5.98	4.17	-0.83	<1	<1	<1	<1	<1	<1	<1	—	—	<1	<1	0.68
EPA 83-6	10/18/94	0.98	5.98	4.17	-0.83	<1	<1	<1	<1	<1	<1	<1	—	—	<1	<1	<1

TABLE 4.2 (Concluded)
FUEL HYDROCARBONS DETECTED IN
GROUNDWATER AND SURFACE WATER
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Sample Location	Sample Date	Depth to Screen Top (ft bgs) ^a	Depth to Screen Base (ft bgs)	Screen Elevation Top (ft msl ^b)	Screen Elevation Base (ft msl)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	P-xylene (µg/L)	M-xylene (µg/L)	O-xylene (µg/L)	M&P-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Total BTEX ^c (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	TPH (mg/L)
EPA 83-7	10/01/93	3.39	8.39	5.33	0.33	2.2	4.3	36	--	--	26	36	62	104.5	--	--	--	--	4.4
EPA 83-7	10/18/94	3.39	8.39	5.33	0.33	1.9	1	<1	<1	<1	<1	--	<1	2.9	--	<1	<1	--	--
PL-2	02/24/93	43.35	48.35	-30	-35	1.3	0.1	0.5	2.7	11.4	0.1	--	14.2	16.1	--	1.2	3.4	2.9	--
PL-2	2/26/93	43.35	48.35	-30	-35	34.2	0.8	5.4	50.9	263	1.3	--	315.2	355.6	--	22.1	62.1	35.7	--
A	2/25/93	--	--	--	--	8.3	2.8	11.7	42	80	52.4	--	174.4	197.2	--	--	--	--	--
C	2/25/93	--	--	--	--	0.4	24.3	147	285	654	146	--	1085	1256.7	--	--	--	--	--
D	2/25/93	--	--	--	--	4.3	342	261	730	1645	494	--	2869	3476.3	--	--	--	--	--
R1	3/23/93	--	--	--	--	0.6	8.7	59.1	84.6	126	21.6	--	232.2	300.6	--	--	--	--	--
R2	3/22/93	--	--	--	--	3.6	10.7	152	107	201	34.3	--	342.3	508.6	--	--	--	--	--
R3	3/22/93	--	--	--	--	6.3	2.5	43	86.4	132	3.9	--	222.3	274.1	--	--	--	--	--
GEOPROBE SAMPLES																			
Geoprobe 83 C-1	09/16/93	7.25	8.75	2.78	1.28	96.5	1.24	2.08	58.6	81.8	<1	--	140.4	240.22	--	4.94	29.7	9.29	--
Geoprobe 83 C-2	09/16/93	13.25	14.75	-3.22	-4.72	<1	<1	2.93	2.71	1.82	<1	--	4.53	7.46	--	4	49.8	8.82	--
Geoprobe 83 C-2 d	09/16/93	13.25	14.75	-3.22	-4.72	<1	<1	2.95	2.7	1.76	<1	--	4.46	7.41	--	3.88	43.4	8.25	--
Geoprobe 83 H 1b ^b	09/16/93	NA ^c	NA	NA	NA	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	5.66	<1	--
Geoprobe 83 H-1	09/15/93	4.25	5.75	6.15	4.65	31	30.4	841	1390	1570	<1	--	2960	3862.4	--	168	886	291	--
Geoprobe 83 H-2	09/16/93	25.25	26.75	-14.85	-16.35	2.3	<1	6.39	10	18.6	<1	--	29.1	38.29	--	21.8	296	<1	--
Geoprobe 83 L-1	09/16/93	4.25	5.75	6.67	5.17	3.76	6.51	26.4	92.8	165	123	--	380.8	417.47	--	13.9	62.7	21.6	--
Geoprobe 83 L-1 d	09/16/93	4.25	5.75	6.67	5.17	3.88	6.73	26.8	93	167	123	--	383	420.41	--	13.7	63.6	21.4	--
Geoprobe 83 L-2	09/16/93	16.25	17.75	-5.33	-6.83	33.7	0.9	9.86	51.5	217	<1	--	269	313.46	--	50.1	267	100	--
Geoprobe 83 O-1	09/15/93	10.25	11.75	-0.06	-1.56	<1	<1	<1	2.14	1.86	<1	--	4	4	--	<1	<1	<1	--
Geoprobe 83 O-2	09/15/93	22.25	23.75	-12.06	-13.56	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	<1	<1	--
Geoprobe 83 P-1	09/14/93	4.25	5.75	2.39	0.89	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	<1	<1	--
Geoprobe 83 P-2	09/14/93	25.25	26.75	-18.61	-20.11	8.12	1.26	4.18	11.5	5.63	<1	--	17.13	30.69	--	3.22	138	36.9	--
Geoprobe 83 Q-1	09/14/93	4.25	5.75	0.94	-0.56	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	<1	<1	--
Geoprobe 83 Q-2	09/14/93	25.25	26.75	-20.06	-21.56	<1	<1	<1	3.38	1.77	<1	--	5.15	5.15	--	<1	114	10.3	--
Geoprobe 83 R-1	09/13/93	4.25	5.75	-0.15	-1.65	<1	<1	<1	<1	1.15	<1	--	1.15	1.15	--	1.92	<1	<1	--
Geoprobe 83 R-2	09/13/93	5.75	7.25	-1.65	-3.15	<1	<1	3.61	6.47	16.3	<1	--	22.77	26.38	--	30.3	54.2	41.5	--
Geoprobe 83 R-3	09/13/93	20.25	21.75	-16.15	-17.65	38.6	1.55	8.61	23.8	36	<1	--	59.8	108.56	--	6.83	114	22.7	--
Geoprobe 83 R-3 d	09/13/93	20.25	21.75	-16.15	-17.65	37.5	1.58	8.51	23.3	35.3	<1	--	58.6	106.19	--	6.82	117	23	--
Geoprobe 83 R-4	09/14/93	33.25	34.75	-29.15	-30.65	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	<1	<1	--
Geoprobe 83 S-1	09/15/93	4.25	5.75	0.66	-0.84	<1	<1	<1	1.1	1.1	<1	--	2.2	3.2	--	2.1	<1	<1	--
Geoprobe 83 S-2	09/15/93	16.25	17.75	-11.34	-12.84	32.7	3.05	3.29	26.4	51.4	<1	--	77.8	411.14	--	9.75	34.7	17.2	--
Geoprobe 83 S-3	09/15/93	25.25	26.75	-20.34	-21.84	<1	<1	<1	1.8	<1	<1	--	2.8	3.8	--	0.5	11.9	0.5	--
Geoprobe 83 U-1	09/14/93	1.8	1.8	ND	ND	<1	<1	<1	<1	<1	<1	--	<1	<1	--	2.28	<1	<1	--
Geoprobe 83 U-2	09/14/93	3.3	4.8	ND	ND	6.76	<1	1.38	25.1	39.7	<1	--	64.8	72.94	--	119	298	182	--
Geoprobe 83 U-2 d	09/14/93	3.3	4.8	ND	ND	6.9	<1	1.39	25.1	39.8	<1	--	64.9	73.19	--	119	299	187	--
Geoprobe 83 U-3	09/14/93	5.9	10	ND	ND	198	1.12	1.41	13.8	13.5	<1	--	27.3	227.83	--	70.9	172	115	--
Geoprobe 83 W-1	09/17/93	4.25	5.75	0.83	-0.67	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	<1	<1	--
Geoprobe 83 W-2	09/17/93	22.25	23.75	-17.17	-18.67	<1	<1	<1	<1	<1	<1	--	<1	<1	--	<1	<1	<1	--
Geoprobe 83 Z-1	09/17/93	5.25	6.75	3.47	1.97	22.6	2.12	19.3	39.8	143	105	--	287.8	331.82	--	171	352	247	--
Geoprobe 83 Z-2	09/17/93	13.25	14.75	-4.53	-6.03	153	18.3	227	594	1270	<1	--	1864.5	2262.8	--	114	420	182	--
Geoprobe 83 Z-3	09/17/93	22.25	23.75	-13.53	-15.03	3.39	<1	1.88	10.4	4.17	<1	--	14.57	19.84	--	3.55	154	19.2	--

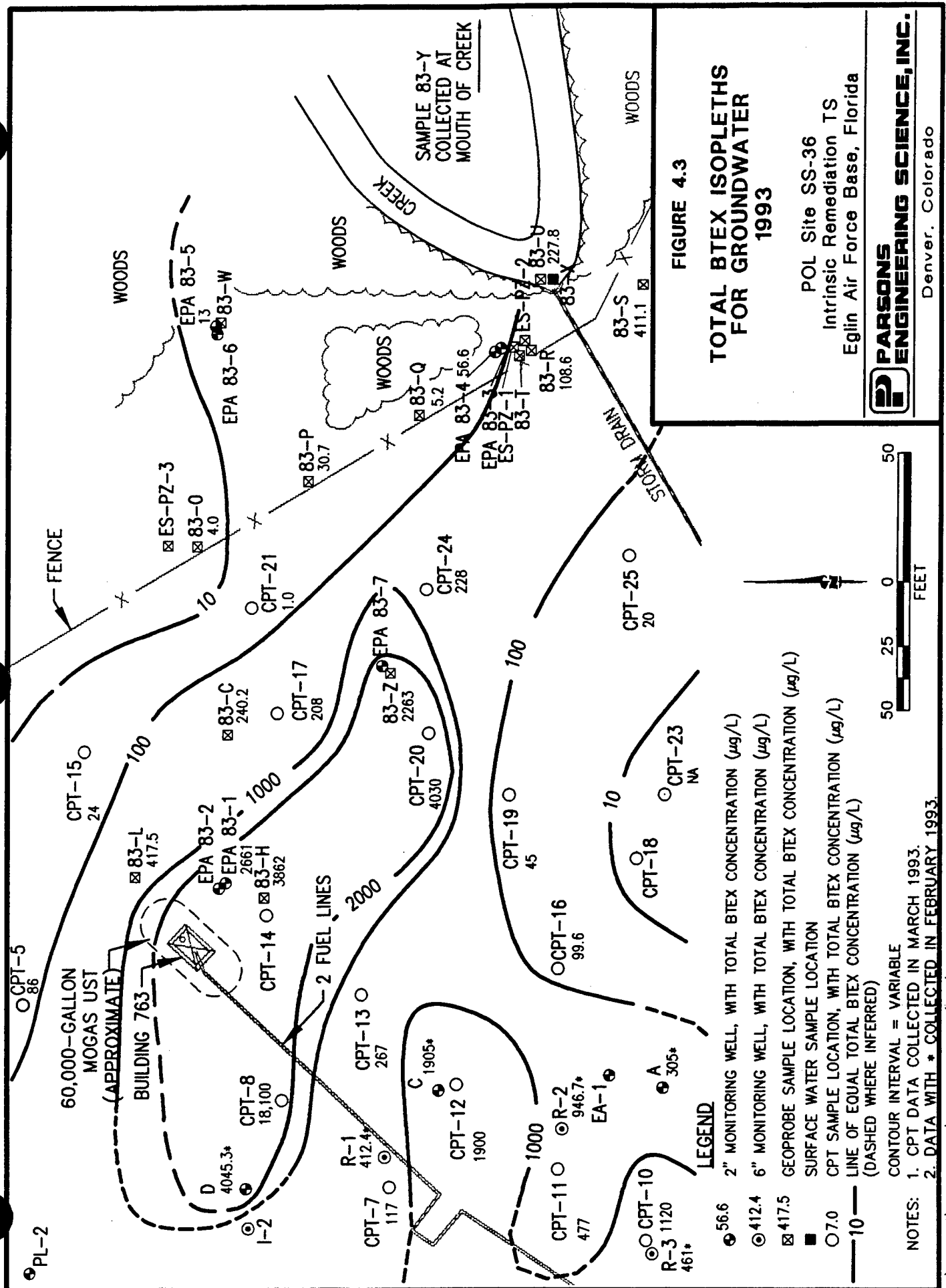
^a ft bgs = feet below ground surface.
^b ft msl = feet relative to mean sea level.
^c Analysis by Rice University.
^d Actually feet below water surface.
^e ND = no data available.
^f -- = not analyzed.
^g d = duplicate sample.
^h fb = field blank.
ⁱ NA = not applicable.

4.3.1.1 Dissolved BTEX Contamination

Figure 4.3 is an isopleth map showing the areal distribution of total BTEX dissolved in groundwater in September 1993. In addition to data collected by Parsons ES and RSKERL personnel, total BTEX data from groundwater samples collected at CPT points by Rice University in March 1993, and total BTEX data collected at several wells immediately southwest of the site by RSKERL researchers in February 1993 also were used to help further define the extents of contamination. Samples collected by RSKERL personnel were analyzed by RSKSOP-122 or RSKSOP-158; it is not known what method was used for the Rice University samples. However, the Rice data are used only to help estimate the areal extent of BTEX contamination. Where nested monitoring points, wells, or sampling points are present, isopleths indicating the areal distribution of BTEX (or any other analyte) are drawn using the maximum concentration detected at that location. A vertical profile of dissolved BTEX concentrations along hydrogeologic section A - A' is presented as Figure 4.4.

BTEX compounds were detected at some depth at every groundwater sampling location in the study area (Table 4.2). Where detected, BTEX concentrations ranged from 4.0 micrograms per liter ($\mu\text{g/L}$) to 4,030 $\mu\text{g/L}$. The maximum observed total BTEX concentration of 4,030 $\mu\text{g/L}$, was detected in the sample collected from CPT20 in March 1993. A sample collected at Geoprobe[®] location 83-H in September 1993 contained 3,862 $\mu\text{g/L}$ of total BTEX. Benzene concentrations, where detected, ranged from 0.5 to 327 $\mu\text{g/L}$. In general, the highest benzene concentrations were observed in samples from locations along the groundwater flow path from Building 763 to the sampling points nearest the creek.

As indicated on Figures 4.3 and 4.4, the BTEX plume extends from the vicinity of the source all the way to the creek at the southeastern margin of the site. The upgradient and southern lateral extents of the plume are not well defined because of the presence of separate hydrocarbon sources upgradient and crossgradient from the site. In particular, dissolved BTEX detected southwest of Building 763 (e.g., in samples from CPT-7, CPT-10, CPT-11, CPT-12, and CPT-16, and in the wells sampled by RSKERL researchers in February 1993) is likely due to the LNAPL body that was discovered in 1984, and investigated by Roy F. Weston, Inc. (1984), Geraghty & Miller (1985), and EA (1987 and 1989). Contamination detected in monitoring well PL-2, which is screened about 35 to 40 feet below the water table, is most likely a result of migration from a source upgradient from the study site.



It is worth noting the vertical distribution of BTEX compounds at Geoprobe® location 83-U. At this location, where groundwater is likely discharging to the creek (as indicated by upward gradients at adjacent monitoring wells), groundwater samples were collected for analysis from three depths. The shallowest sample was about 1.5 feet below the creek bottom, the middle sample was about 3 feet below the creek bottom, and the deepest sample was 4.5 feet below the creek bottom. The deepest sample contained 227.83 µg/L of total BTEX, the middle sample contained 72.94 µg/L of total BTEX, and the shallow sample contained less than 1 µg/L of total BTEX.

Samples of surface water from the creek also were collected for BTEX analysis. These samples were collected at locations 83-X (the same as Geoprobe® location 83-U) and 83-Y (at the mouth of the creek). At both locations, samples were collected from a freshwater layer and the underlying saltwater layer. In addition, the Geoprobe® device was used to collect pore water samples from the sediment in those locations. None of the BTEX compounds were detected in any of these samples at individual compound detection limits of 1 µg/L.

In October 1994, monitoring wells EPA 83-1 to EPA 83-7 were resampled. In all but one well (EPA 83-3), total BTEX concentrations decreased (or changed very little) between September 1993 and October 1994. Changes in 1993 and 1994 BTEX concentrations from these wells are presented in Table 4.3 and on its accompanying graph, and a vertical profile of 1994 BTEX concentrations is presented on Figure 4.5. In 1994, the highest observed BTEX concentration was 625.3 µg/L, compared to 2,661 µg/L in September 1993. Benzene concentrations also decreased during the same time period, with the highest 1994 benzene concentration being 46.3 µg/L in well EPA 83-2.

4.3.1.2 Other Petroleum-Related Contaminants

As part of their concurrent site investigation of the entire POL Site SS-36 area, personnel from EA collected groundwater samples from wells EPA 83-1 through EPA 83-7 and submitted those samples to their labs for analysis of contaminants listed in Rule 62-770.730 (5) of the Florida Administrative Code (FAC). For this site, which is contaminated by MOGAS, four of these specified analytes [1,2-dichloroethane, 1,2-dibromoethane (EDB), methyl tert-butyl ether (MTBE), and lead] are of concern. Lead was the only one of these analytes that was detected in site monitoring wells. At wells EPA 83-1 and EPA 83-2, lead concentrations were 1.0 and 1.8 µg/L, respectively.

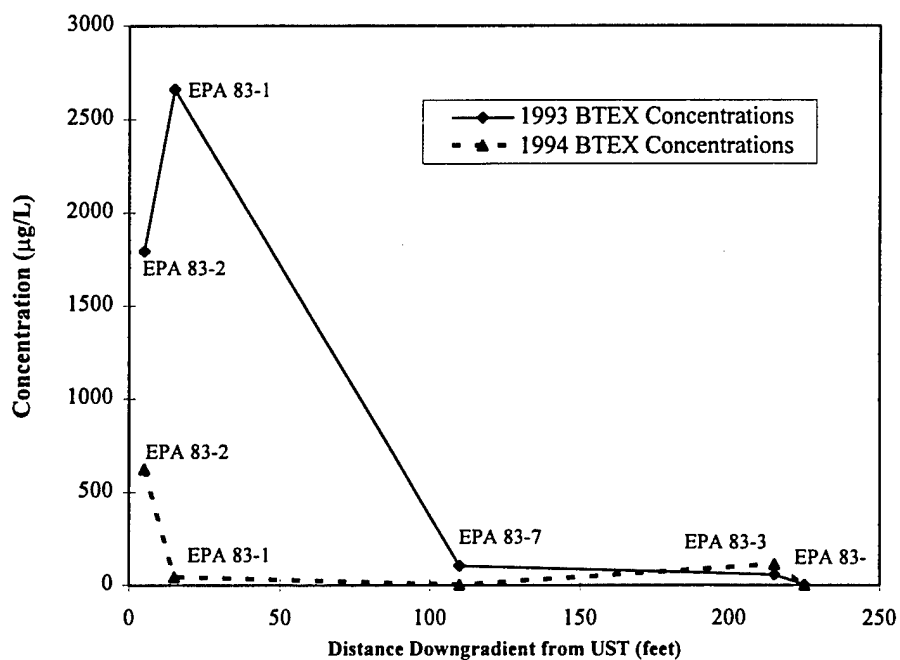
TABLE 4.3
GROUNDWATER BTEX CONCENTRATION CHANGES
BETWEEN 1993 AND 1994
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

Sample Location	Sample Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	P-xylene (µg/L)	M-xylene (µg/L)	O-xylene (µg/L)	M&P-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Change in total BTEX 1993 - 1994 (µg/L)	Change in benzene 1993 - 1994 (µg/L)
EPA 83-1	09/30/93	21	12	140	NA ^{a/}	NA	12	860	872	1045		
EPA 83-1 d ^{b/}	09/30/93	300	1300	51	NA	NA	430	580	1010	2661		
EPA 83-1	10/18/94	2	1	3.1	24.7	12.9	1	NA	38.6	44.7	-2616.3	-298
EPA 83-2	09/30/93	240	740	62	NA	NA	320	430	750	1792		
EPA 83-2	10/18/94	46.3	74.8	13.1	93.1	179	219	NA	491.1	625.3	-1166.7	-193.7
EPA 83-3	09/30/93	34	2.3	2.3	NA	NA	<1	18	18	56.6		
EPA 83-3	10/18/94	22.2	1.8	6.9	23.9	53.2	4.6	NA	81.7	112.6	56	-11.8
EPA 83-4	09/30/93	<1	<1	1.2	NA	NA	<1	<1	<1	1.2		
EPA 83-4	10/18/94	<1	1.4	<1	<1	<1	<1	NA	<1	1.4	0.2	0
EPA 83-5	10/01/93	<1	<1	<1	NA	NA	<1	13	13	13		
EPA 83-5	10/18/94	<1	<1	<1	<1	<1	<1	NA	<1	<1	-13	0
EPA 83-6	10/01/93	<1	<1	<1	NA	NA	<1	<1	<1	<1		
EPA 83-6	10/18/94	<1	<1	<1	<1	<1	<1	NA	<1	<1	0	0
EPA 83-7	10/01/93	2.2	4.3	36	NA	NA	26	36	62	104.5		
EPA 83-7	10/18/94	1.9	1	<1	<1	<1	<1	NA	<1	2.9	-101.6	-0.3

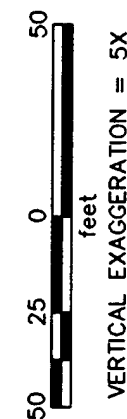
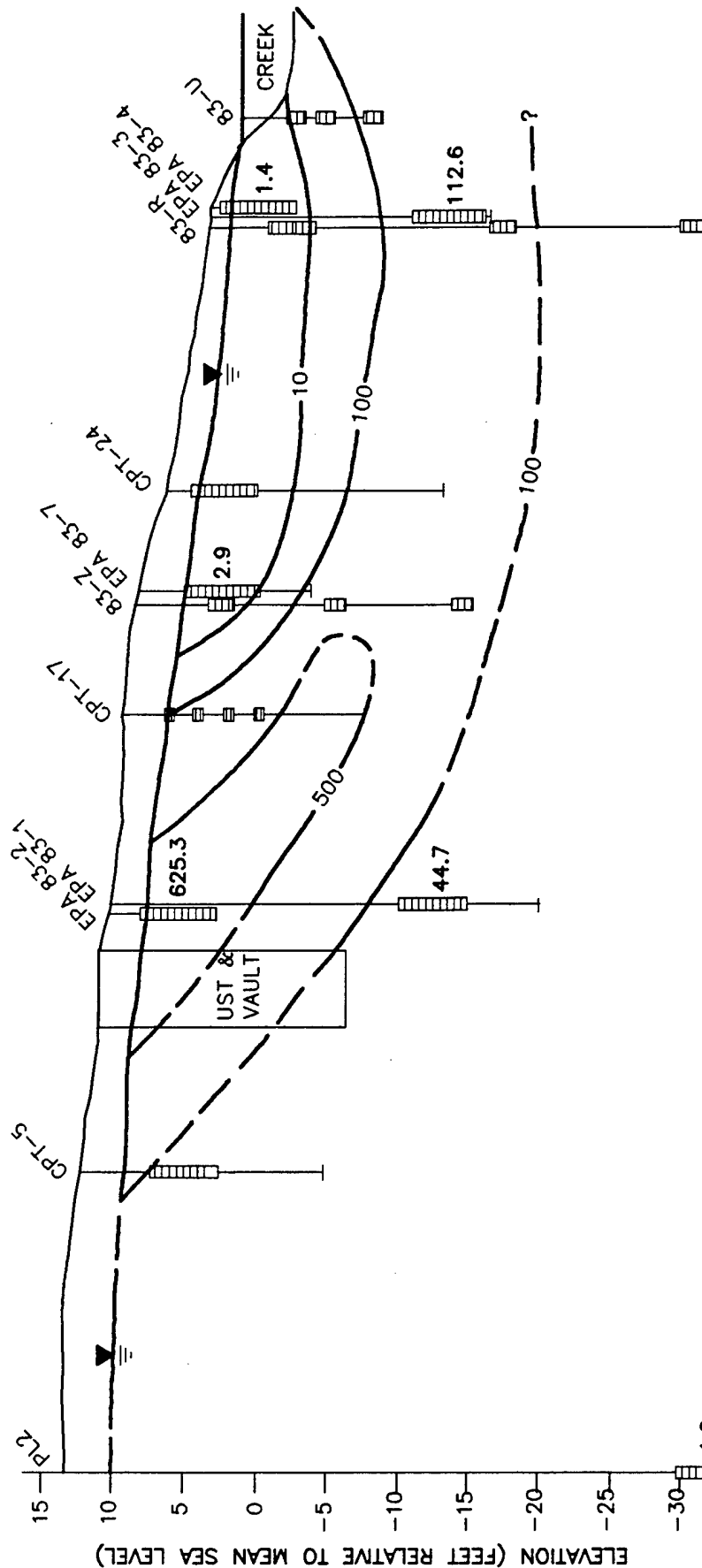
^{a/} NA = Not analyzed.

^{b/} d = Duplicate sample.

BTEX Concentrations Along a Flow Path
From EPA 83-2 to EPA 83-4



A'



- LEGEND**
- Borehole/Sampling location name
 - Borehole
 - Well screen or sampling interval, with total BTEX concentration ($\mu\text{g/L}$)
 - Bottom of borehole
 - Approximate water table surface (Dashed where inferred)
 - Line of equal total BTEX concentration ($\mu\text{g/L}$) (Dashed where inferred)
 - Contour Interval = Variable

FIGURE 4.5
VERTICAL PROFILE OF
TOTAL BTEX ISOPLETHS
FOR GROUNDWATER
1994

POL Site SS-36
 Intrinsic Remediation TS
 Eglin Air Force Base, Florida

PARSONS
ENGINEERING SCIENCE, INC.
 Denver, Colorado

Table 4.4 summarizes the results of these analyses, and the analytical data are included in Appendix B.

TABLE 4.4
CONCENTRATIONS OF TARGET COMPOUNDS IN GROUNDWATER
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Well Identification	Date	1,2-dichloroethane (µg/L)	EDB (µg/L)	MTBE (µg/L)	Lead (µg/L)
EPA 83-1	9/30/93	ND ^{a/}	ND	ND	1.0
EPA 83-2	9/30/93	ND	ND	ND	1.8
EPA 83-3	9/30/93	ND	ND	ND	<1.0
EPA 83-4	9/30/93	ND	ND	ND	<1.0
EPA 83-5	10/1/93	ND	ND	ND	<1.0
EPA 83-6	10/1/93	ND	ND	ND	<1.0
EPA 83-7	10/1/93	ND	ND	ND	<1.0

^{a/} ND = not detected.

Detection limits for 1,2-dichloroethane, EDB, and MTBE were 1.0, 0.02, and 5.0 µg/L, respectively.

4.3.2 Inorganic Chemistry and Geochemical Indicators of Biodegradation

Microorganisms obtain energy for cell production and maintenance by catalyzing the transfer of electrons from electron donors to electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at the site are natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992). Electron acceptors are elements or compounds that occur in relatively oxidized states, and include oxygen, nitrate, ferric iron, sulfate, and carbon dioxide. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms

typically use electron acceptors (as available) in the following order of preference: nitrate, ferric orthohydroxide, sulfate, and finally carbon dioxide.

The driving force of BTEX degradation is electron transfer and is quantified by the Gibbs free energy of the reaction (ΔG_r) (Stumm and Morgan, 1981; Bouwer, 1994; Godsey, 1994). The value of ΔG_r represents the quantity of free energy consumed or yielded to the system during the reaction. Table 4.5 lists stoichiometry of the redox equations involving BTEX and the resulting ΔG_r . Although thermodynamically favorable, most of the reactions involved in BTEX oxidation cannot proceed abiotically because of the lack of activation energy. Microorganisms are capable of providing the necessary activation energy; however, they will facilitate only those redox reactions that have a net *yield* of energy (i.e. $G_r < 0$).

Depending on the types and concentrations of electron acceptors present (e.g., nitrate, ferric iron, sulfate, carbon dioxide), pH conditions, and redox potential, anaerobic biodegradation can occur by denitrification, ferric iron reduction, sulfate reduction, or methanogenesis. Other, less common anaerobic degradation mechanisms such as manganese reduction may dominate if the physical and chemical conditions in the subsurface favor use of these electron acceptors. Anaerobic destruction of BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990). Environmental conditions and microbial competition will ultimately determine which processes will dominate. Vroblesky and Chapelle (1994) show that the dominant terminal electron accepting process can vary both temporally and spatially in an aquifer with fuel hydrocarbon contamination.

Site groundwater data for electron acceptors such as sulfate suggest that intrinsic remediation of hydrocarbons by sulfate reduction is taking place in the shallow aquifer. In addition, data for ferrous iron (Fe^{2+}) and methane suggest that anaerobic degradation via ferric iron reduction and methanogenesis is reducing BTEX concentrations. Geochemical parameters for site groundwater are discussed in the following sections.

TABLE 4.5
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

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

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

TABLE 4.5 (concluded)

COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

Coupled Ethylbenzene Oxidation reactions	ΔG°_r (kcal/mole Ethylbenzene)	ΔG°_r (kJ/mole Ethylbenzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5 O_2 + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,g} + 5 H_2O$ <i>Ethylbenzene oxidation / aerobic respiration</i>	-1066.13	-4461	3.17:1
$8.4 NO_3^- + 8.4 H^+ + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,g} + 9.2 H_2O + 4.2 N_{2,g}$ <i>Ethylbenzene oxidation / denitrification</i>	-1080.76	-4522	4.92:1
$84 H^+ + 42 Fe(OH)_{3,a} + C_6H_5C_2H_5 \Rightarrow 8 CO_2 + 42 Fe^{2+} + 110 H_2O$ <i>Ethylbenzene oxidation / iron reduction</i>	-778.48	-3257	22:1 ^{a/}
$10.5 H^+ + 5.25 SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,g} + 5.25 H_2S^0 + 5 H_2O$ <i>Ethylbenzene oxidation / sulfate reduction</i>	-166.75	-697.7	4.75:1
$5.5 H_2O + C_6H_5C_2H_5 \Rightarrow 2.75 CO_{2,g} + 5.25 CH_4$ <i>Ethylbenzene oxidation / methanogenesis</i>	-39.83	-166.7	0.79:1 ^{b/}

Coupled m-Xylene Oxidation Reactions	ΔG°_r (kcal/mole m-xylene)	ΔG°_r (kJ/mole m-xylene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5 O_2 + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,g} + 5 H_2O$ <i>m-Xylene oxidation / aerobic respiration</i>	-1063.25	-4448	3.17:1
$8.4 NO_3^- + 8.4 H^+ + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,g} + 9.2 H_2O + 4.2 N_{2,g}$ <i>m-Xylene oxidation / denitrification</i>	-1077.81	-4509	4.92:1
$84 H^+ + 42 Fe(OH)_{3,a} + C_6H_4(CH_3)_2 \Rightarrow 8 CO_2 + 42 Fe^{2+} + 110 H_2O$ <i>m-Xylene oxidation / iron reduction</i>	-775.61	-3245	22:1 ^{a/}
$10.5 H^+ + 5.25 SO_4^{2-} + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,g} + 5.25 H_2S^0 + 5 H_2O$ <i>m-Xylene oxidation / sulfate reduction</i>	-163.87	-685.6	4.75:1
$5.5 H_2O + C_6H_4(CH_3)_2 \Rightarrow 2.75 CO_{2,g} + 5.25 CH_4$ <i>m-Xylene oxidation / methanogenesis</i>	-36.95	-154.6	0.79:1 ^{b/}

^{a/} mass of ferrous iron produced during microbial respiration.

^{b/} mass of methane produced during microbial respiration.

4.3.2.1 Dissolved Oxygen

DO concentrations were measured at monitoring wells and Geoprobe® sample locations in September 1993. Table 4.6 summarizes DO concentrations. In general, DO concentrations are well below 1 milligram per liter (mg/L), indicating the conditions throughout the shallow aquifer are anaerobic. This is likely due to reducing conditions created by the presence of organic matter (peat bodies) and the microbial consumption of DO in the vicinity of the upgradient hydrocarbon spills. As a result, very little DO is available at this site, and aerobic respiration does not appear to be a significant biodegradation pathway throughout most of the shallow aquifer.

In one location, however, there is evidence that sufficient DO is available for aerobic respiration. The shallow sampling point at Geoprobe sampling location 83-U contained 3.8 mg/L of DO, while the deeper samples at this location contained less than 0.6 mg/L of DO. As measured in the surface water above 83-U (samples from location 83-X), the DO content of the surface water may be as high as 5.1 mg/L. This suggests that petroleum hydrocarbons may be biodegrading due to aerobic respiration in the vicinity of the groundwater - surface water interface. This mechanism likely helps limit the mass of hydrocarbons that enter the creek.

The stoichiometry of BTEX mineralization to carbon dioxide and water caused by aerobic microbial biodegradation is presented in Table 4.5. The average mass ratio of oxygen to total BTEX is approximately 3.14 to 1. This translates to the mineralization of approximately 0.32 mg of BTEX for every 1.0 mg of DO consumed. With a maximum observed groundwater DO concentration of approximately 1.2 mg/L, the shallow groundwater at this site may have the capacity to assimilate a maximum of 0.384 mg/L (384 µg/L) of total BTEX through aerobic biodegradation. This is a conservative estimate of the assimilative capacity of DO because microbial cell mass production was not taken into account by the stoichiometry presented in Table 4.5. Given that the observed DO concentration in groundwater below the bottom of the creek is about 3.8 mg/L, the assimilative capacity of the groundwater near the creek is approximately 1.22 mg/L (1,220 µg/L).

When cell mass production is accounted for, the mineralization of benzene to carbon dioxide and water is given by:

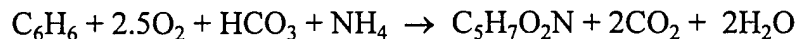


TABLE 4.6
GROUND WATER AND SURFACE WATER GEOCHEMICAL DATA
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Sample Location	Sample Date	Depth to Screen Top (ft bgs) ^a	Screen Elevation Top (ft msl) ^b	Water Temp. (°C)	pH	Conductivity (µmhos)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Total Alkalinity (mg/L)	Alkalinity as Calcium (mg/L)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Ammonia Nitrogen (mg/L)	NO ₃ +NO ₂ Nitrogen (mg/L)	Methane (mg/L)	Chloride (mg/L)	TOC (mg/L)
SURFACE WATER																	
83-X Fresh	09/17/93	0.25 ^d	NA ^d	24.9	— ^d	665	5.1	—	—	—	—	—	—	—	—	—	—
83-X Salt	09/17/93	1.25 ^d	NA	28.2	—	24900	2.9	—	—	—	—	—	—	—	—	139	—
83-X S/W Sediment	09/17/93	1.83 ^d	NA	28.7	—	—	2.8	—	—	—	—	—	—	—	—	8080	—
83-Y Fresh	09/17/93	0.15 ^d	NA	25.9	—	2540	5.6	—	—	—	—	—	—	—	—	652	—
83-Y Salt	09/17/93	0.6 ^d	NA	28.7	—	21900	5.6	—	—	—	—	—	—	—	—	7100	—
83-Y S/W Sediment	09/17/93	1 ^d	NA	29.7	—	—	5	—	—	—	—	—	—	—	—	—	—
GEOPROBE SAMPLES																	
Geoprobe 83 C-1	09/16/93	7.25	2.78	27	6.3	67	0	-253	25	27.2	1.2	2.28	0.49	<0.05	3.8	1.31	5.9
Geoprobe 83 C-2	09/16/93	13.25	-3.22	25.7	6.4	24	0.5	-200	31	24	1.1	0.56	0.6	<0.05	4.51	1.64	3.5
Geoprobe 83 C-2 d	09/16/93	13.25	-3.22	—	—	—	—	—	—	—	—	0.5	—	—	—	1.44	—
Geoprobe 83 H-1	09/15/93	4.25	6.15	27.7	6.3	149	0.7	-182	55	58.5	4.3	0.56	2.41	<0.05	10.98	4.98	12.4
Geoprobe 83 H-1 d	09/15/93	4.25	6.15	—	—	—	—	—	—	—	—	0.51	—	—	—	4.93	—
Geoprobe 83 L-1	09/16/93	25.25	-14.85	24.5	6.4	84	0	-209	36	27.5	5	0.12	0.68	<0.05	4.21	4.15	11.3
Geoprobe 83 L-2	09/16/93	4.25	6.67	28.6	6.4	47	0	-201	20	13.8	2.6	3.92	0.37	0.11	1.71	1.79	8.3
Geoprobe 83 O-1	09/16/93	16.25	-5.33	25.6	6.4	92	0.6	-207	40	33.8	4	<0.05	0.59	0.1	8.12	2.2	6.7
Geoprobe 83 O-2	09/15/93	10.25	-11.75	26.8	6.2	48	0.1	-181	20	19.8	0.8	1	0.29	<0.05	8.34	<0.5	3.1
Geoprobe 83 P-1	09/15/93	22.25	-12.06	24.8	6.6	132	0.3	-91	69	38.3	10.5	0.53	0.74	<0.05	1.13	<0.5	4.9
Geoprobe 83 P-1 d	09/14/93	4.25	2.39	28.7	5.7	34	0.3	-141	13	4.1	0.7	3.68	0.06	<0.05	0.6	<0.5	4.2
Geoprobe 83 P-1 d	09/14/93	4.25	2.39	—	—	—	—	—	—	3.8	—	—	—	—	—	—	—
Geoprobe 83 P-2	09/14/93	25.25	-18.61	24.2	6.4	108	0	-160	41	38.8	4.4	3.26	0.77	<0.05	5.99	0.68	4.4
Geoprobe 83 P-2 d	09/14/93	25.25	-18.61	—	—	—	—	—	—	—	—	—	0.77	<0.05	—	—	—
Geoprobe 83 Q-1	09/14/93	4.25	0.94	28	5.9	51	0.2	-154	20	12.3	2.6	<0.5	0.34	<0.05	5.18	1.06	10.1
Geoprobe 83 Q-2	09/14/93	25.25	-20.06	23.8	6.2	108	0.4	-133	45	40.1	4.1	<0.5	1.02	<0.05	3.78	0.52	6.5
Geoprobe 83 Q-2 d	09/14/93	25.25	-20.06	—	—	—	—	—	—	—	—	—	—	—	—	—	6.6
Geoprobe 83 R-1	09/13/93	4.25	-0.15	30	5.6	42	0.8	-117	28	11.6	0.6	<0.5	0.76	<0.05	4.32	<0.5	20
Geoprobe 83 R-1 d	09/13/93	4.25	-0.15	—	—	—	—	—	—	—	—	—	0.76	<0.05	—	—	—
Geoprobe 83 R-2	09/13/93	5.75	-1.65	29.7	5.6	57	0.2	-152	13	11.6	1.1	<0.5	1.64	<0.05	8.02	<0.5	23.2
Geoprobe 83 R-3	09/13/93	20.25	-16.15	26.1	6.1	126	0.2	-40	59	40.7	6.6	<0.5	1.56	<0.05	5.69	<0.5	10
Geoprobe 83 R-3 d	09/13/93	20.25	-16.15	—	—	—	—	—	—	—	—	—	1.56	<0.05	—	—	—
Geoprobe 83 R-4	09/14/93	33.25	-29.15	—	6.3	112	—	-110	54	27.3	10	<0.5	0.68	<0.05	1.89	1.79	6.1
Geoprobe 83 S-1	09/15/93	4.25	0.66	28.4	6.7	164	0.5	-86	76	70	0.7	4.94	0.25	0.13	2.49	2.99	6.1
Geoprobe 83 S-1 d	09/15/93	4.25	0.66	—	—	—	—	—	—	—	—	—	0.25	0.12	—	—	—
Geoprobe 83 S-2	09/15/93	16.25	-11.34	24.1	6.5	64	1.1	-142	22	23.5	3.8	0.28	0.89	<0.05	4.91	1.59	8
Geoprobe 83 S-3	09/15/93	25.25	-20.34	25.2	6.7	119	0.45	-91	63	31.8	8.4	<0.05	1.17	<0.05	0.69	3.65	7.2
Geoprobe 83 S-3 d	09/15/93	25.25	-20.34	—	—	—	—	—	—	—	—	—	—	—	—	—	7.4
Geoprobe 83 U-1	09/14/93	1.8	ND ^d	ND	7.1	23300	3.8	99	75	70	<0.05	<0.5	0.16	<0.05	0.69	<0.5	4.4
Geoprobe 83 U-2	09/14/93	3.3	ND	28.9	5.9	78	0.6	-159	37	28.2	2.8	1.76	2.51	<0.05	14.22	<0.5	7.6
Geoprobe 83 U-3	09/14/93	5.9	ND	30.1	5.9	137	0.3	-133	46	36.2	3.3	5.62	2.86	<0.05	12.48	<0.5	10.3

TABLE 4.6 (Concluded)
GROUND WATER AND SURFACE WATER GEOCHEMICAL DATA
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Sample Location	Sample Date	Depth to Screen Top (ft bgs) ^{a/}	Depth to Screen Base (ft bgs)	Screen Elevation Top (ft msl) ^{b/}	Screen Elevation Base (ft msl)	Water Temp. (°C)	pH	Conductivity (µmhos)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Total Alkalinity (mg/L)	Alkalinity as Calcium (mg/L)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Ammonia Nitrogen (mg/L)	NO ₃ +NO ₂ Nitrogen (mg/L)	Methane (mg/L)	Chloride (mg/L)	TOC (mg/L)
MONITORING WELLS																			
Geoprobe 83 U-3 d	09/14/93	5.9	10	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	10.8
Geoprobe 83 W-1	09/17/93	4.25	5.75	0.83	-0.67	--	5.8	76	--	-148	20	22.5	1	<0.05	0.07	0.09	3.24	7.18	8.8
Geoprobe 83 W-1 d	09/17/93	4.25	5.75	0.83	-0.67	--	--	--	--	--	--	22.5	--	--	--	--	--	--	--
Geoprobe 83 W-2	09/17/93	22.25	23.75	-17.17	-18.67	22.9	6.6	96	1.2	-33	48	30	1.2	<0.05	0.96	0.19	4.95	2.48	9.4
Geoprobe 83 Z-1	09/17/93	5.25	6.75	3.47	1.97	29.1	5.5	40	0.1	-167	13	13.8	1.1	0.59	0.83	0.1	16.97	5.58	8.5
Geoprobe 83 Z-1 d	09/17/93	5.25	6.75	3.47	1.97	--	--	--	--	--	--	--	--	0.59	--	--	--	5.58	--
Geoprobe 83 Z-2	09/17/93	13.25	14.75	-4.53	-6.03	24.8	6.1	96	0.2	-164	49	27.5	7.8	0.62	1.31	0.12	16.82	3.15	15.1
Geoprobe 83 Z-2 d	09/17/93	13.25	14.75	-4.53	-6.03	--	--	--	--	--	--	--	--	--	1.32	0.17	--	--	--
Geoprobe 83 Z-3	09/17/93	22.25	23.75	-13.53	-15.03	24.2	6.4	108	0.1	-194	66	38.8	5.6	<0.05	1.81	0.17	3.36	2.69	14.4
Geoprobe 83 Z-3 d	09/17/93	22.25	23.75	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15
MONITORING WELLS																			
PL-2	02/24/93	43.35	48.35	-30	-35	21.8	6.23	102	3.1	--	20.3	--	--	31.2	0.08	--	0.36	11.3	2.3
PL-2	02/26/93	43.35	48.35	-30	-35	18.9	6.35	--	1	--	--	--	6	--	--	--	4.71	--	4.3
EPA 83-1	10/18/94	20.21	25.21	-9.86	-14.86	25.6	6.48	174	0.1	-168	--	58	--	5.64	--	0.07	1.41	13.2	6.9
EPA 83-2	10/18/94	2.28	7.28	8.18	3.18	25.3	6.49	358	0.06	-190	--	168	--	3.47	--	0.1	11.787	8.4	22.8
EPA 83-3	10/18/94	14.41	19.41	-10.48	-15.48	25.2	6.1	146	0.15	-137	--	50	--	0.67	--	0.07	5.483	12.3	8.4
EPA 83-4	10/18/94	0.99	5.99	3.04	-1.96	25	5.57	44	0.16	-178.3	--	14	--	3.93	--	0.07	7.042	2.36	19.8
EPA 83-5	10/18/94	14.73	19.73	-9.62	-14.62	24.2	5.7	66	0.2	-178	--	14	--	1.27	--	0.08	4.672	8.26	4.1
EPA 83-6	10/18/94	0.98	5.98	4.17	-0.83	24	5.78	46	0.26	-190.7	--	7	--	5.69	--	0.07	0.641	3.62	13
EPA 83-7	10/18/94	3.39	8.39	5.33	0.33	14.2	5.15	21	0.3	-116	--	2	--	2.59	--	0.09	5.858	1.37	11.4
A	2/25/93	--	--	--	--	16.2	6.15	--	0.6	--	--	--	6.1	--	--	--	9.16	--	--
C	2/25/93	--	--	--	--	18.2	6.01	--	0.8	--	--	--	3.2	--	--	--	8.51	--	--
D	2/25/93	--	--	--	--	18.6	6.26	--	0.8	--	--	--	3.2	--	--	--	7.25	--	--
R1	3/23/93	12.81	17.81	-0.34	-5.34	19.7	6.3	198	0.1	--	88.3	--	3.5	5.21	2.58	0.1	5.31	1.75	--
R2	3/22/93	12.73	17.73	-2.95	-7.95	17.2	6.1	206	0	--	96.7	--	--	1.5	3.44	0.1	15.3	1.97	--
R3	3/22/93	12.66	17.66	-2.43	-7.43	19.5	6	123	0.2	--	55	--	--	1.94	2.8	0.1	6.64	1.73	--

^{a/} ft bgs = feet below ground surface

^{b/} ft msl = feet relative to mean sea level.

^{c/} Actually feet below water surface.

^{d/} NA = not applicable.

^{e/} -- = data not available.

This equation indicates that 5.0 fewer moles of DO are required to mineralize 1 mole of benzene when cell mass production is taken into account. On a mass basis, the ratio of DO to benzene is given by:

$$\begin{array}{ll} \text{Benzene} & 6(12) + 1(6) = 78 \text{ gm} \\ \text{Oxygen} & 2.5(32) = 80 \text{ gm} \end{array}$$

$$\text{Mass Ratio of Oxygen to Benzene} = 80/78 = 1.03:1$$

On the basis of these stoichiometric relationships, 1.03 mg of oxygen are required to mineralize 1 mg of benzene. Similar calculations can be made for toluene, ethylbenzene, and the xylenes. On the basis of these calculations, approximately 0.97 mg of total BTEX is mineralized to carbon dioxide and water for every 1.0 mg of DO consumed. With an average site DO concentration of approximately 1.2 mg/L, the shallow groundwater at this site may have the capacity to assimilate 1.16 mg/L (1,160 µg/L) of total BTEX if microbial cell mass production is taken into account. In the vicinity of the creek, the assimilative capacity of the groundwater is about 3.7 mg/L (3,700 µg/L), if microbial cell mass production is taken into account.

4.3.2.2 Nitrate/Nitrite

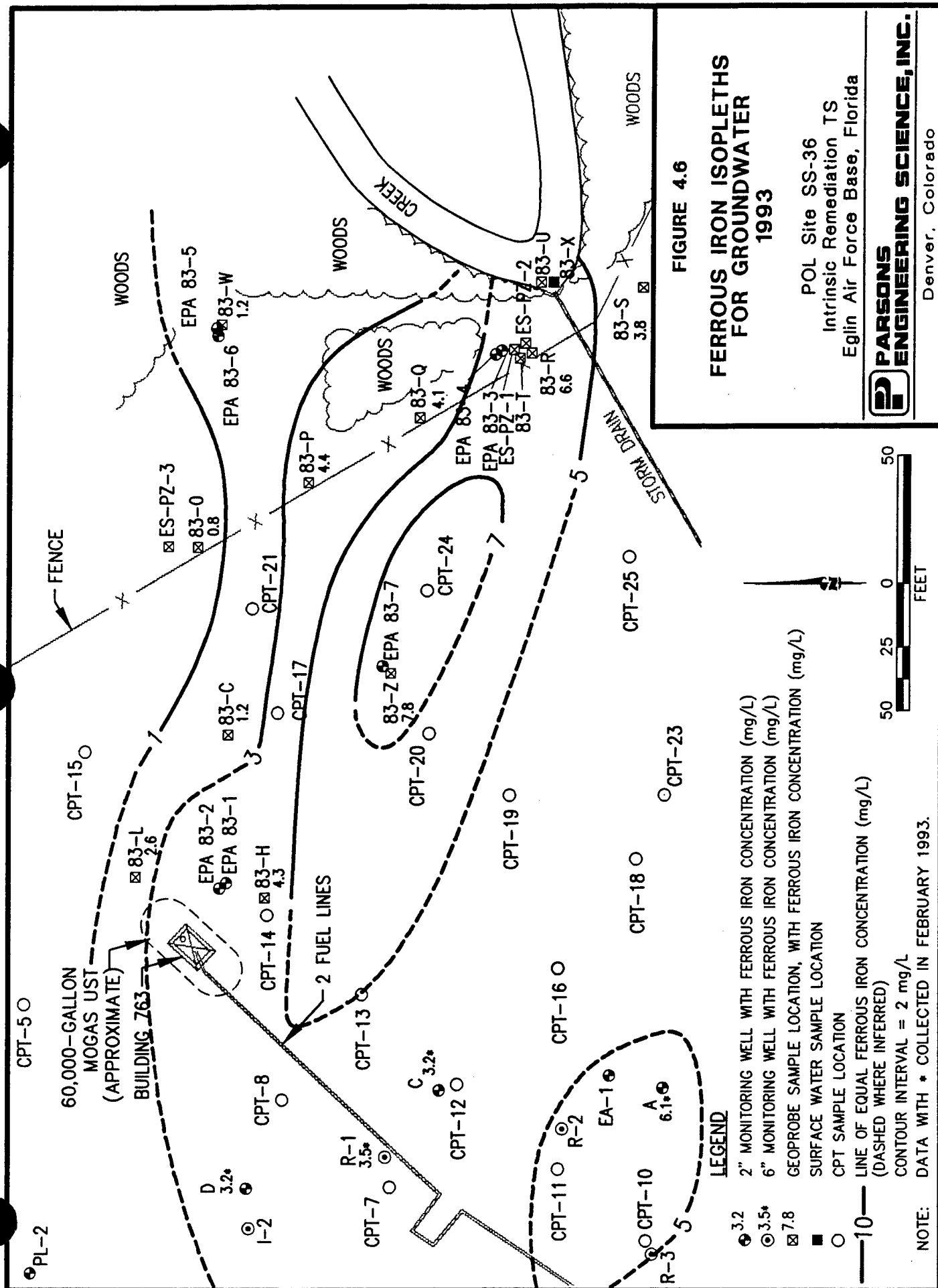
Concentrations of nitrate + nitrite [as nitrogen (N)] were measured at groundwater monitoring wells and Geoprobe® sampling points in September 1993. Nitrate concentrations at the site range from <0.05 mg/L to 0.19 mg/L. Table 4.6 summarizes measured nitrate and nitrite (as N) concentrations. Given the low nitrate and nitrite (as N) concentrations, it appears that anaerobic biodegradation of BTEX via the microbially mediated process of denitrification is not a significant process at this site. Even at sidegradient wells where little or no BTEX was detected, nitrate and nitrate (as N) concentrations were not significantly above the method detection limit of 0.05 mg/L.

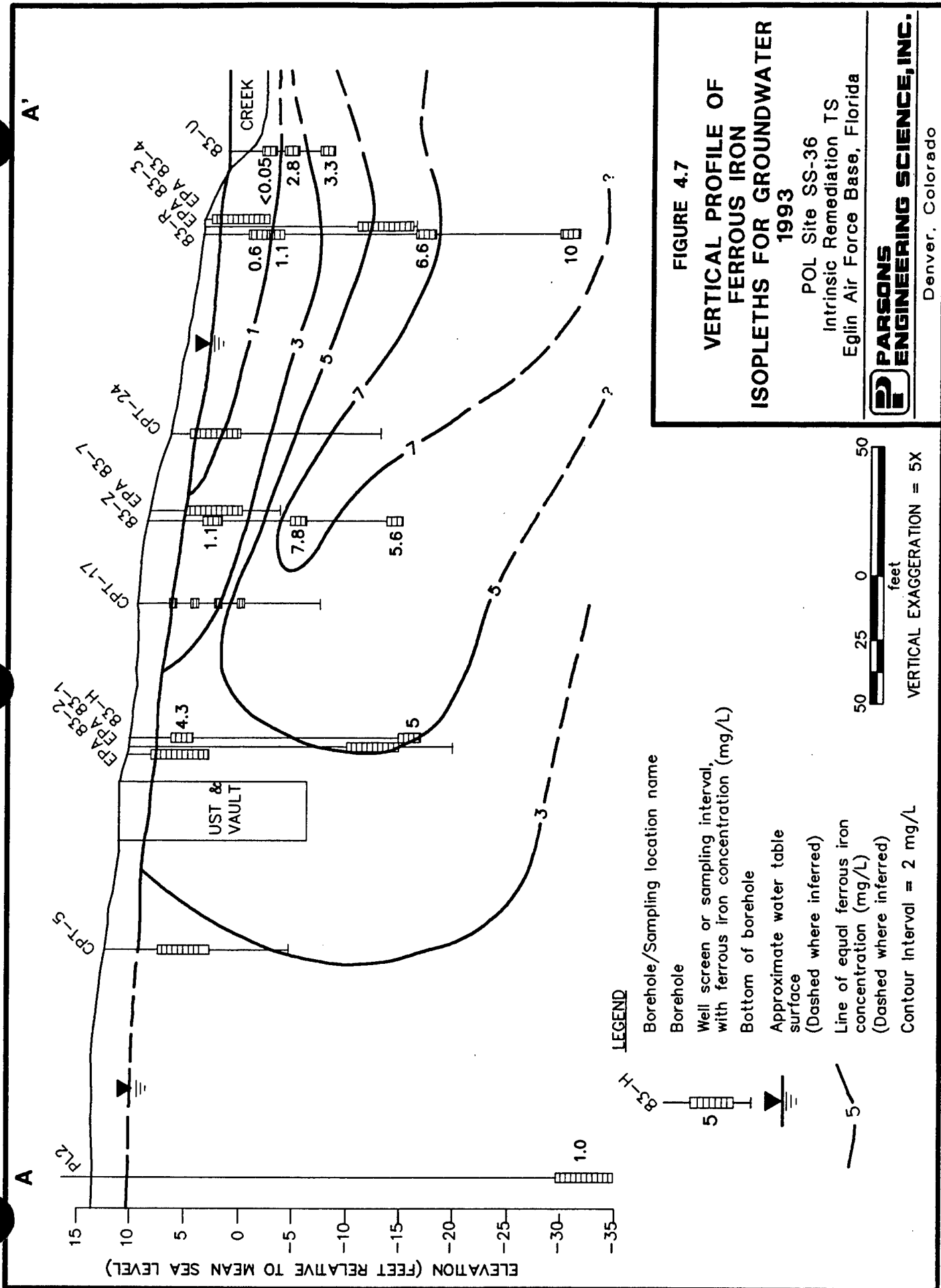
The stoichiometry of BTEX mineralization to carbon dioxide, water, and nitrogen caused by denitrification (in the absence of microbial cell production) is presented in Table 4.5. The average mass ratio of nitrate to total BTEX is approximately 4.9 to 1. This translates to the mineralization of approximately 0.20 mg of BTEX for every 1.0 mg of nitrate consumed. As the highest nitrate and nitrite (as N) concentration was only 0.19 mg/L, the shallow groundwater at this site has a negligible capacity to assimilate BTEX through denitrification.

4.3.2.3 Ferrous Iron

Ferrous iron (Fe^{2+}) concentrations at the study site were measured at monitoring wells and at Geoprobe[®] sample locations in September 1993. In addition, RSKERL researchers measured ferrous iron concentrations at several wells immediately southwest of the site in March 1993. Table 4.6 summarizes ferrous iron concentrations. Figure 4.6 is an isopleth map showing the areal distribution of ferrous iron in groundwater, and Figure 4.7 is an isopleth map showing the vertical distribution of ferrous iron along hydrogeologic cross-section A - A'. Comparison of Figures 4.6 to 4.3 and 4.7 to 4.4 shows graphically that the area with elevated total BTEX concentrations has elevated ferrous iron concentrations. This suggests that ferric iron (Fe^{3+} , in the form of ferric iron hydroxide) is being reduced to ferrous iron during biodegradation of BTEX compounds. Ferrous iron concentrations of 10 mg/L and 7.8 mg/L were observed in deep samples from Geoprobe[®] sample locations 83-R and 83-Z, respectively. These locations are downgradient (horizontally and vertically) of the locations with the highest total BTEX concentrations. Background levels of ferrous iron are generally at or below 1.2 mg/L, as measured at wells with little or no BTEX contamination.

The stoichiometry of BTEX oxidation to carbon dioxide, ferrous iron, and water by iron reduction through anaerobic microbial biodegradation is presented in Table 4.5. On average 37.5 moles of ferric iron hydroxide are required to metabolize one mole of total BTEX. Conversely, an average of 37.5 moles of ferrous iron are produced for each mole of total BTEX consumed. On a mass basis, this translates to approximately 21.8 mg ferrous iron produced for each 1 mg of total BTEX metabolized. Given a background ferrous iron concentration of approximately 1 mg/L (as indicated in samples from Geoprobe[®] locations 83-C and 83-W) and a maximum detected ferrous iron concentration of 10 mg/L, the shallow groundwater has the capacity to assimilate approximately 0.41 mg/L (410 $\mu\text{g/L}$) of total BTEX through iron reduction. This is a conservative estimate of the assimilative capacity of iron because microbial cell mass production was not taken into account by the stoichiometry shown in Table 4.5. In addition, this calculation is based on observed ferrous iron concentrations and not on the amount of ferric hydroxide available in the aquifer. Therefore, iron assimilative capacity could be much higher.





Recent evidence suggests that the reduction of ferric iron to ferrous 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 groundwater could reduce ferric orthohydroxides 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. Because the reduction of ferric iron cannot proceed without microbial intervention, the elevated concentrations of ferrous iron that were measured in the contaminated groundwater at the site are very strong indicators of microbial activity.

4.3.2.4 Sulfate

Sulfate concentrations were measured at groundwater monitoring wells and Geoprobe[®] sampling locations in September 1993. In addition, RSKERL researchers collected samples for sulfate analysis from several monitoring wells immediately southwest of the study site in February 1993. Sulfate concentrations measured at the site in September 1993 ranged from <0.05 mg/L to 5.62 mg/L, and sulfate concentrations measured in February 1993 ranged from <0.5 mg/L to 9.79 mg/L. A sulfate concentration of 31.2 mg/L was measured at well PL-2, but this well is screened near the base of the shallow aquifer, upgradient from the study site. Table 4.6 summarizes measured sulfate concentrations. The correlation between elevated BTEX concentrations and depleted sulfate concentrations is not clear. Sulfate concentrations were generally depleted in wells where elevated BTEX concentrations were detected; however, wells with lower levels of BTEX contamination did not always contain elevated sulfate concentrations.

The stoichiometry of BTEX mineralization to carbon dioxide, sulfur, and water by sulfate reduction through anaerobic microbial biodegradation is presented in Table 4.5. The average mass ratio of sulfate to total BTEX is approximately 4.7 to 1. This translates to the mineralization of approximately 0.21 mg of total BTEX for every 1.0 mg of sulfate consumed. Sulfate concentrations near the margins of the BTEX plume ranged from 2.28 mg/L to 9.97 mg/L. Assuming a conservative background sulfate concentration of 5 mg/L, the shallow groundwater at this site has the capacity to assimilate 1.06 mg/L (1,060 µg/L) of total BTEX through sulfate reduction. Again, this is a conservative

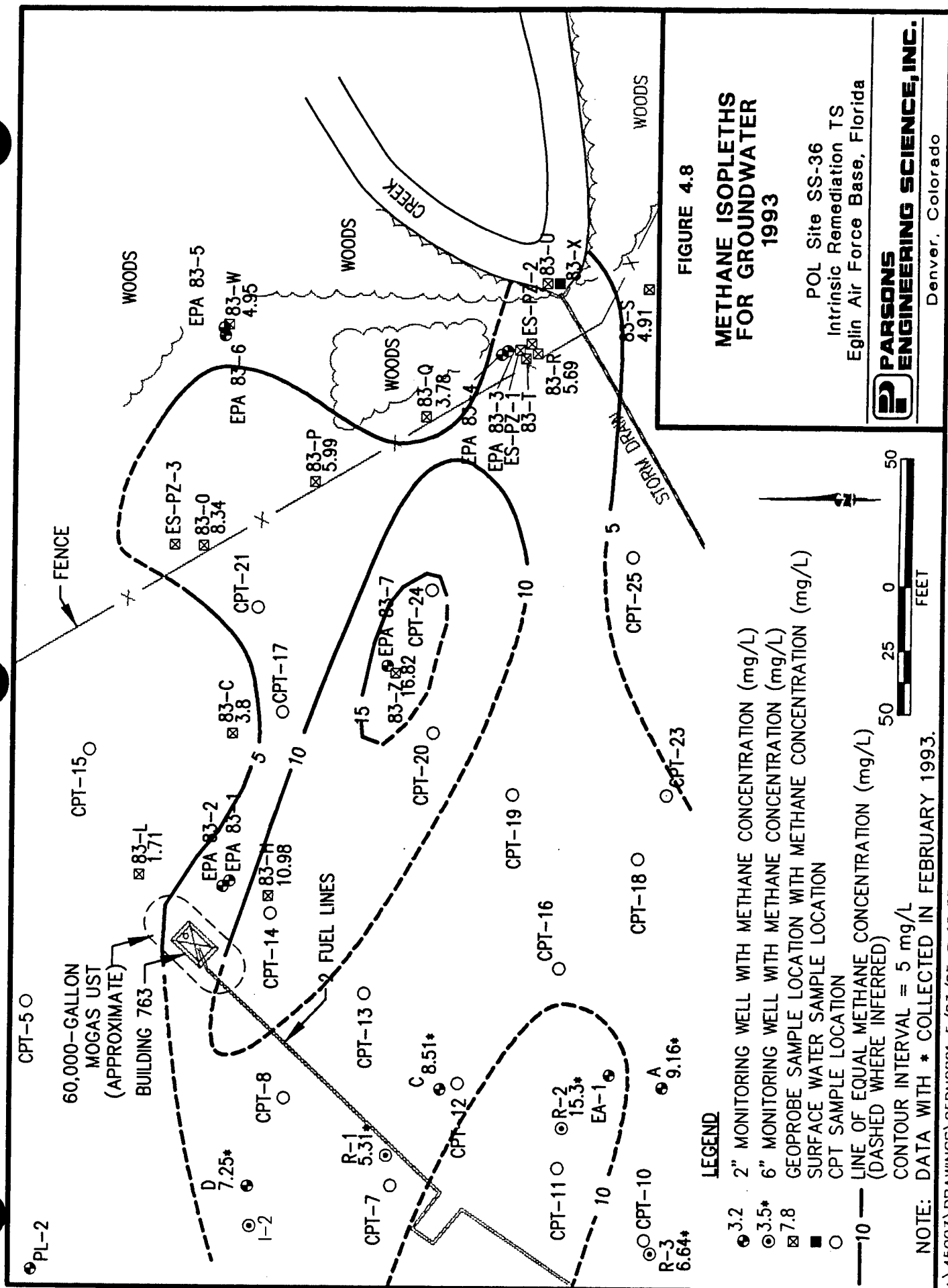
estimate of the assimilative capacity of sulfate because microbial cell mass production has not been taken into account by the stoichiometry presented in Table 4.5.

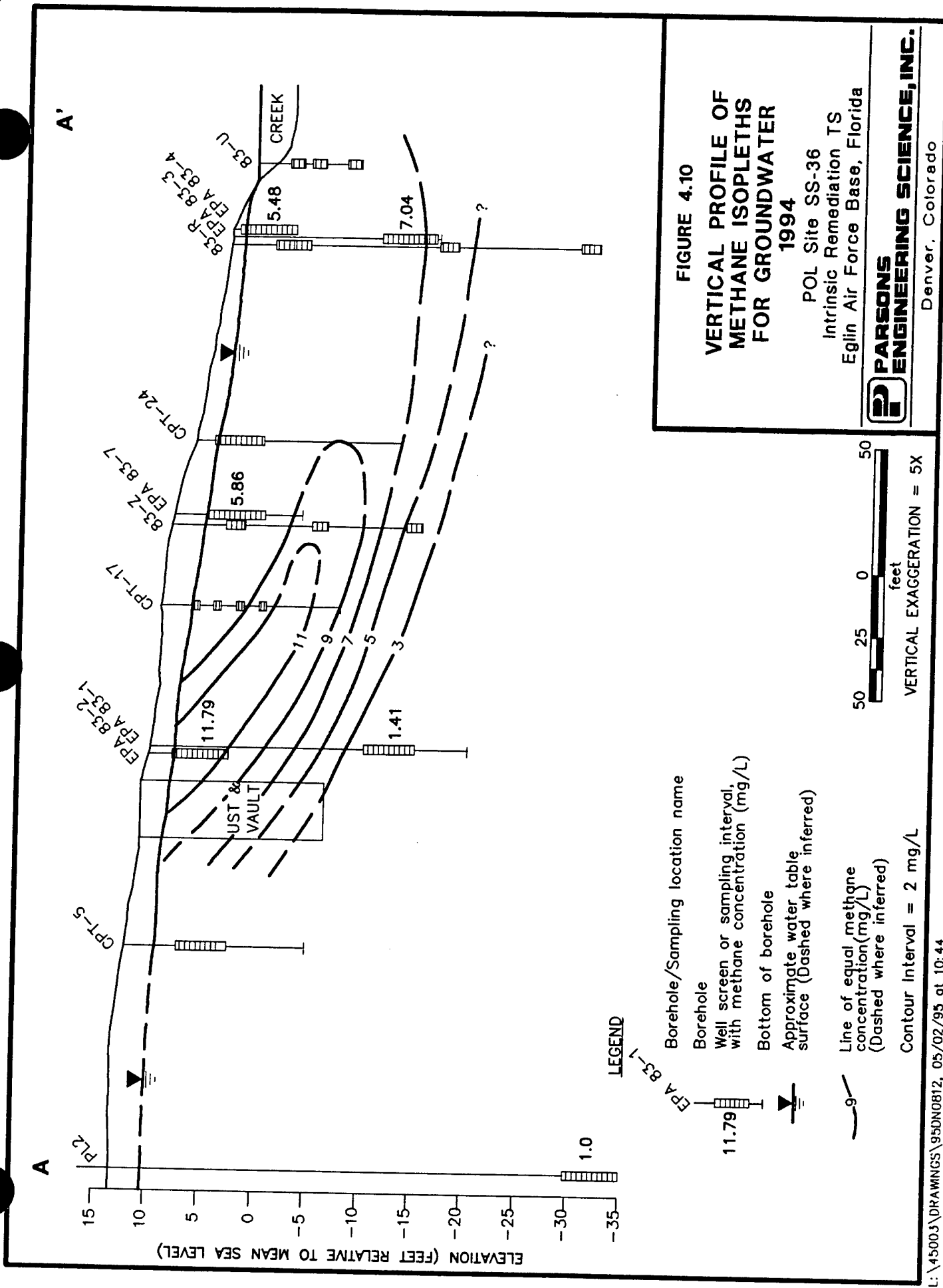
4.3.2.5 Methane in Groundwater

Methane concentrations were measured at monitoring wells and Geoprobe[®] sampling locations in September 1993. In addition, RSKERL researchers measured methane concentrations at monitoring wells immediately southwest of the study site in February 1993. Table 4.6 summarizes methane concentrations. Figure 4.8 is an isopleth map showing the areal distribution of methane in groundwater in 1993. Figures 4.9 and 4.10 show the vertical distribution of methane in groundwater in 1993 and 1994, respectively. Comparison of Figures 4.8 and 4.9 with Figures 4.3 and 4.4 shows graphically that areas with elevated total BTEX concentrations correlate with elevated methane concentrations. This is a strong indication that anaerobic biodegradation of the BTEX compounds is occurring at the site.

Methane concentrations ranged from 1.71 mg/L to 16.82 mg/L. Background levels of methane at wells and Geoprobe[®] sampling locations in areas with little or no detected BTEX contamination are generally below 5 mg/L. Samples collected from monitoring wells and Geoprobe[®] sampling locations in areas with the highest BTEX concentrations (e.g., locations 83-Z and 83-H) contain the highest methane concentrations. In these locations, methane concentrations range from about 5.7 to 16.82 mg/L.

The stoichiometry of BTEX oxidation to carbon dioxide and methane by methanogenesis is presented in Table 4.5. On average, approximately 1 mg of total BTEX is mineralized for every 0.78 mg of methane produced. Given a maximum detected methane concentration of 16.82 mg/L and an assumed background concentration of 5 mg/L, the shallow groundwater has the capacity to assimilate approximately 15.15 mg/L (15,150 µg/L) of total BTEX through methanogenesis. This is a conservative estimate of the assimilative capacity due to methanogenesis because microbial cell mass production was not taken into account by the stoichiometry shown in Table 4.5. In addition, these calculations are based on observed methane concentrations and not on the amount of carbon dioxide available in the aquifer. Because methanogenesis produces more carbon dioxide than it consumes, an unlimited supply of carbon dioxide is theoretically available once the process of methanogenesis has been initiated. Therefore, methanogenic assimilative capacity could be much higher.





Between 1993 and 1994, methane concentrations along the plume centerline appeared to decrease slightly, as seen by comparing Figures 4.9 and 4.10. At the same time, BTEX concentrations decreased. It is likely that the methane concentrations decreased because less methane was produced as the BTEX concentrations decreased through continuing biodegradation.

4.3.2.6 Reduction/Oxidation Potential

Redox potentials were measured at monitoring wells and Geoprobe[®] sampling locations in September 1993, and in monitoring wells in October 1994. Redox potential is a measure of the relative tendency of a solution to accept or transfer electrons. The redox potential of a groundwater system depends on which electron acceptors are being reduced by microbes during BTEX oxidation. Table 4.6 summarizes available redox potential data. The groundwater redox potentials measured at the site in 1993 ranged from -30 millivolts (mV) to -253 mV. In 1994, measured groundwater redox potentials ranged from -116 mV to -190 mV. These measurements are relatively low, indicating that the groundwater in the shallow aquifer is reducing. This is consistent with the electron acceptor data, which indicate that the groundwater system beneath the study site has moved through the progression of redox reactions indicated on Table 4.5 and discussed in Section 4.3.2. The only location where the redox potential indicates slightly oxidizing conditions is the shallowest groundwater sample from Geoprobe[®] location 83-U. Because there is probably some exchange with oxygenated surface water at this location, the groundwater in this sample had a redox potential of 99 mV.

4.3.2.7 Alkalinity

Total alkalinity (as calcium carbonate) was measured at Geoprobe sampling locations in September 1993 and at monitoring wells immediately southwest of the site in February 1993. These measurements are summarized in Table 4.6. Alkalinity is a measure of a groundwater's ability to buffer changes in pH caused by the addition of biologically generated acids. Total alkalinity at the site is in the low range for groundwater, varying from 3.8 mg/L at 83-P to 96.7 mg/L at R-2. The reduced alkalinity of the groundwater at this site may be a result of the accumulation of organic acids produced by the biodegradation of petroleum hydrocarbons and also by the organic acids produced by the decay of the organic matter (e.g., peat) in the aquifer matrix. This

amount of alkalinity should be sufficient to buffer potential changes in pH caused by biologically mediated BTEX oxidation reactions.

4.3.2.8 pH

pH was measured at Geoprobe[®] sampling locations in September 1993 and at monitoring wells immediately southwest of the site in February 1993. These measurements are summarized in Table 4.6. The pH of a solution is the negative logarithm of the hydrogen ion concentration $[H^+]$. Groundwater pH measured at the site ranges from 5.6 to 6.7. This range of pH is within the optimal range for BTEX-degrading microbes. pH of the groundwater probably is slightly low because of the acids produced by the biodegradation of petroleum hydrocarbons and also by the organic acids produced by the decay of natural organic matter (e.g., peat) in the aquifer matrix.

4.3.2.9 Temperature

Groundwater temperature was measured at Geoprobe[®] sampling locations in September 1993 and at monitoring wells immediately southwest of the site in February 1993. Table 4.6 summarizes groundwater temperature readings. Temperature affects the types and growth rates of bacteria that can be supported in the groundwater environment, with higher temperatures generally resulting in higher growth rates. Temperatures in the shallow aquifer during September 1993 varied from 22.9°C to 30°C. During February 1993, groundwater temperatures were lower, ranging from 16.0°C to 23.1°C. These are relatively high temperatures for shallow groundwater, suggesting that bacterial growth rates may be relatively high.

4.3.3 Expressed Assimilative Capacity

The data presented in the preceding sections suggest that mineralization of BTEX compounds is occurring through the microbially mediated processes of aerobic respiration (primarily near the creek), iron and sulfate reduction, and methanogenesis. Based on the stoichiometry presented in these sections, the expressed BTEX assimilative capacity of groundwater at the Eglin AFB study site is at least 17,000 µg/L (Table 4.7). The highest dissolved total BTEX concentration observed at the site during this investigation was 3,862 µg/L, at Geoprobe[®] location 83-H, although a concentration of 18,000 µg/L was detected in CPT-8 in the spring of 1993.

TABLE 4.7
EXPRESSED ASSIMILATIVE CAPACITY OF SITE GROUNDWATER
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

Electron Acceptor or Process	Expressed BTEX Assimilative Capacity ($\mu\text{g/L}$) ^{a/}
Dissolved Oxygen	380
Nitrate	-- ^{b/}
Iron Reduction	410
Sulfate	1,060 ^{c/}
Methanogenesis	15,150
Expressed Assimilative Capacity	17,000
Highest Observed Total BTEX Concentration	3,862

^{a/} Not including increased assimilative capacity due to DO enrichment near creek.

^{b/} Nitrate concentrations in site groundwater were negligible.

^{c/} Correlation is not clear.

The large difference between the expressed assimilative capacity and the maximum detected BTEX concentration implies that natural processes will eventually biodegrade the BTEX remaining in the system; however, because of mass transfer, kinetic, and other chemical and biological limitations, the total reservoir of electron acceptors is not available for immediate biodegradation of the BTEX. In addition, other petroleum compounds (such as naphthalene and other long-chain hydrocarbons) and natural organic matter (e.g., derived from peat) are dissolved in the groundwater or sorbed onto the aquifer matrix, further increasing the demand on the assimilative capacity. Furthermore, the present day maximum total BTEX concentration may be a small fraction of the original maximum concentration. Immediately after the spill, mobile LNAPL may have been present on the groundwater surface and dissolved total BTEX concentrations as high as 130,000 $\mu\text{g/L}$ may have been present in the groundwater.

4.3.4 Additional Considerations

In addition to contaminant and electron acceptor data, other information can be used to assess and quantify the effects of natural attenuation. Sorption of contaminants, an important process governing the fate and transport of dissolved contaminants, has been quantified using data from the literature. In addition, rates of hydrocarbon attenuation and biodegradation have been determined from a microcosm study and from calculations based on site contaminant data. These factors are discussed in the following sections.

4.3.4.1 Sorption

Many organic contaminants, including the BTEX compounds, are removed from solution by sorption onto the aquifer matrix. Sorption is the process whereby dissolved contaminants partition from the groundwater and adhere to the particles making up the aquifer matrix. Sorption of dissolved contamination onto the aquifer matrix results in slowing (retardation) of the contaminant relative to the average advective groundwater flow velocity and a reduction in dissolved BTEX concentrations in groundwater. In most aquifers, organic matter tends to control the sorption of fuel hydrocarbons. Given the presence of peat and other organic matter in the shallow aquifer sediments, sorption likely plays a significant role in limiting contaminant migration at this site.

Calculation of retardation coefficients (detailed in Appendix C) generally requires TOC concentration data for the aquifer matrix. Although no soil TOC data were collected at this site, data from the technical literature and from another study performed in a similar geologic environment can be used to estimate a range of TOC concentrations have been used for evaluation of sorption at the study site.

Retardation coefficients were calculated using these data and the relationships described in Appendix C. For these calculations, it was assumed that the effective porosity of the aquifer is 0.30, and that the bulk density of the aquifer matrix is 1.6 kilograms per liter (kg/L) (Freeze and Cherry, 1979). These calculations also incorporated published values of the soil sorption coefficient (K_{oc}) for the BTEX compounds (as listed in Wiedemeier *et al.*, 1995). It also was assumed that TOC concentrations ranged from 0.026 percent to 0.7 percent. This range was selected because it was derived from the technical literature and it falls within the range of values observed at Patrick AFB, Florida (a site with a very similar geologic environment). As

indicated on Table C.1 in Appendix C, calculated retardation coefficients for the study site range from 1.11 to 18.47. However, for the purposes of this study, the range of average retardation coefficients (1.42 to 3.50) will be used. Use of the minimum values would be too conservative because the bodies of peat observed at this site likely serve to inhibit migration along the flow path between the UST and the creek.

4.3.4.2 Microcosm Study

Researchers from USEPA RSKERL performed a microcosm study on a soil sample collected from immediately below the water table during drilling of the borehole for monitoring well EPA 83-4. This sample was shipped to the RSKERL in Ada, Oklahoma, where USEPA researchers split the sample into several subsamples for the microcosm study. All laboratory handling of microcosms was performed under anoxic conditions. Some of the subsamples were sterilized for use as control microcosms. Then, the control and the "live" microcosms were inoculated with a water solution containing benzene and toluene. Initial samples of this pore water were collected and analyzed for benzene and toluene. After 34 weeks of incubation, samples of pore water from all the microcosms were collected and analyzed for benzene and toluene. Study results are presented along with the laboratory analytical results in Appendix B.

Pore water samples from the control microcosms showed no decrease in toluene concentrations, and benzene concentrations decreased by an average of 30 percent. Samples from the "live" microcosms indicated that toluene concentrations decreased to below method detection limits, while benzene concentrations decreased by an average of 42 percent. RSKERL personnel calculated a biodegradation rate of 0.016 week^{-1} (0.0023 day^{-1}) for benzene and a biodegradation rate of 0.079 week^{-1} (0.011 day^{-1}) for toluene. The calculated benzene degradation rate likely underestimates the actual rate because of the changes observed in the control microcosm. However, both degradation rates are useful, and both represent lower bounds for each compound. They are lower bounds because apparent benzene concentration decreases were reduced due to the losses observed in the control microcosm (thus resulting in an underestimation of benzene degradation rates), and it is not known when toluene concentrations decreased to below the detection limit.

In addition to this evidence of microbial activity, EA (1987) tested several soil and groundwater samples for bacteria densities, including total bacteria and hydrocarbon-

degrading bacteria. Their evidence indicated that populations of hydrocarbon-degrading bacteria in soil and groundwater were higher in locations where contaminant concentrations were elevated, suggesting that the petroleum hydrocarbons stimulated the growth of the native microbe population.

4.3.4.3 Biodegradation Rates (Field Methods)

As with a large number of biological processes, biodegradation can generally be described using a first-order rate constant. In one dimension, first-order decay is described by the following ordinary differential equation:

$$\frac{dC}{dt} = -\lambda C$$

Where: C = concentration at time t [M/L³]

λ = coefficient of anaerobic decay (first-order rate constant) [1/T]

Solving this differential equation yields:

$$C = C_0 e^{-\lambda t}$$

Three methods for determining first-order biodegradation rates are used herein. The first method involves the use of a conservative tracer to calculate anaerobic degradation rates. The second method was derived by Buscheck and Alcantar (1995) to determine total biodegradation rates and is valid for steady-state plumes. The third method is useful for shrinking plumes. Calculations of site-specific biodegradation rates are presented in Appendix C, along with explanations of these methods. First-order decay rate constants presented in the technical literature are also listed in Appendix C.

As indicated in Appendix C, the first-order anaerobic biodegradation rate for total BTEX, calculated using TMB as a tracer, is approximately 0.6 percent per day, or 0.006 day⁻¹. If the method of Buscheck and Alcantar (1995) is used, the total biodegradation rate at this site is 1 percent per day, or 0.01 day⁻¹. This rate is greater than the rate calculated using TMB-corrected BTEX data because this method also accounts for aerobic degradation, and any loss of TMB makes those rates more conservative. The shrinking-plume method yields an average biodegradation rate of 0.008 day⁻¹. These rates, and the rates indicated by the microcosm study, are summarized on Table 4.8.

TABLE 4.8
SUMMARY OF CALCULATED BIODEGRADATION RATES
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

Method	Rate (day ⁻¹)
Microcosm Study	0.002 (benzene) 0.011 (toluene)
TMB Tracer	0.006 ^{a/}
Buscheck and Alcantar (1995)	0.01 ^{a/}
Shrinking Plume Method	0.008 ^{a/}
Technical Literature (as summarized by Wiedemeier <i>et al.</i> , 1995)	0.005 - 0.18 ^{a/}

^{a/} Rates calculated for total BTEX.

The actual biodegradation rate is likely to be somewhere within the range of these estimates, because the plume may actually be shrinking (concentrations decreased in most wells between 1993 and 1994), so it is possible that the Buscheck and Alcantar (1995) method may slightly overestimate the degradation rate. In addition, the tracer method may underestimate the anaerobic degradation rate if any TMB is consumed by aerobic degradation (e.g., as oxygenated recharge enters the groundwater). These rates compare favorably with the microcosm study, which indicated biodegradation rates of at least 0.011 day⁻¹ for toluene and 0.002 day⁻¹ for benzene. These rates also compare favorably to values listed in the literature, which range from 0.001 day⁻¹ to 0.04 day⁻¹ (see Appendix C).

4.3.4.4 Degradation of Residual LNAPL Source

The concentration of petroleum hydrocarbons in groundwater in contact with fuel spills is controlled by the concentration of the particular hydrocarbon in the residual (and/or mobile) LNAPL. Raoult's Law predicts that the equilibrium concentration would be the water solubility of that particular hydrocarbon, multiplied by its mole fraction in the LNAPL. When wells that have been installed across LNAPL spills are monitored for several years, frequently the concentration of BTEX compounds are seen to decline several orders of magnitude. This is largely due to intrinsic remediation of the LNAPL

itself, supported by natural weathering processes, including diffusion of oxygen through the vadose zone. Apparently, the BTEX compounds are degraded first, leaving a residual of branched and normal alkanes. As a result, petroleum hydrocarbon contamination disappears from the groundwater, although considerable quantities of total petroleum hydrocarbons (TPH) may remain in the aquifer. The effect is well illustrated in the following case study for the Eglin AFB site, prepared by RSKERL researchers.

Chemical evidence from sampling of residual LNAPL in site soil and dissolved hydrocarbons in site groundwater indicates that the residual LNAPL is severely weathered and is contributing much less dissolved BTEX to site groundwater than would be expected from fresh MOGAS. To document this, USEPA researchers collected soil core samples across the water table at monitoring wells EPA 83-2, EPA 83-4, and EPA 83-7 and analyzed the samples for TPH and BTEX. These results were used in conjunction with groundwater sampling results to evaluate the effects of weathering on the residual LNAPL and on the dissolved hydrocarbon contamination related to the LNAPL.

The partitioning of BTEX from gasoline to groundwater has been thoroughly examined by Cline *et al.* (1991). They examined the variation in fuel to water partition coefficients for 31 samples of gasoline. Their estimates of K_{fw} for various gasoline components are presented in Table C.4 of Appendix C. Data on the concentrations of TPH and individual BTEX compounds in soil core samples from the spill at Eglin AFB are presented in Table 4.9. Assuming the specific gravity of gasoline is 0.74, The following relationship was used to estimate C_f for a given BTEX compound (e.g., benzene) in a given core sample:

$$C_f = \frac{\text{Benzene}(mg/Kg)}{\text{TPH}(mg/Kg)} \times \frac{0.74(Kg)TPH}{1.0(l)TPH} \times \frac{10^6(mg)TPH}{1.0(Kg)TPH}$$

The concentration of the BTEX compounds in groundwater in contact with that particular core material were predicted by dividing C_f by K_{fw} from Table C.4 of Appendix C. Table 4.10 compares the predictions to the actual concentration of BTEX compounds in groundwater from monitoring wells screened across the depth interval from which the core samples were acquired.

TABLE 4.9

**COMPARISON OF TPH AND BTEX CONCENTRATIONS IN SOIL SAMPLES
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA**

Depth (feet)	TPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	p-Xylene (mg/kg)	m-Xylene (mg/kg)	o-Xylene (mg/kg)
Adjacent to the Spill (EPA-83-1 and EPA 83-2))							
3.0-3.4	2140	2.66	5.68	4.01	10.6	21.2	17.2
3.0-3.5	1550	0.165	18.2	2.05	41.7	69.1	59.2
Half of the Way to the Creek (EPA-83-7)							
4.0-5.0	1170	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6.0-7.0	5310	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Adjacent to the Creek (EPA-83-3 and EPA 83-4)							
1.5-2.0	1210	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2.0-2.5	1970	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2.3-3.0	7090	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

TABLE 4.10

**COMPARISON OF GROUNDWATER BTEX CONCENTRATIONS TO
THOSE PREDICTED BY EQUILIBRIUM PARTITIONING CALCULATIONS
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA**

Soil Sample or Well Screen Interval (ft bgs)	Type of Concentration	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)
Well EPA 83-2, Near the Gasoline Spill							
3.0-3.4	predicted	2600	1600	310	840	1700	1600
3.0-3.5	predicted	230	7000	217	4600	7600	7800
2.28 - 7.28	measured 09/93	300	1400	35	540		410
2.28 - 7.28	measured 10/94	46	75	13	93	179	219
Well EPA 83-7, 70 feet down gradient (One Half of the Distance to the Creek)							
4.0-5.0	predicted	<18	<5	<1.4	<1.5	<1.5	<1.7
6.0-7.0	predicted	<4	<1	<0.3	<0.3	<0.3	<0.4
3.39 - 8.39	measured 09/93	2.2	4.3	36	36		26
3.39 - 8.39	measured 10/94	1.9	1.0	<1	<1	<1	<1
Well EPA 83-4, 150 feet Down Gradient, Adjacent to the Creek							
1.5-2.0	predicted	<17	<5	<1.4	<1.4	<1.4	<1.7
2.0-2.5	predicted	<11	<3	<0.8	<0.9	<0.9	<1.0
2.3-3.0	predicted	<3	<0.8	<0.2	<0.2	<0.2	<0.3
0.99 - 5.99	measured 09/93	<1	<1	<1	<1	<1	<1
0.99 - 5.99	measured 10/94	<1	1.4	<1	<1	<1	<1

The residual LNAPL near the creek (in the vicinity of EPA 83-4), and halfway between the UST and the creek (in the vicinity of EPA 83-7), was so weathered that no BTEX compound was detectable at concentrations greater than 0.01 mg/kg, although considerable quantities of TPH remained (Table 4.9). Duplicate samples from the area of EPA 83-2 were weathered, but appreciable concentrations of BTEX remained, and the pattern of weathering varied between the two core samples.

Groundwater in contact with the weathered gasoline residual near the spill contained BTEX concentrations that were either in good agreement with those predicted from analysis of the cores, or were somewhat lower than would be predicted by core analysis (Table 4.10). Comparison of groundwater sample data from September 1993 and October 1994 (Section 4.3.1.1) indicate that intrinsic remediation is continuing in the spill area. Despite high concentrations of TPH downgradient from the spill, the residual gasoline is so highly weathered that it cannot maintain concentrations of dissolved BTEX in groundwater equivalent to those observed in 1993.

4.3.5 Discussion and Conclusions

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 and Subramanian, 1984; Reinhard *et al.*, 1984; Young, 1984; Bartha, 1986; Wilson *et al.*, 1986, 1987, and 1990; Barker *et al.*, 1987; Baedecker *et al.*, 1988; Lee, 1988; Chiang *et al.*, 1989; Grbic'-Galic', 1989 and 1990; Cozzarelli *et al.*, 1990; Leahy and Colewell, 1990; Altenschmidt and Fuchs, 1991; Alvarez and Vogel, 1991; Baedecker and Cozzarelli, 1991; Ball *et al.*, 1991; Bauman, 1991; Borden, 1991; Brown *et al.*, 1991; Edwards *et al.*, 1991 and 1992; Evans *et al.*, 1991a and 1991b; Haag *et al.*, 1991; Hutchins and Wilson, 1991; Hutchins *et al.*, 1991a and 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 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.

Comparison of BTEX and biodegradation byproduct isopleth maps for the Eglin AFB study site provides strong qualitative evidence of biodegradation of BTEX compounds,

primarily due to methanogenesis and ferric iron reduction. Evidence also suggests that aerobic respiration (near the creek) and sulfate reduction are contributing to petroleum hydrocarbon degradation. However, the uncertain correlation between BTEX concentrations and depleted sulfate concentrations suggests that sulfate reduction may be occurring in small areas within the shallow aquifer, or that sulfate reduction was becoming less important as a biodegradation process as the aquifer conditions (at the time of sampling) were changing in response to the biological activity (i.e., redox conditions were beginning to favor another form of BTEX biodegradation, most likely methanogenesis). When some of the monitoring wells were resampled in October 1994, sulfate concentrations along the line of hydrogeologic cross-section A - A' (through the center of the plume) were generally higher than previously observed, ranging from 0.67 mg/L to 5.69 mg/L. This suggests that, between 1993 and 1994, sulfate reduction became less important as BTEX concentrations decreased and methanogenesis became the dominant biodegradation mechanism.

Given the assimilative capacities calculated for each process, methanogenesis is currently the most important biodegradation mechanism at this site, except in the vicinity of the creek. Near the creek, where groundwater is in contact with oxygenated surface water, it appears that aerobic respiration is the dominant biodegradation mechanism. This suggests that as groundwater contaminated with BTEX nears the groundwater - surface water interface, aerobic biodegradation will further reduce BTEX concentrations. In addition, shallow groundwater near the creek probably exchanges DO with surface water at the interface, which provides a virtually inexhaustible supply of DO.

In addition to the geochemical evidence of biodegradation, the decreases in BTEX concentrations observed at monitoring wells EPA 83-1 through EPA 83-7 also provide strong evidence of the effectiveness of natural attenuation processes. Within the course of 1 year (September 1993 to October 1994), BTEX concentrations decreased or remained constant at all but one of the wells. In addition, benzene concentrations decreased during the same time, from a maximum of 300 µg/L to a maximum of 46.3 µg/L.

While biodegradation mechanisms are destroying a significant amount of dissolved BTEX compounds, another natural attenuation mechanism (sorption) is likely to be playing an important role in reducing groundwater contaminant concentrations. At least two peat units are present in the study area, and the sand units locally contain organic

material. A significant mass of dissolved hydrocarbons has likely sorbed onto the organic matter present in these units. Besides removing contaminants from the groundwater, sorption also has effectively reduced the velocity of the dissolved contaminants so that they are traveling slower than the advective groundwater velocity.

Biodegradation rates for BTEX compounds dissolved in groundwater at the site have been calculated from a microcosm study and from field data. Results of the microcosm study performed by RSKERL scientists indicate toluene biodegradation rates of at least 0.01 day^{-1} and benzene biodegradation rates of at least 0.002 day^{-1} . The anaerobic biodegradation rate calculated for total BTEX (using TMB as a tracer) is 0.006 day^{-1} , and a total biodegradation rate of 0.01 day^{-1} was calculated using the method of Buscheck and Alcantar (1995). Using the shrinking-plume method yields an estimated average biodegradation rate of 0.008 day^{-1} . These rates are in good agreement, given that the microcosm rates represent lower bounds, and that the tracer results only account for anaerobic degradation and may also underestimate that rate.

Finally, the evidence collected at this site strongly suggests that detectable concentrations of dissolved BTEX compounds are not entering the creek. Dissolved BTEX data for surface water and groundwater beneath the creek indicate that total BTEX concentrations diminish rapidly near the groundwater - surface water interface, decreasing from $227.8 \text{ } \mu\text{g/L}$ to below detection limits in about 7 feet. If any detectable concentrations of BTEX reach the surface water, other mechanisms such as increased volatilization and dilution, photooxidation, and continued biodegradation will act to further reduce concentrations.

It should be noted that these conclusions apply specifically to the plume that was investigated for this study. As seen on Figure 4.3, other plumes are present in the vicinity of the study site. These plumes are the result of spills and leaks at other facilities within the POL Yard. Similar patterns of natural attenuation may be present in these plumes.

SECTION 5

GROUNDWATER MODELING

5.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

In order to help estimate degradation rates for BTEX compounds dissolved in groundwater at the Eglin AFB study site and to help predict the future migration of these compounds, Parsons ES modeled the fate and transport of the dissolved BTEX plume. The modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to potential downgradient receptors; and 3) to provide technical support for the intrinsic remediation 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, the reduction in contaminant mass caused by natural attenuation is expected to exceed model predictions. This analysis is not intended to represent a baseline assessment of potential risks posed by site contamination.

The model codes MODFLOW (McDonald and Harbaugh, 1988) and MT3D[®] (Zheng, 1990) were used to estimate the potential for dissolved BTEX migration and degradation by naturally occurring mechanisms operating at the site. MODFLOW was used to generate a groundwater flow model for the site, and the flow field from this model was incorporated into the transport solution computed by MT3D[®]. The MT3D[®] code incorporates advection, dispersion, sorption, and biodegradation to simulate contaminant plume migration and degradation. MT3D[®] uses a solution similar to the USGS Method of Characteristics (MOC) two-dimensional (2-D) solute transport model of Konikow and Bredehoeft (1978). The model was modified by Zheng (1990) to allow three-dimensional (3-D) solutions, and to allow use of a modified MOC method that reduces numerical dispersion. Biodegradation of dissolved and sorbed contaminants can be simulated through the use of a first-order decay constant. These codes were selected over the

Bioplume II code because of the complex nature of the groundwater flow system and because nearly all biodegradation at the site is anaerobic.

In recent years it has become apparent that anaerobic processes such as denitrification, iron reduction, sulfate reduction, and methanogenesis can 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). Because evidence indicates that anaerobic biodegradation processes are dominant at the site, these processes were accounted for using a first-order decay coefficient based on those presented in Sections 4.3.4.2 and 4.3.4.3. The following subsections discuss in more detail the model setup, input parameters and assumptions, model calibration, and simulation results.

5.2 CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

Prior to developing a groundwater 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 MT3D[®] code is that dispersion, sorption and biodegradation are major factors controlling contaminant fate and transport at the site. Data and information presented in Sections 3 and 4 suggest that ferric hydroxide and carbon dioxide (methanogenesis) are being used as electron acceptors for anaerobic biodegradation. Data also indicate that significant concentrations of organic carbon are present in the aquifer matrix, and that sorption is likely an important process. Biodegradation of petroleum hydrocarbons was simulated using a decay constant, and sorption (assumed to be a linear process) was simulated using a coefficient of retardation. Selection of these parameters is discussed in Section 5.3.5.

On the basis of the data presented in Section 3, the shallow saturated zone was conceptualized and modeled as a shallow unconfined aquifer composed of fine- to medium-grained sand (Figures 3.2 and 3.3). Because there are significant vertical flow gradients at this site, and because the saturated zone is heterogeneous in the vertical dimension, a 3-D solution seemed appropriate. However, there is poor lateral control on the plume extents to the south and southwest of the source area (due to other contaminant sources upgradient of the study site). As a result, a vertical profile model was selected to examine contaminant fate and transport along the centerline of the dissolved BTEX

plume (i.e., approximately along the line of cross-section A - A', shown on Figure 3.2). This model is essentially 2-D, with the major dimensions oriented vertically and parallel to the flow path. Perpendicular to flow, the model has a unit thickness (i.e., it is 1 foot thick in that dimension).

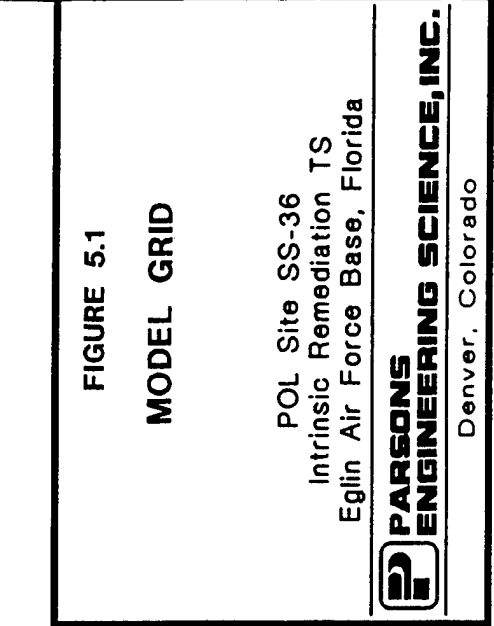
For the purposes of the model, it was assumed that contaminants were first introduced to the groundwater at this site when the MOGAS was spilled in 1988. For some time after the time of the spill, mobile and residual LNAPL above and slightly below the water table were the sources of dissolved BTEX. Most of this LNAPL was likely concentrated in the vicinity of the UST, while some moved downgradient toward the creek due to either overland flow and infiltration of MOGAS during the spill or downgradient migration of an LNAPL lens along the water table. Available evidence indicates that mobile LNAPL is no longer present at the site, and that the remaining residual LNAPL is significantly weathered. However, the residual product may act as a continuing minor source in some locations. Therefore, it was assumed that contaminants entered groundwater via dissolution from residual LNAPL trapped below the water table, and by dissolution into recharge (infiltrating precipitation) as it passed through the LNAPL above the water table. Both these sources likely diminished as the BTEX weathered out of the LNAPL, so less contaminant mass entered the groundwater as time passed.

5.3 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., for 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 model parameters that were varied during model calibration are discussed in Section 5.4.

5.3.1 Grid Design and Boundary Conditions

A 20-layer by 30-cell grid was used to model the Eglin AFB site. Each grid cell was 17 feet long by 2.5 feet tall. The grid was oriented so that the longest dimension was parallel to the overall direction of groundwater flow [i.e., along the line of hydrogeologic cross-section A - A' (Figure 3.3)]. The model grid covers an area of 22,500 square feet. The full extent of the model grid is indicated on Figure 5.1.



MODEL GRID

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For the groundwater flow model, model boundaries are mathematical statements that represent hydrogeologic boundaries, such as areas of specified head (e.g., surface water bodies or contour lines of 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., ft³/ft²/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 groundwater 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 in the zone being modeled (generally the zone containing the contaminant plume)
 H_0 = Head in external zone (separated from plume by semipermeable layer)
 K' = Hydraulic conductivity of semipermeable layer

B' = Thickness of semipermeable layer.

For the groundwater flow model, 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, groundwater 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.

Specified-head boundaries for the model were set on the upgradient and downgradient ends of the model grid to simulate the southeasterly groundwater flow observed at the site. In the uppermost cells, boundaries were set in the approximate location of the water table indicated by water level data collected in September 1993. Moving downward along these boundaries, heads for the remaining specified-head cells were calculated using the gradients observed in the well pairs nearest the boundaries. The heads along the northwestern boundary were estimated to range from 9.6 to 5.2 feet above msl, while on the southeastern model boundary, heads were estimated to range from 1.75 to 3.55 feet above msl. The location of this contour was estimated from available water elevation and gradient data. Specified-head cells also were used to represent the creek that feeds into Weekly Bayou. This method was chosen over the MODFLOW river package because the creek is deep enough to occupy more than one model layer (the river package is limited to representing streams contained within a single model layer). Creek heads all were specified to be 1.6 feet above msl.

The bottom and lateral (perpendicular to flow) 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 bottom boundary was assumed to be at about 37 feet below msl, which is approximately where the Pensacola Clay forms the basal boundary of the shallow aquifer. The upper model boundary was defined by the simulated water table surface.

5.3.2 Groundwater Elevations and Gradients

The groundwater elevations presented in Table 3.1 were used to define the starting heads and constant heads input into the MODFLOW model. Groundwater flow in the vicinity of the site is to the southeast with an average gradient of approximately 0.002

ft/ft. Data quantifying seasonal variations in groundwater flow direction and gradient at the site are not available, but previous groundwater flow data (e.g., EA, 1987) and the BTEX and electron acceptor plume configurations are consistent with the observed groundwater flow direction. As a result, it was assumed that the observed water levels were representative of steady-state conditions. As described in Section 5.4.1, the model was calibrated to the observed water table.

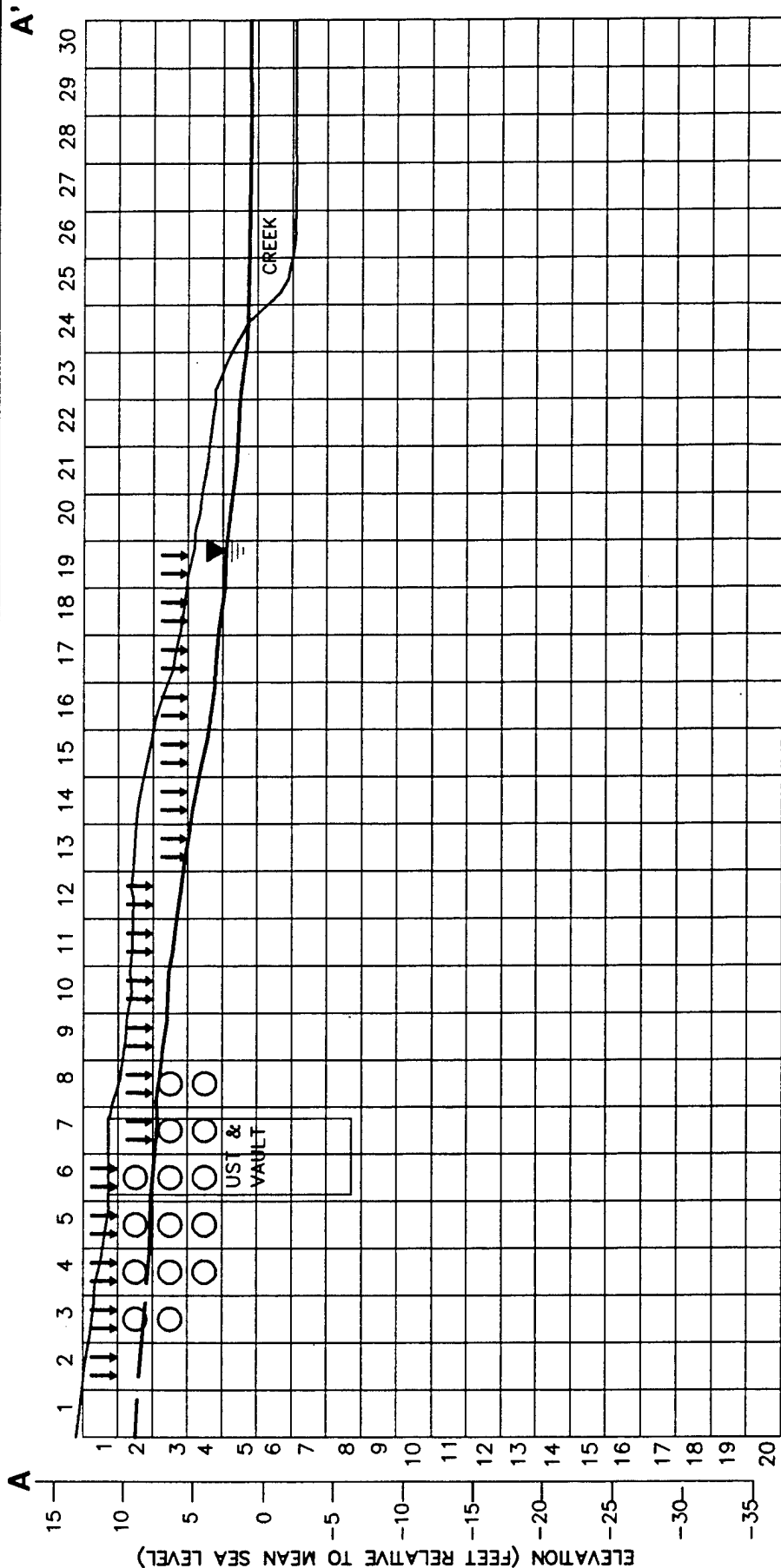
5.3.3 BTEX Sources

As noted in Section 5.2, dissolved BTEX compounds entered (and continue to enter) site groundwater by two main processes: through contact between groundwater and mobile or residual LNAPL at or below the water table, and by migration of recharge (precipitation) through soil containing mobile or residual LNAPL above the water table.

Both of these processes can be represented by the source-sink mixing package of MT3D[®]. For the recharge loading, the user can specify the contaminant mass entering the system per each unit (volume) of recharge specified in the MODFLOW portion of the model. These rates can vary from cell to cell, and also can be changed over time (i.e., to reflect a diminishing source due to weathering and dissolution). For dissolution of BTEX from LNAPL below the water table, the user can place wells that inject water into the aquifer at a very low flow rate (to avoid altering the hydraulic balance of the model) into the MODFLOW model, and then specify contaminant loading rates for these wells in MT3D[®]. As with the recharge option, the loading rates for these sources also can vary temporally and spatially. These sources provide a boundary condition for the transport model, and are equivalent to specified-flux (Neumann-type) boundaries in a flow model. Schematic source configurations are indicated on Figure 5.2.

5.3.4 Biodegradation Rates

Available data strongly suggest that anaerobic degradation is occurring at the site. Although some aerobic biodegradation of dissolved BTEX may occur near the water table or immediately below the creek, combined anaerobic processes account for nearly all of the assimilative capacity of site groundwater (Table 4.7). Anaerobic degradation must therefore be simulated with MT3D[®] to make predictions are meaningful. The MT3D[®] code simulates biodegradation by assuming that such degradation follows first-



Approximate water table surface, September 1993 (Dashed where inferred)

Location of simulated injection well

Location where contaminants are introduced with recharge

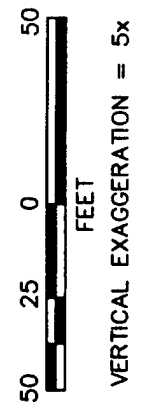


FIGURE 5.2

MODEL GRID, SHOWING LOCATIONS OF SIMULATED CONTAMINANT SOURCES

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

order kinetics. As indicated in Sections 4.3.4.2 and 4.3.4.3, site-specific BTEX degradation rates were determined from field data using three different methods, supported by the results of a microcosm study performed by USEPA RSKERL personnel. On the basis of those data, a BTEX biodegradation rate constant of 0.009 day^{-1} was used in the MT3D[®] model to simulate biodegradation of the dissolved BTEX. This value was selected because it is within the range of values indicated by the microcosm study and the calculations, as well as within the range of values reported in the literature. MT3D[®] also allows input of a degradation constant for the fraction of contaminants that sorb to the aquifer matrix. To be conservative, the value of this constant was set at 0.007 day^{-1} .

5.4 MODEL CALIBRATION

Model calibration is an important component in the development of any numerical model. Calibration of the 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 flow model presented herein was calibrated by altering hydraulic parameters such as hydraulic conductivity and recharge rates in a trial-and-error fashion until simulated heads approximated observed field values within a prescribed accuracy. After calibration of the flow model, the numerical transport model was calibrated by altering contaminant loading rates and transport parameters in a trial-and-error fashion until the simulated BTEX plume approximated observed field values. Table 5.1 summarizes important model input. Complete model input and output files are included in Appendix D.

5.4.1 Flow Model Calibration

The shallow groundwater system at the study 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, and by recharge of the aquifer through infiltration of rainfall. Potential recharge by, or discharge to, other sources was omitted because of a lack of reliable data. Only water levels at the constant-head cells, the recharge rate, and the cell-by-cell hydraulic conductivity values were varied to calibrate the water table surface. The model was calibrated as a steady-state solution, assuming that the September 1993 water levels were representative of steady-state conditions.

TABLE 5.1
SUMMARY OF SELECTED MODEL INPUT PARAMETERS
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

GROUNDWATER FLOW MODEL (MODFLOW)

Parameter	Description	Where Applied	Value (or Range of values)
Stress Periods/Time Steps	Controls time that simulation represents	--	Not used (steady-state)
Horizontal Hydraulic Conductivity	Governs flow of water in horizontal directions; Variations based on site hydrogeology	Entire Model Domain	4.8 ft/day to 101 ft/day
Vertical Hydraulic Conductivity	Governs flow of water in vertical direction; Variations based on site hydrogeology	Entire Model Domain	0.72 ft/day to 15 ft/day
Recharge	Flux due to infiltration of precipitation	Top cell of each model layer	0.005 ft/day to 0.006 ft/day
Injection Well Pumping Rates	Injection wells used in transport model for introduction of contaminants below water table; rate is set low enough to minimize effect on model head solution	18 cells in vicinity of UST & spill	0.01 ft ³ /day

CONTAMINANT TRANSPORT MODEL (MT3D[®])

Parameter	Description	Where Applied	Value (or Range of values)
Stress Periods/Time Steps	Controls time that simulation represents	--	9 stress periods, each consisting of one time step lasting one year
Effective Porosity	Governs contaminant velocity	Entire Domain	0.20
Longitudinal Dispersivity	Controls spreading of contaminant plume along the primary flow direction	Entire Domain	5 feet
Ratio of lateral and vertical to longitudinal dispersivity	Controls spreading of plume perpendicular to flow in the horizontal and vertical planes	Entire Domain	0.1
Injection Well Contaminant Concentrations	Controls contaminant mass entering system due to dissolution below water table	In vicinity of UST & spill	0.019 to 0.16 kg/ft ³
Recharge Contaminant Concentrations	Controls contaminant mass entering system via recharge from precipitation	In vicinity of UST & spill	0.0002 to 0.0075 kg/ft ³
Aquifer Bulk Density	Used to determine retardation of contaminants	Entire Model Domain	45.3 kg/ft ³
Decay Constant	Used to simulate biodegradation of contaminants as a first-order process	Entire Domain	0.009 day ⁻¹ (for dissolved contaminants) 0.007 day ⁻¹ (for sorbed contaminants)

Hydraulic conductivity is an important aquifer characteristic that determines the ability of the water-bearing strata to transmit groundwater. An accurate estimate of hydraulic conductivity is important to help quantify advective groundwater flow velocities and to define the flushing potential of the aquifer and the quantity of electron-acceptor-charged groundwater that is entering the site from upgradient locations. Other transport models, such as Bioplume II, have been shown to be sensitive to variations in hydraulic conductivity (Rifai *et al.*, 1988). Lower values of hydraulic conductivity result in a slower-moving plume, and higher values of hydraulic conductivity result in a faster-moving plume. In addition, the plume will spread more rapidly at higher values of hydraulic conductivity.

Data from previous reports, geologic logs, and water level measurements were used in conjunction with hydraulic conductivity as determined from aquifer tests to estimate an initial hydraulic conductivity of 21.6 ft/day for the entire model domain. Where zones of fine-grained soil were indicated by geologic logs or CPT logs, hydraulic conductivities were lowered by a factor of 10 to provide a starting array that would better reflect the observed variations in site hydrogeology.

To better match heads in the model to observed values, the conductivities were progressively varied in blocks and rows until the simulated water levels for cells corresponding to the selected well locations matched the observed water levels as closely as possible. Figure 5.3 shows the calibrated hydraulic head profile. In the calibrated model, horizontal hydraulic conductivities ranged from 4.8 ft/day to 101 ft/day (3.3×10^{-3} ft/min to 7.0×10^{-2} ft/min); vertical hydraulic conductivities ranged from 0.72 ft/day to 15 ft/day.

Recharge rates are typically assumed to represent some fraction of the average annual precipitation rate (64 inches per year, or 0.015 ft/day). For this model, it was assumed that recharge would vary between 10 and 50 percent of the precipitation rate. This is a reasonable assumption because the high permeability of the shallow soils and the shallow water table allow rapid infiltration of rainwater. In the calibrated model, recharge rates varied between 0.005 and 0.006 ft/day, or from 33 to 40 percent of the average precipitation rate.

Water level elevation data from five monitoring well locations were used to compare measured and simulated heads for calibration. The five selected locations were EPA 83-1, EPA 83-2, EPA 83-3, EPA 83-4, and EPA 83-7.

A'

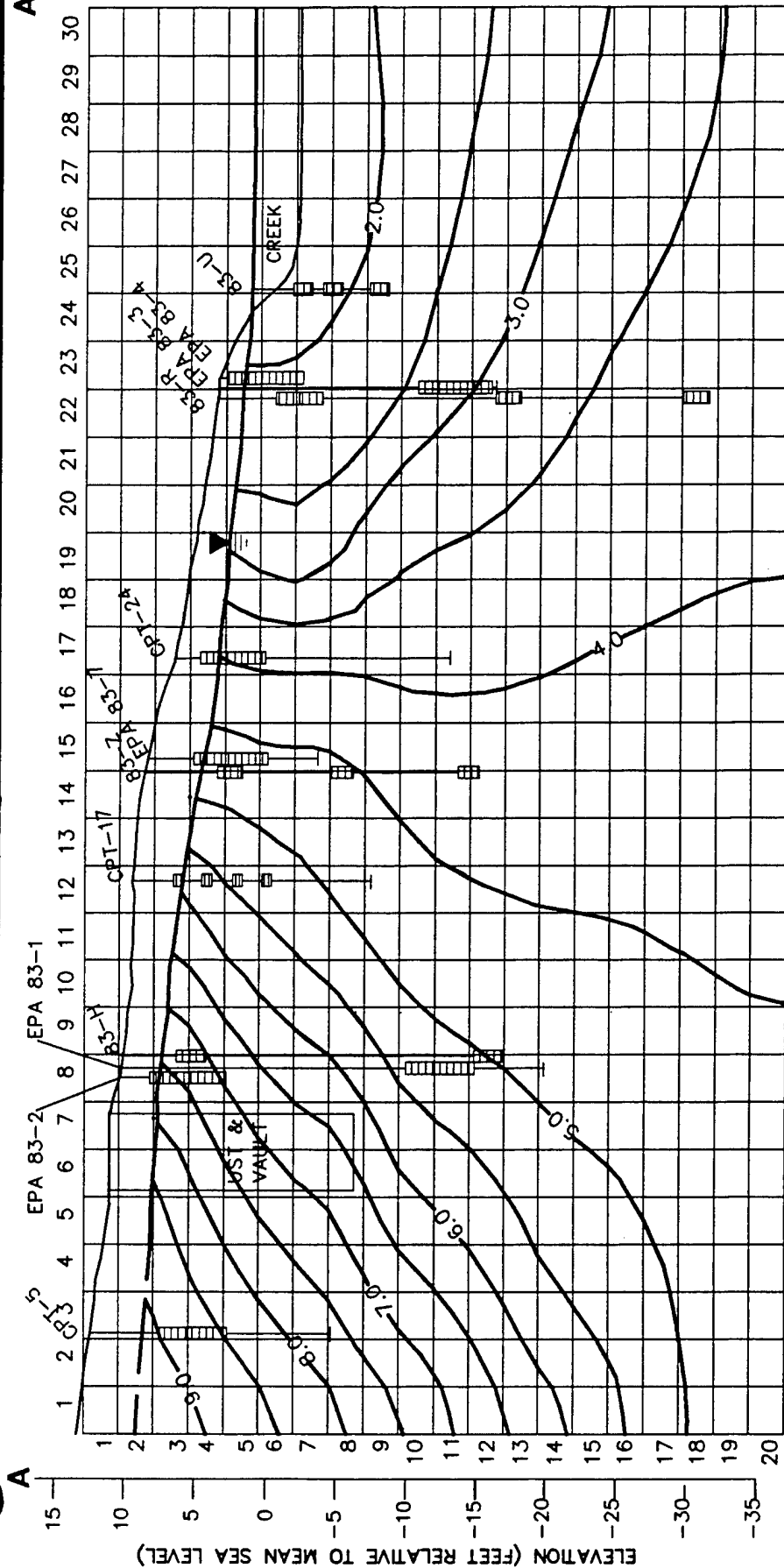


FIGURE 5.3

CALIBRATED MODEL HEADS

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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Contour Interval = 0.5 feet



VERTICAL EXAGGERATION = 5x

LEGEND

Borehole/Sampling location name

Borehole

Well screen or sampling interval

Bottom of borehole

Approximate water table
surface, September 1993
(Dashed where inferred)

Line of equal simulated
head (feet msl)

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

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

Where: n = the number of points where heads are being compared

h_m = measured head value

h_s = simulated head value.

The RMS error between observed and calibrated values at the 5 comparison points was 0.29 foot, which corresponds to a calibration error of 3.6 percent (water table elevations dropped about 8 feet over the length of the model grid). RMS error calculations are summarized in Appendix D.

In solving the groundwater flow equation, MODFLOW establishes the hydraulic head array 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 99.99 percent of the water flux into and out of the system being numerically accounted for (i.e., a 0.01-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.

5.4.2 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 September 1993. To do this, model runs were made using the calibrated steady-state hydraulic parameters. Calibration of the fate and transport portion of a model generally requires that the contaminant distribution be known for two different times. Contaminant data for the study area from 1993 and 1994 were available; in addition, it is known that the release of MOGAS happened before June 1988, or about 7 years before the 1993 data were collected.

Because local plume concentrations could be described at two different times (1993 and 1994), and because the MOGAS was released in 1988, the plume calibration

simulations were made with a time constraint of 7 years (an extra year was added to the calibration model in case new data from 1995 become available). In other words, computed BTEX plume concentrations and configurations were compared to September 1993 BTEX data after 5 years of simulation time incorporating introduction, transport, and degradation of contaminants in groundwater. In addition, the computed BTEX plume after 6 years of simulation time was compared to the data collected in October 1994.

The introduction of contaminants into site groundwater was simulated using two types of sources, as noted in Section 5.3.3. It was assumed that in the first 2 years of simulation time, contaminant loading rates would be the greatest, with the rates then diminishing through the remaining time steps. This was done to reflect the decrease in BTEX mass that could partition from mobile or residual LNAPL, as caused by dissolution, weathering, volatilization, and sorption onto site soils. As noted in Section 4.3.4.4, almost no BTEX remained in the residual LNAPL in the soil, except near the UST. This was considered when BTEX loading rates were reduced for each successive stress period, with the rates diminishing more rapidly away from the UST.

Starting total BTEX and concentrations for the injection wells and the recharge areas were initially determined by estimating the concentration necessary to give the water entering the system nearest the UST a total BTEX concentration of at least 130 mg/L [about the maximum BTEX concentration that could be expected in groundwater in contact with fresh MOGAS (American Petroleum Institute, 1985; Bruce *et al.*, 1991)]. These initial loading rates decreased gradually downgradient from the UST area. Much of the calibration then consisted of varying the injection concentrations (including decreasing the concentrations over time) for the various wells and the recharge concentrations until the modeled total BTEX plumes for 1993 and 1994 approximated the total BTEX plumes observed in September 1993 and October 1994. The biodegradation rate coefficient, the retardation coefficient, the effective porosity, and the dispersivity were also varied during the calibration process. By varying these parameters, the BTEX plume was calibrated to achieve the most comparable match between the observed and modeled plumes, in terms of plume extent and BTEX concentrations. The calibrated plume configurations for 1993 and 1994 are shown on Figures 5.4 and 5.5, respectively.

The calibrated model plumes are similar, but not identical, to the observed BTEX plumes (Figures 4.4 and 4.5). In both cases, the total areas of the simulated BTEX

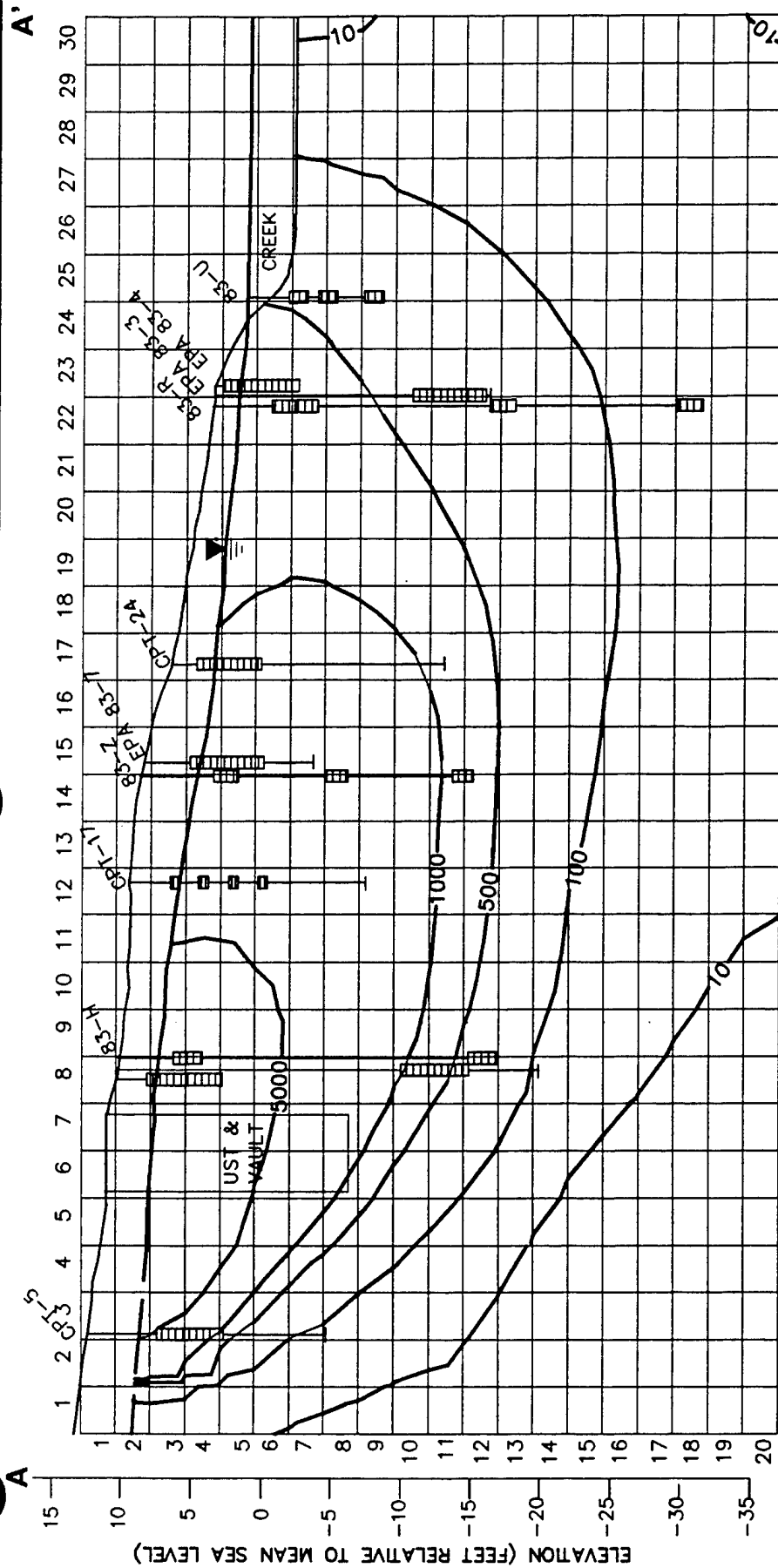


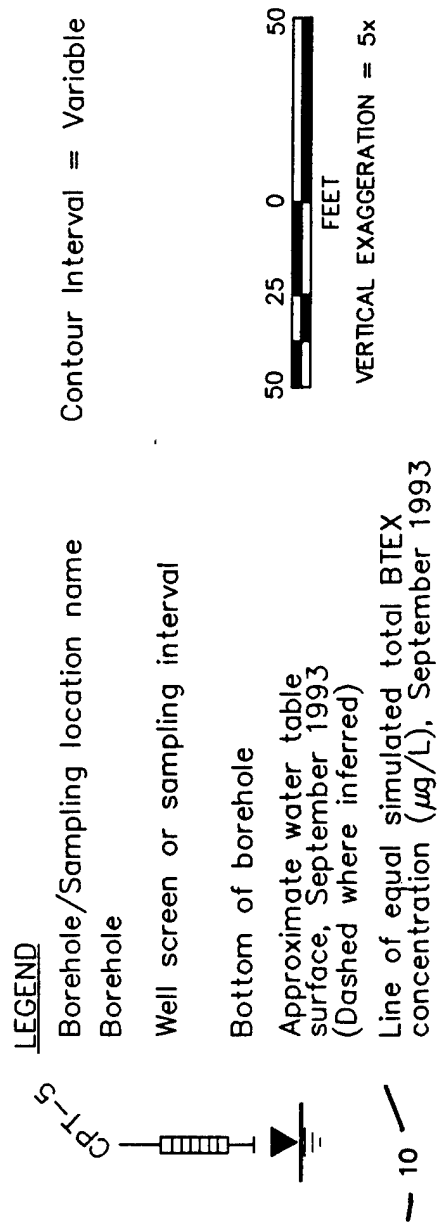
FIGURE 5.4

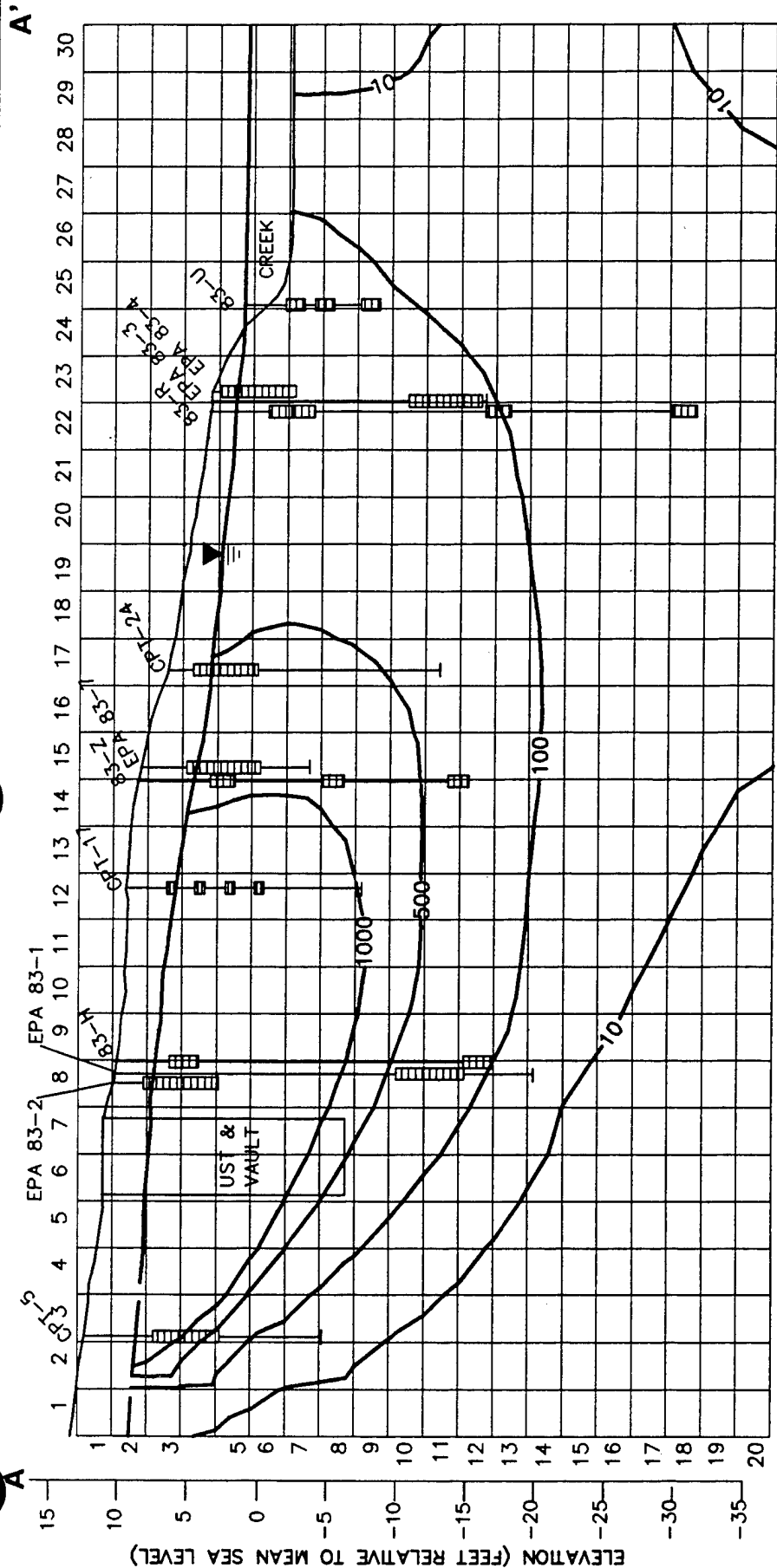
**CALIBRATED MODEL BTEX
CONCENTRATIONS FOR 1993
(T = 5 YEARS)**

**POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida**



Denver, Colorado





LEGEND

Borehole/Sampling location name

Borehole

Well screen or sampling interval

Bottom of borehole

Approximate water table surface, September 1993
(Dashed where inferred)

Line of equal simulated total BTEX concentration ($\mu\text{g/L}$), September 1994

Contour Interval = Variable



FEET

VERTICAL EXAGGERATION = 5x

FIGURE 5.5

CALIBRATED MODEL BTEX CONCENTRATIONS FOR 1994 (T = 6 YEARS)

POL Site SS-36

Intrinsic Remediation TS

Eglin Air Force Base, Florida



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plumes are greater than indicated by field data. For 1993, the simulated and observed 100- $\mu\text{g/L}$ isopleths (at depth) are similar in shape, and the simulated BTEX concentrations in the vicinity of the UST are similar to or greater than those observed at monitoring well EPA 83-2 and at Geoprobe[®] location 83-H. Near the source area, and in the shallow portions of the aquifer, the 1994 model plume has concentrations higher than those observed in 1994. For example, an area of 1,000- $\mu\text{g/L}$ concentrations is present near the UST (Figure 5.5), although concentrations that high were not observed.

For both the 1993 and the 1994 time steps, it was not possible to reproduce the decreasing BTEX concentrations in the shallow portion of the aquifer downgradient of CPT-17. The observed decreases are likely a result of the infiltration of precipitation charged with electron acceptors, which then stimulates biodegradation at a rate faster than observed in the main portion of the plume. In addition, the rapid decrease in BTEX concentrations observed at Geoprobe[®] sample location 83-U (near the bank of the creek) could not be reproduced. This rapid decrease is likely the result of mixing of the oxygenated surface water and the groundwater discharging to the creek, which apparently is stimulating rapid aerobic biodegradation of BTEX. These processes cannot be simulated with MT3D[®] and therefore, as noted above, the plumes were calibrated to match the extents of the isopleths in the deeper part of the plume, and to match or exceed the observed maximum BTEX concentrations.

As a result of the considerations noted in the preceding paragraphs, the computed contaminant distribution represents a greater total mass of BTEX because many concentrations are higher than those observed, and because the model cannot simulate the additional biodegradation in the vicinity of the creek and the water table in the downgradient portions of the plume. Because of this, and because the extents of the calibrated model BTEX plume are similar to the observed extents, the predictions made by this model should be conservative.

5.4.2.1 Discussion of Parameters Varied During Plume Calibration

As noted previously, the transport parameters varied during plume calibration were the coefficient of retardation, the dispersivity, the biodegradation rate constant, and the effective porosity. These parameters were varied with intent of reproducing plume migration to match the observed plume limits to the extent possible. While these parameters were varied with this common intent, each had a slightly different impact on

the size and shape of the simulated plume. BTEX loading rate also were varied, but they only control the mass of BTEX in the system and not the transport of that mass.

5.4.2.1.1 Dispersivity

Much controversy surrounds the concepts of dispersion and dispersivity. Longitudinal dispersivity values for sediments similar to those found at the site range from 0.1 to 200 feet (Walton, 1988). To be conservative, longitudinal dispersivity was originally estimated as 5 feet. Transverse and vertical dispersivity values generally are estimated as one-tenth (0.1) of the longitudinal dispersivity values (Domenico and Schwartz, 1990). During plume calibration, longitudinal dispersivity was increased to as much as 20 feet. This was done in an attempt to spread the computed plume margin (vertically) far enough to approximate the observed plume margin and also to help increase the longitudinal extent of the plume to better match the observed extent. However, altering this parameter did not have a significant effect on the plume configuration, so the original value of 5 feet was retained.

5.4.2.1.2 Biodegradation Rate Constant

As discussed in Section 5.3.5, the biodegradation rate constant was originally estimated to be 0.009 day^{-1} for dissolved BTEX and 0.007 day^{-1} for sorbed BTEX. These estimates were well-supported by the data from the microcosm study and by the calculations based on the field data. These values were varied slightly during plume calibration, but the calibrated model used the original estimates. This prevented the plume from migrating too far in the calibration run, and at the same time prevented contaminant concentrations in the source area and center of the plume from being excessively high.

5.4.2.1.3 Coefficient of Retardation

Calculation of coefficients of retardation for the BTEX compounds is discussed in Section 4.3.4.1, and the results of these calculations are summarized in Appendix C. To be conservative, the minimum range of retardation coefficients calculated for the BTEX compounds (1.42 to 3.25, for benzene) was used as a constraint for model input. The coefficient of retardation originally used as model input was 1.45. The lower the assumed coefficient of retardation, the farther the BTEX plume will migrate

downgradient. As with the biodegradation rate, this value was changed during the calibration process, but the final calibrated model used the original estimate of 1.45.

5.4.2.1.4 *Effective Porosity*

Effective porosity affects the calculation of the groundwater velocity, which governs the rate of contaminant migration. For previous calculations (e.g., of the groundwater velocity and the retardation coefficient), the effective porosity of aquifer materials at the site was estimated to be 0.30. However, during model calibration, the effective porosity was reduced to 0.20, producing faster groundwater and contaminant velocities. Making this change helped reproduce the observed plume extents, particularly in the downgradient portion of the model domain. When this change was made, model input was adjusted so that the retardation coefficient remained at 1.45.

5.5 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to determine the effect of varying model input parameters on model output. The sensitivity analysis for this model was conducted by varying hydraulic conductivity, the retardation coefficient, the effective porosity, dispersivity, the biodegradation rate constant, and the contaminant loading rates.

To perform the sensitivity analyses, individual runs of the plume calibration model were made with the same input as the calibrated model, except that one of the aforementioned parameters was varied. The models were run for a 7-year period, just as the original was, so that the independent effect of each variable could be assessed. Results from year 5 of these simulations (i.e., 1993) were compared to the calibrated model results for the same time step. A total of 12 sensitivity runs of the calibrated model were made, with the following variations:

- 1) Hydraulic conductivity uniformly increased by a factor of 5;
- 2) Hydraulic conductivity uniformly decreased by a factor of 5;
- 3) Retardation coefficient increased to 3.0;
- 4) Retardation coefficient decreased to 1.0;
- 5) Effective porosity increased to 0.30;
- 6) Effective porosity decreased to 0.10;
- 7) Dispersivity values increased by a factor of 2;

- 8) Dispersivity values decreased by a factor of 2;
- 9) Biodegradation rate constant doubled;
- 10) Biodegradation rate constant halved;
- 11) Loading rates decreasing more slowly; and
- 12) Loading rates decreasing more rapidly.

The results of the sensitivity analyses are shown graphically on Figures 5.6, 5.7, 5.8, 5.9, 5.10, and 5.11. These figures display the modeled BTEX concentrations versus distance along a line that roughly describes a flow path starting at a cell the UST area, curving down through the aquifer, and ending at a cell just below the creek. This manner of displaying data is useful because the path roughly follows the centerline of the modeled plume. Furthermore, the figures allow easy visualization of the changes in BTEX concentration caused by varying model input parameters.

The effects of varying hydraulic conductivity are shown on Figure 5.6. Uniformly increasing the hydraulic conductivity by a factor of five spread out the plume such that the maximum observed concentrations in the source area were only about one-third of the calibrated maximum, while concentrations downgradient were two to three times greater. In contrast, decreasing the hydraulic conductivity by a factor of five slowed overall plume migration, which shortened the plume and in turn caused an increase in maximum BTEX levels. Increased BTEX concentrations in the source area are caused by reductions in the plume travel rate, and by the decreased downgradient migration of the plume.

The effects of varying the retardation coefficient (R) are shown on Figure 5.7. Increasing R to 3.00 results in the maximum BTEX concentration decreasing by approximately 1,500 $\mu\text{g/L}$, and the concentrations throughout the plume are two to three times lower than in the calibrated model. On the other hand, decreasing R to 1.00 (no retardation) produces a plume with concentrations up to 750 $\mu\text{g/L}$ greater than in the calibrated plume, although the concentration differences decrease along the flow path. These results suggest that the R used for the calibrated simulation is acceptable, because higher values of R will result in concentrations that are lower than observed, especially as the plume nears the creek. Lower values of R will result in concentrations greater than observed, particularly in the source area.

Figure 5.8 shows the effects of varying the effective porosity. Increasing this parameter to 0.30 results in the BTEX concentrations increasing slightly throughout the plume. This apparent increase in contaminant mass is the result of the decrease in

Concentration Distribution for Various Values of Hydraulic Conductivity

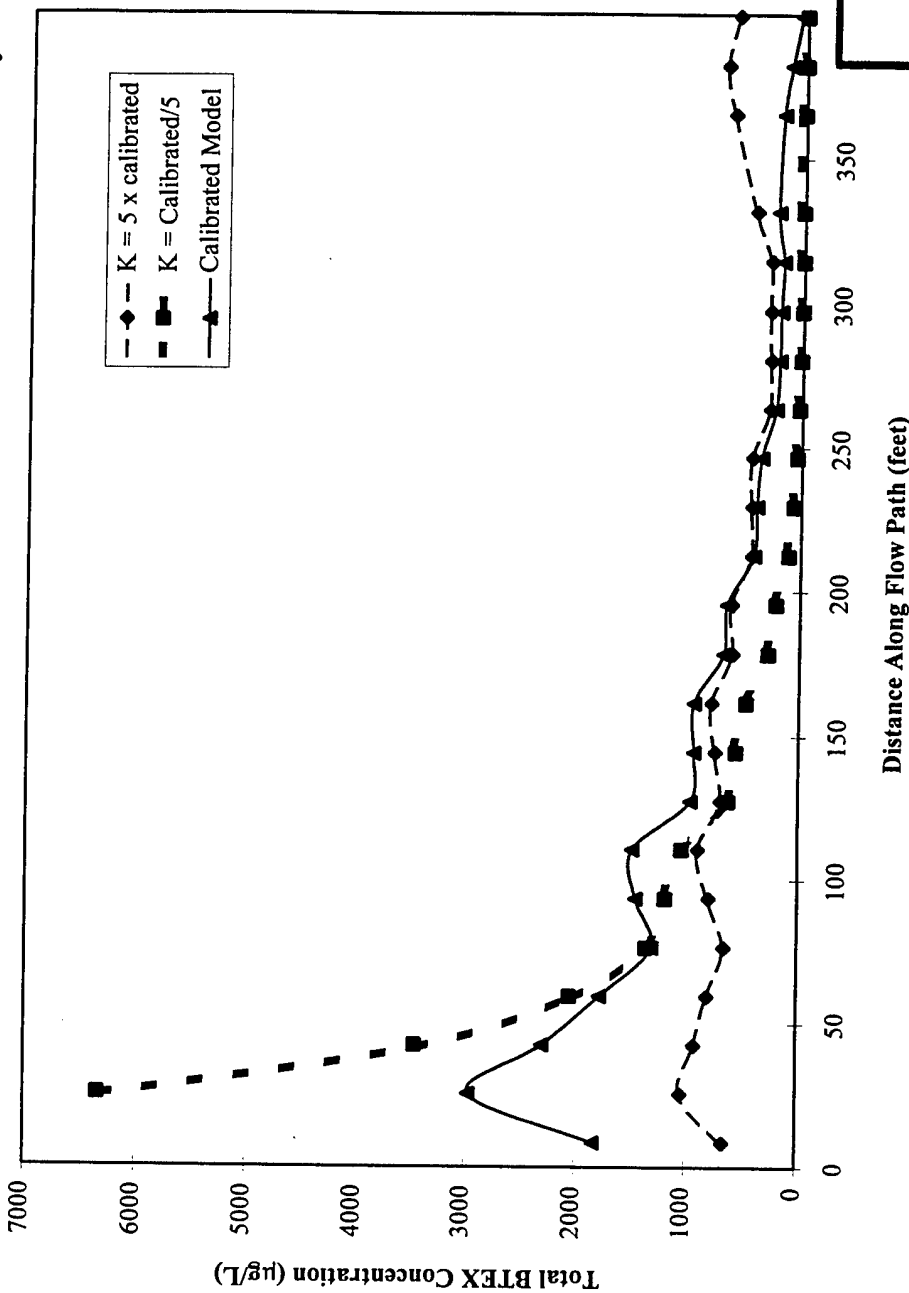


FIGURE 5.6

MODEL SENSITIVITY TO VARIATIONS IN HYDRAULIC CONDUCTIVITY

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



Denver, Colorado

Concentration Distribution for Various Values of the Retardation Coefficient

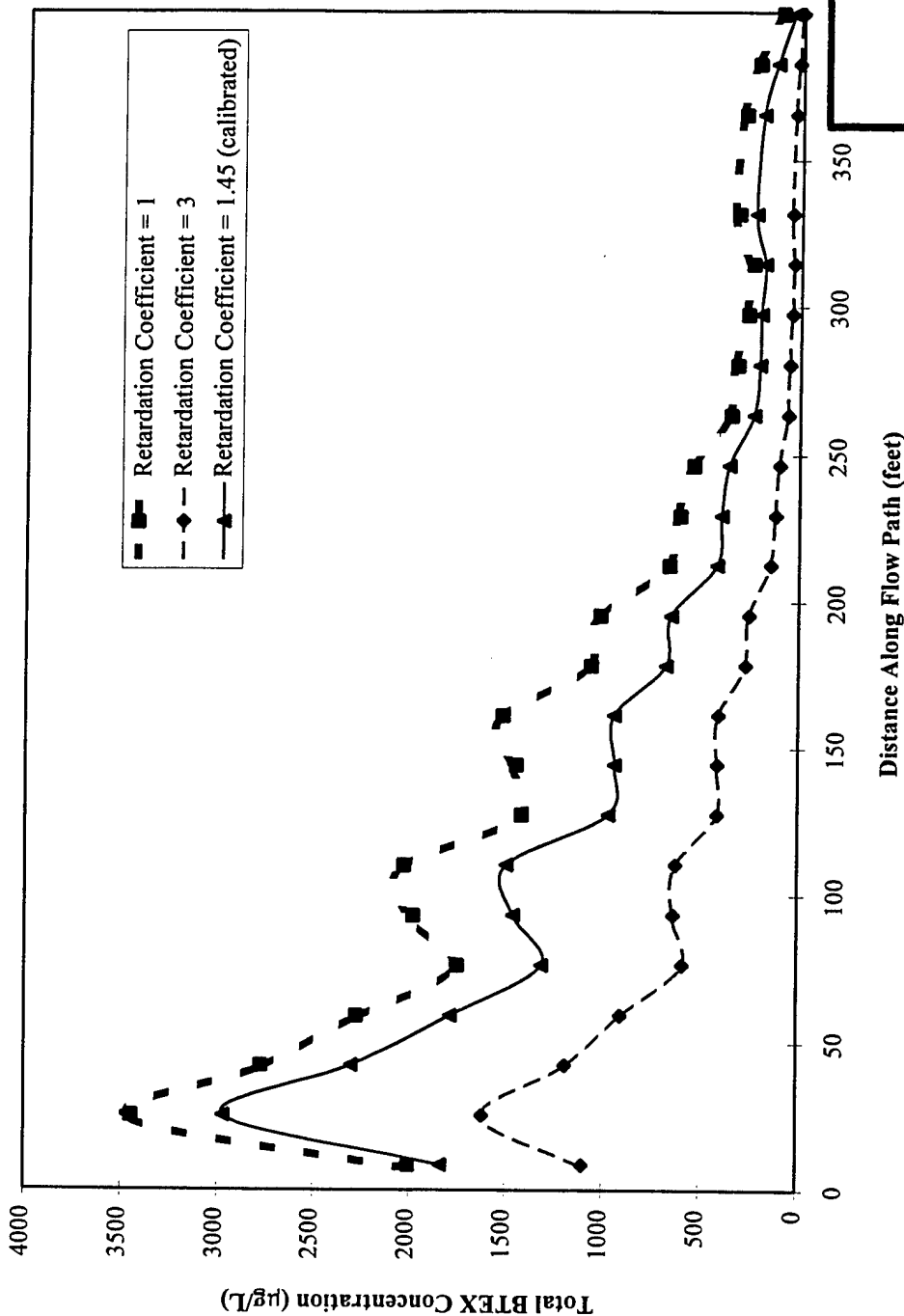


FIGURE 5.7

MODEL SENSITIVITY TO VARIATIONS IN THE RETARDATION COEFFICIENT

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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Concentration Distribution for Various Values of Effective Porosity

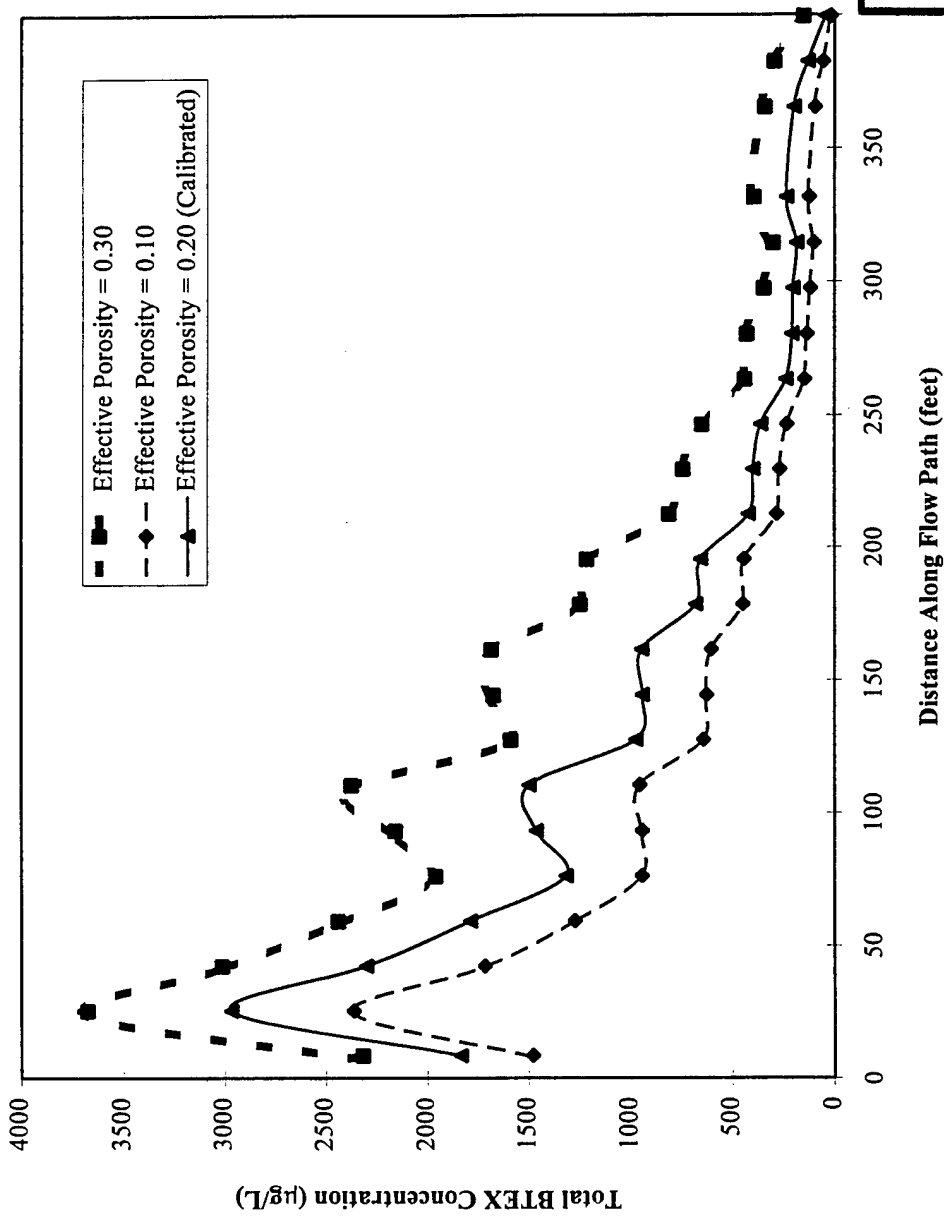


FIGURE 5.8

MODEL SENSITIVITY TO VARIATIONS IN EFFECTIVE POROSITY

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

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Concentration Distribution for Various Values of Dispersivity

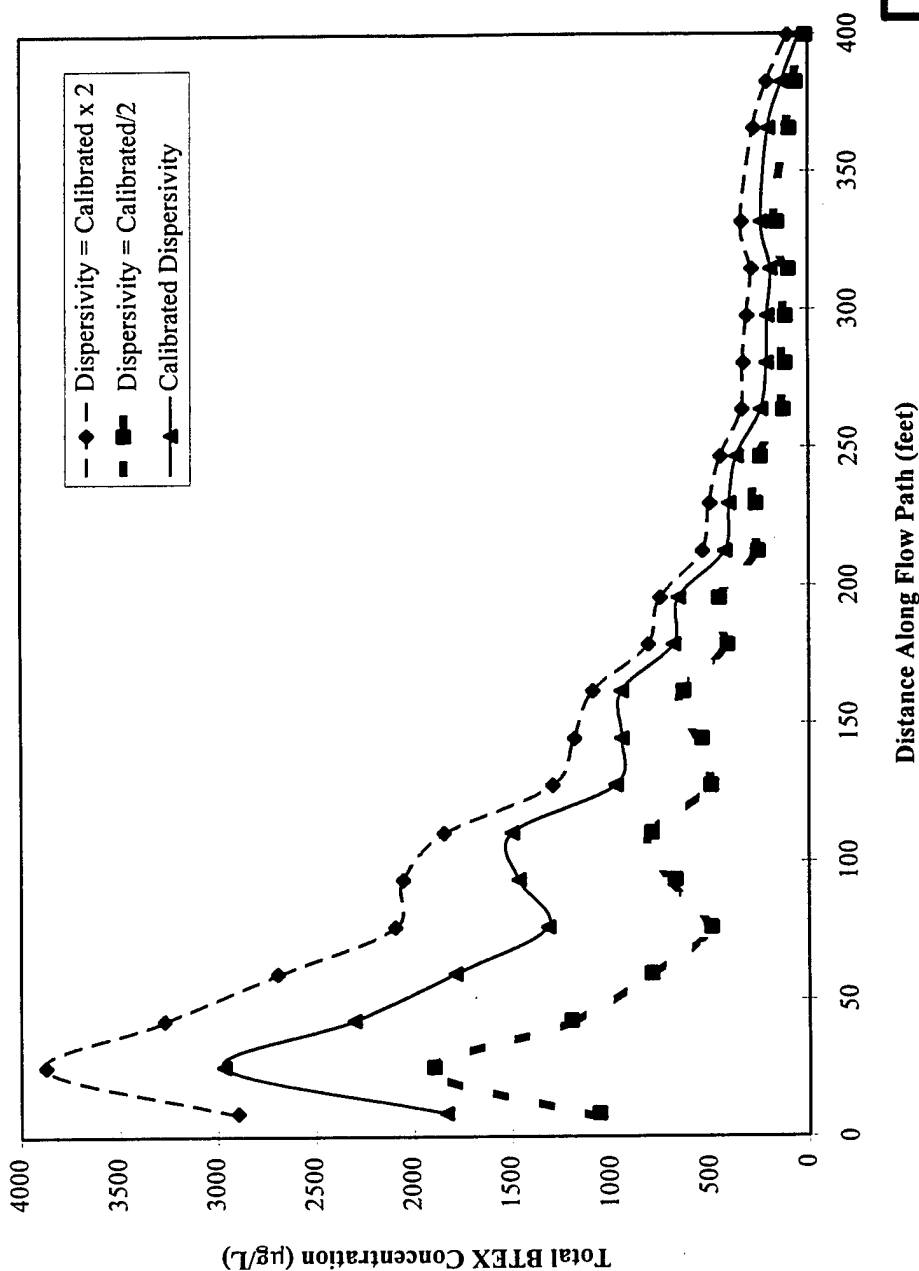


FIGURE 5.9

MODEL SENSITIVITY TO VARIATIONS IN DISPERSIVITY

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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Concentration Distribution for Various Values of the Biodegradation Rate Constant

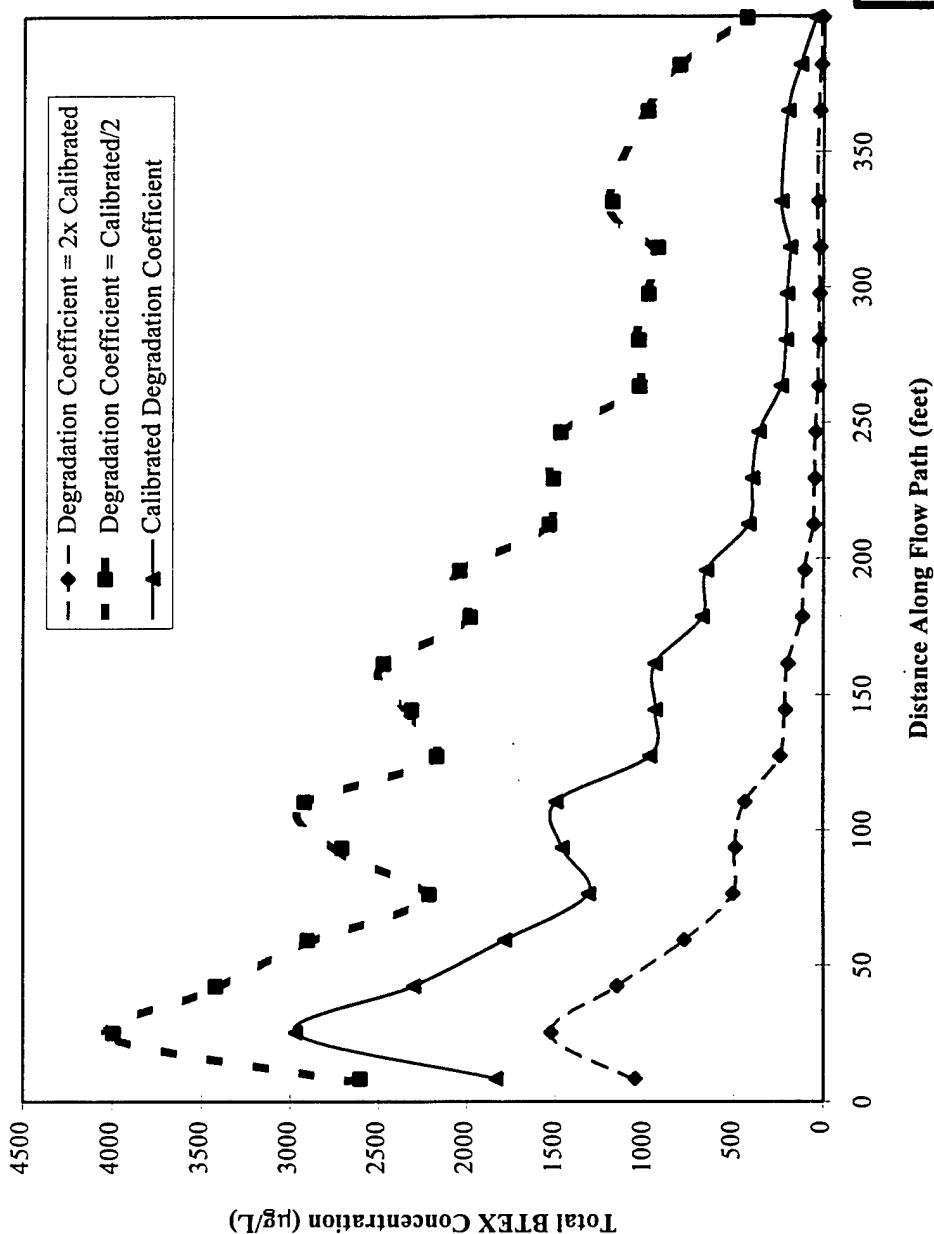


FIGURE 5.10

MODEL SENSITIVITY TO
VARIATIONS IN THE
BIODEGRADATION RATE CONSTANT

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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Concentration Distribution for Various Source Loading Rates

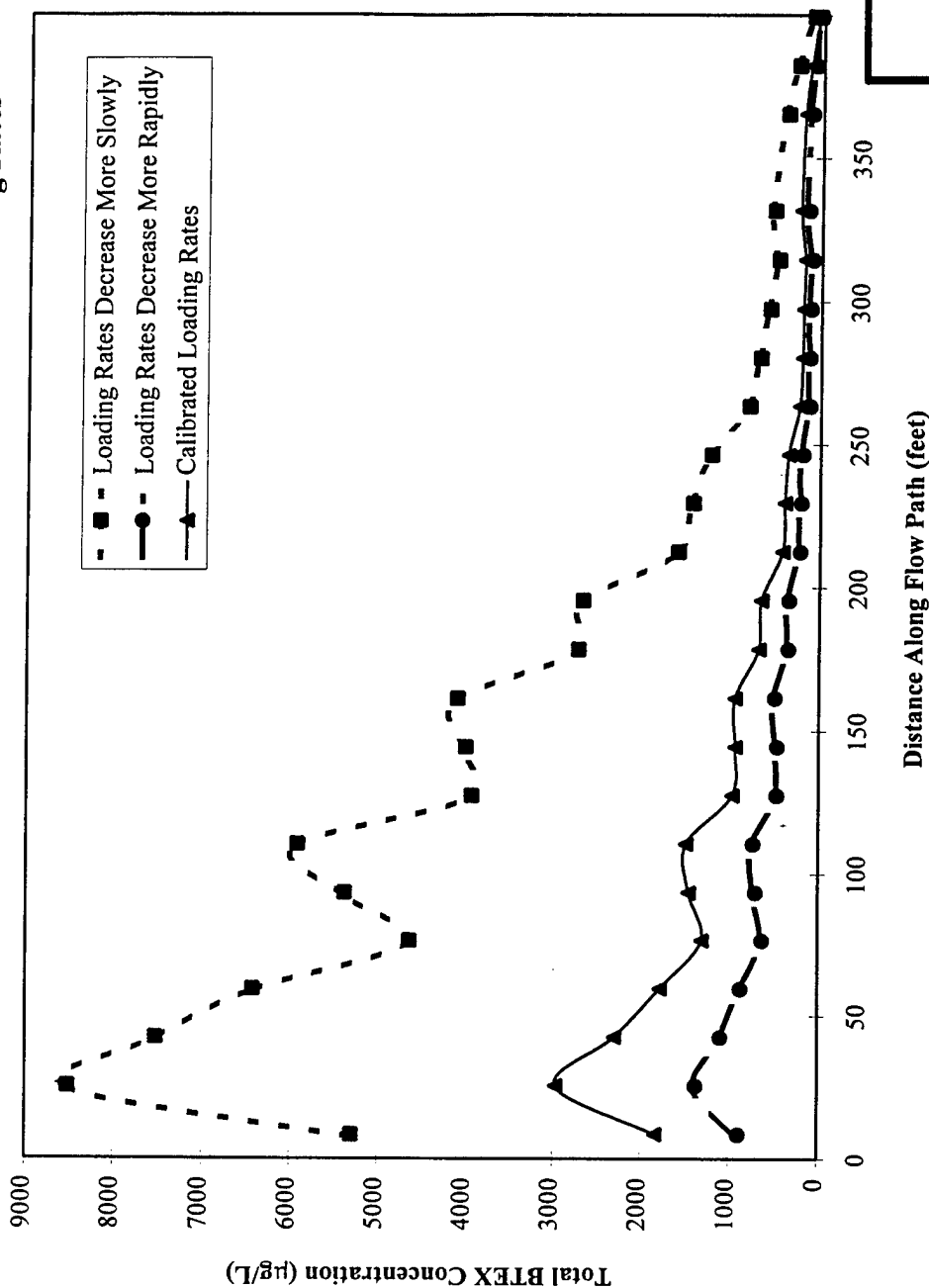


FIGURE 5.11

MODEL SENSITIVITY TO VARIATIONS IN THE SOURCE LOADING RATES

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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the groundwater velocity, which slows migration and plume spreading. Conversely, decreasing the effective porosity increases the groundwater velocity, speeding up the BTEX migration and spreading and resulting in a slight apparent decrease of the computed BTEX concentrations. The model is moderately insensitive to this coefficient.

The effects of varying dispersivity are illustrated on Figure 5.9. Both longitudinal and vertical dispersivity were varied for this analysis, as the ratio of the two values was kept constant at 0.10. Increasing the dispersivity by a factor of two resulted in BTEX concentrations decreasing by one-half to two-thirds throughout the plume. Decreasing dispersivity by a factor of two produced a plume with an extent similar to the calibrated plume, but with concentrations about one-fourth to one-third again as great as those in the calibrated model. The model appears to be moderately sensitive to dispersivity within the range of reasonable values evaluated for this analysis.

The effects of varying the biodegradation rate constant (for the dissolved BTEX only) are illustrated on Figure 5.10. Doubling this parameter halves BTEX concentrations in the source area, and further downgradient the concentrations are even smaller fractions of those observed in the calibrated model. Conversely, decreasing the biodegradation rate constant by a factor of two increases BTEX concentrations throughout the model by at least 1,000 $\mu\text{g/L}$. Therefore, the model is quite sensitive to this parameter, suggesting that an appropriate value was used for the calibrated model.

Changes in BTEX concentrations due to variations in the rate at which BTEX is introduced to the groundwater are illustrated on Figure 5.11. When loading rates decrease more slowly than in the calibrated model, concentrations are much higher, particularly in the source area. If loading rates are reduced more rapidly, the concentrations are lower in the source area and through the central portion of the plume, but are similar in the downgradient portion of the plume. This indicates that the loading rates and the changes in those rates in the calibrated model are reasonable. Slowing the decrease in the rates would yield concentrations much higher than in the calibrated model. A faster decrease would yield lower concentrations, although the differences would not be as drastic as for the other case.

The results of the sensitivity analysis suggest that the calibrated model used for this report is reasonable. The calibrated model is most sensitive to hydraulic conductivity, the biodegradation rate constant, and the changes in the BTEX loading rates. It is moderately sensitive to moderately insensitive to the other parameters tested. Increasing the

biodegradation rate constant or the hydraulic conductivity greatly diminishes the predicted BTEX concentrations. Lowering the values of the same parameters increases concentrations to beyond reasonable values. If contaminant loading rates decrease more slowly than in the calibrated model, modeled BTEX concentrations will be unrealistically high. While the model is less sensitive to dispersivity, effective porosity, and the retardation coefficient, adjustment of those parameters contributed toward producing an appropriate plume configuration.

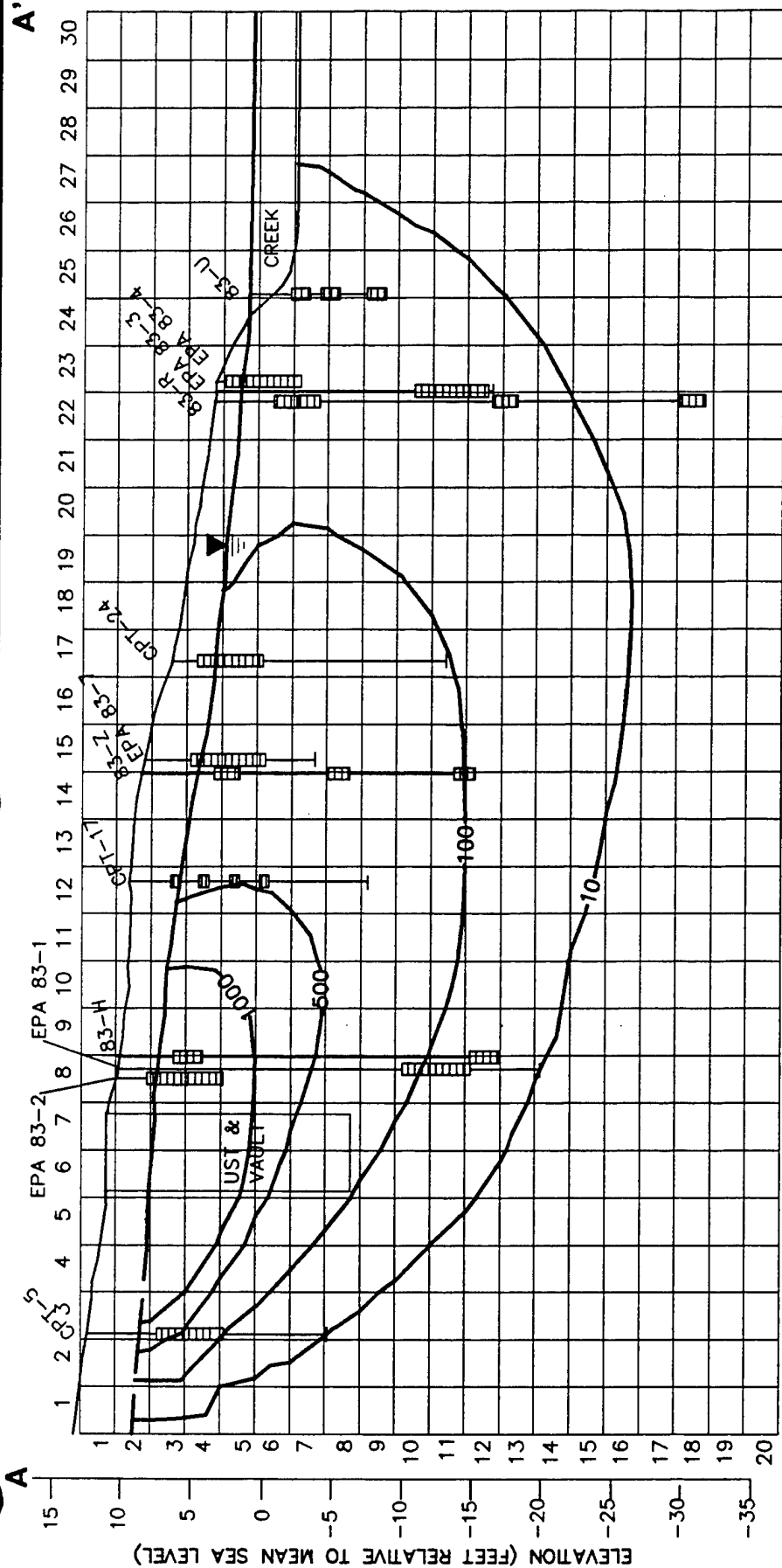
5.6 MODEL RESULTS

To predict fate and transport of dissolved BTEX compounds at the study site, three MODFLOW/MT3D[®] simulations (PREDICT1, PREDICT2, and PREDICT3) were run under different sets of conditions. The first simulation (PREDICT1) was based on the assumption that the conditions that produced the calibrated model remain constant, including the rates at which BTEX were introduced to the aquifer in year 6 (1994) of the calibrated model. The second simulation (PREDICT2) incorporated a reduction in BTEX loading rates based on the assumption that the source areas would continue to weather, and that BTEX loading rates would decrease to zero after a period of 5 years (i.e., with no BTEX introduced after the year 2000). PREDICT3, the third simulation, assumed that loading rates everywhere decrease to zero by the end of 1995. In all cases, the simulation was run for 37 total years, so that results were available through the year 2025 (i.e., 30 years beyond the present). Complete input and output files are presented in Appendix D. Model results are described in the following sections.

5.6.1 Continuation of Calibrated Conditions (Model PREDICT1)

Model PREDICT1 was used to simulate the migration and biodegradation of the BTEX plume assuming that the conditions that produced the calibrated model continue, including continuing loading of dissolved BTEX compounds at the same rates as for year 6 (1994) of the calibrated model. This model does not account for additional physical and microbial weathering of the residual product remaining in site soils. Therefore, the results of this simulation provide a very conservative prediction of plume migration.

Figure 5.12 shows the predicted plume for Fall 1997 (after 3 additional years of simulation time). Modeled BTEX concentrations are slightly less than indicated for 1994



LEGEND

Borehole/Sampling location name

Borehole

Well screen or sampling interval

Bottom of borehole

Approximate water table surface, September 1993 (Dashed where inferred)

Line of equal simulated total BTEX concentration ($\mu\text{g/L}$), Fall 1997

Contour Interval = Variable



VERTICAL EXAGGERATION = 5x

FIGURE 5.12

PREDICTED BTEX CONCENTRATIONS FOR 1997 MODEL PREDICT1

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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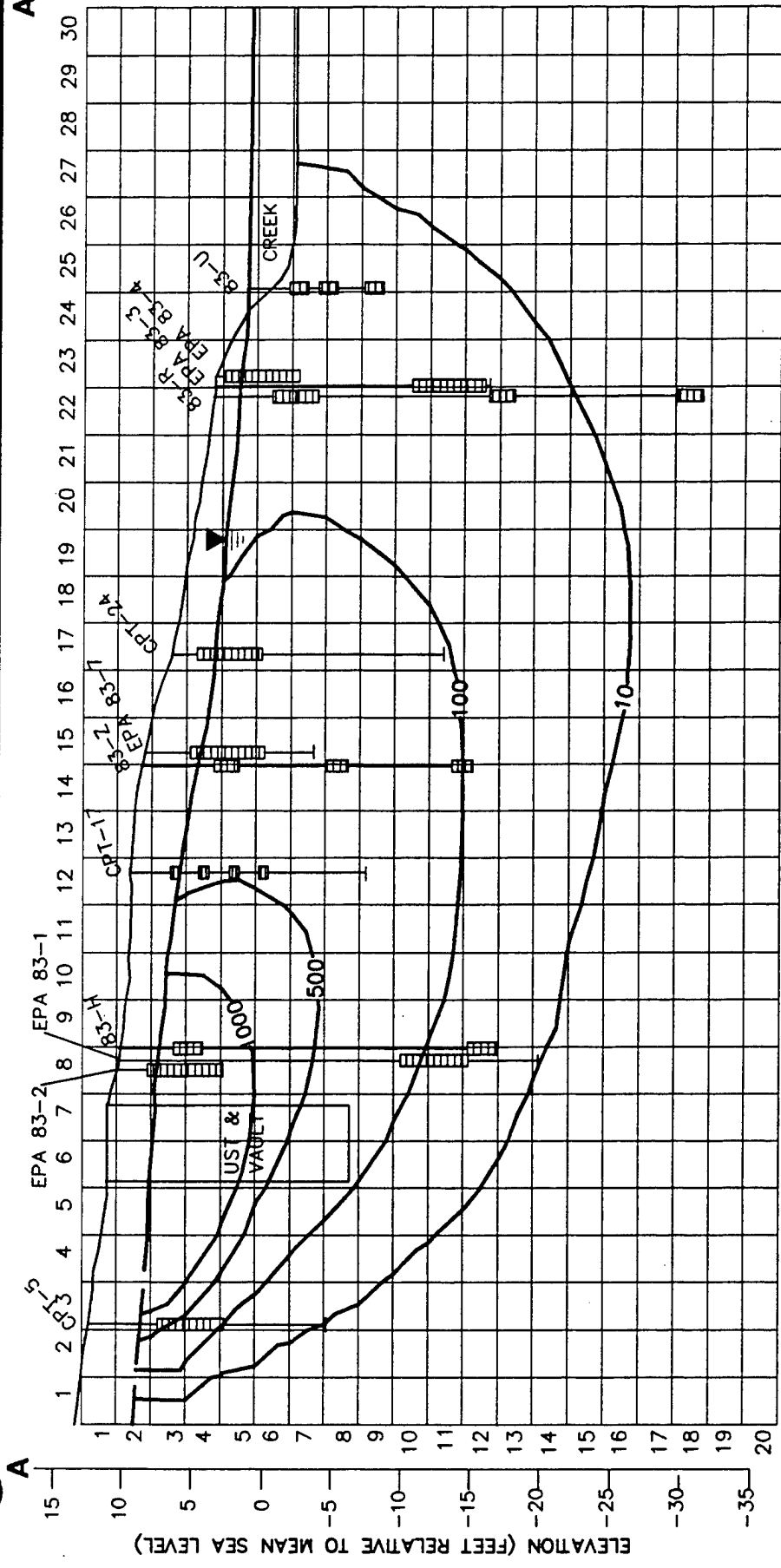
in the calibrated model (Figure 5.5). In addition, the plume shrinks compared to that simulated for Fall 1994, as indicated by the positions of all of the isopleths. For model year 2025, after an additional 28 years of simulation time (Figure 5.13), the maximum simulated BTEX concentration is 8,677 $\mu\text{g/L}$, and the plume configuration is nearly identical to that predicted for 1996. Beyond 1996, the modeled plume stabilizes, with a configuration similar to those shown in Figures 5.12 and 5.13. After the plume stabilizes, the maximum concentration (in the source area) is about 8,700 $\mu\text{g/L}$. Downgradient, concentrations immediately beneath the creek range from 0.4 to 52 $\mu\text{g/L}$.

These results suggest that the observed BTEX plume should stabilize within 2 to 4 years, assuming that contaminants are continually introduced. Stabilization of a plume reflects a configuration in which the downgradient portion of the plume is attenuated by biodegradation, dispersion, and sorption, but BTEX is replenished from the upgradient source at a rate sufficient to keep the plume front in a relatively stationary position. In actuality, as the residual hydrocarbons in the source area continue to weather and degrade, BTEX loading rates would decrease and the plume would eventually recede after reaching its maximum extent (unless a new source of hydrocarbons is introduced). In addition, these results suggest that even under this worst-case scenario, BTEX concentrations potentially reaching the creek would be lower than those observed in 1993, and so it is unlikely that BTEX would be detected in surface water samples.

5.6.2 Gradual Source Weathering (Model PREDICT2)

Although some residual hydrocarbons remain below the water table and continue to act as a source of dissolved BTEX, evidence presented in Section 4.3.4.4 indicates that the residual LNAPL is severely weathered and the very little BTEX remains in the LNAPL. To illustrate the impact of continued source weathering upon dissolved BTEX migration, model PREDICT2 incorporated continued gradual decreases in BTEX loading rates, assuming that for 5 years after the end of the calibrated model, all BTEX loading rates would remain constant, then decrease to zero (i.e., by 2000, loading rates become zero). This time frame was selected by plotting the dissolved BTEX concentrations measured at well EPA 83-2 and Geoprobe® sample location 83-H-1 (i.e., the sampling locations closest to the source area), and projecting when these concentrations would drop to zero. These plots are presented in Appendix D. Both linear and semi-logarithmic plots were prepared; the linear plot indicates that BTEX loading should have been zero prior to 1994, while the semi-log plot indicates that it would take another 6 to 7 years for

A'



LEGEND

- Borehole/Sampling location name
- Borehole
- Well screen or sampling interval
- Bottom of borehole
- Approximate water table surface, September 1993 (Dashed where inferred)
- Line of equal simulated total BTEX concentration ($\mu\text{g/L}$), Fall 2025
- Contour Interval = Variable
- 50 25 0 50
FEET
VERTICAL EXAGGERATION = 5x

FIGURE 5.13

**PREDICTED BTEX
CONCENTRATIONS FOR 2025
MODEL PREDICT1**

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

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Denver, Colorado

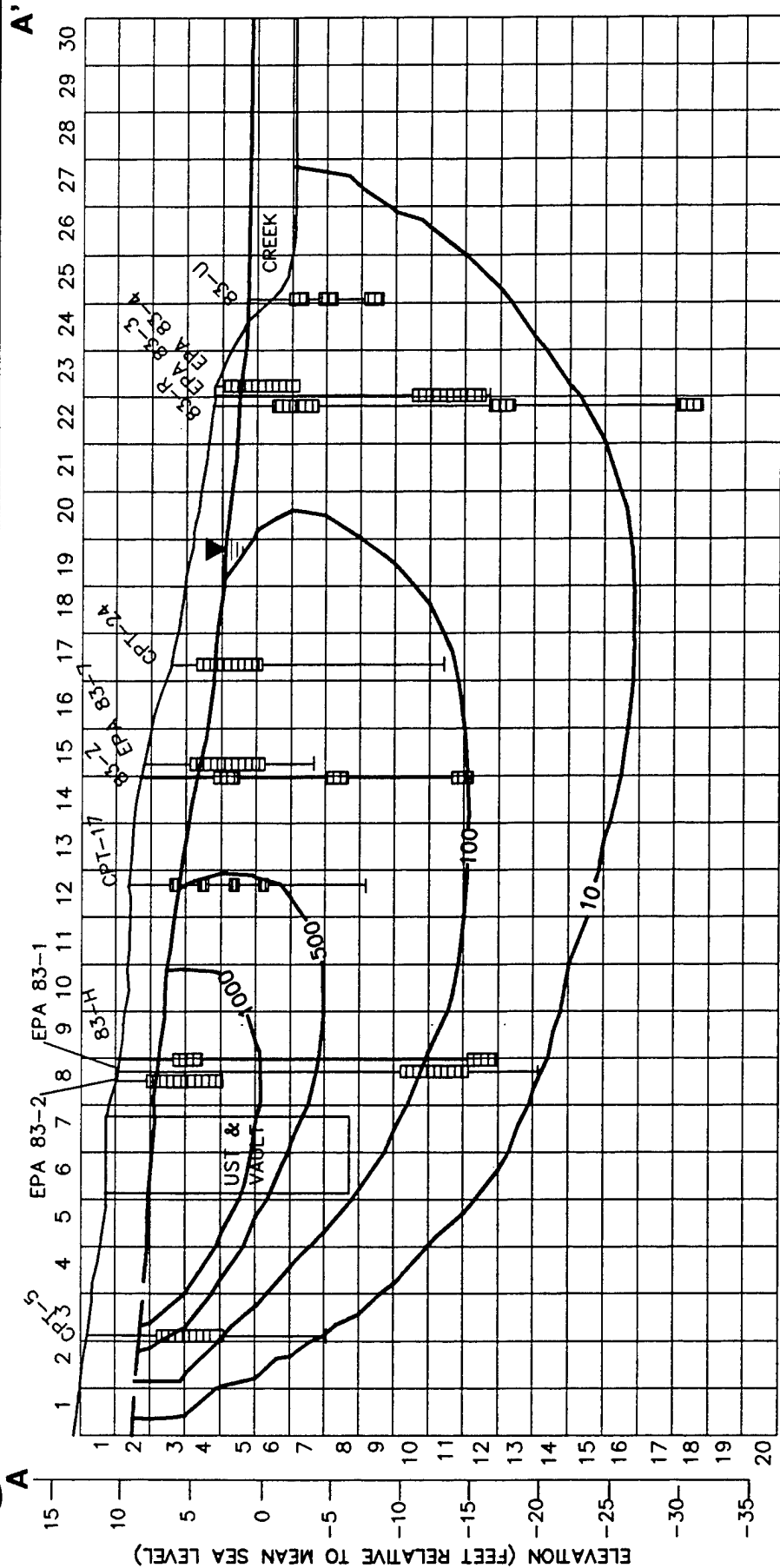
BTEX dissolution to cease. Therefore, to be conservative (although not overly so), it was assumed that it would take 6 years beyond 1994 (i.e., after the year 2000) for loading rates to drop to zero.

Like PREDICT1, this simulation was run to predict BTEX transport until the year 2025. Figures 5.14, 5.15, and 5.16 show the results of this model for the years 1997, 2001, and 2003, respectively. Results for this case suggest that dissolved BTEX concentrations will continue to decrease relatively rapidly, and the plume will gradually shrink until sometime in the year 2004, at which point the model suggests that there will be no BTEX compounds remaining in the shallow groundwater (assuming that no new BTEX contamination will enter this site from upgradient sources in the POL Yard).

Figure 5.14 shows the computed plume configuration for 1997, or after 9 years of total simulation time. The highest simulated BTEX concentration in the UST area is about 7,200 $\mu\text{g/L}$. The plume extents predicted for this time step are smaller than those observed in 1994. Figure 5.15 shows the computed plume configuration 4 years later, or for the year 2001. The computed BTEX plume continues to shrink, and the maximum BTEX concentration in the UST area decreases to 5,400 $\mu\text{g/L}$. As time passes, the BTEX plume continues to shrink and concentrations continue to decrease. Figure 5.16 shows the predicted plume configuration 15 years after the spill, or in the year 2003. Dissolved BTEX compounds are only present in the vicinity of the Building 763 source area, with a maximum concentration of about 140 $\mu\text{g/L}$. Beyond the year 2003, the model predicts that all dissolved BTEX will have been eliminated by natural attenuation processes.

5.6.3 Rapid Source Weathering (Model PREDICT3)

As noted above, a linear plot of dissolved BTEX concentrations versus time for the source area suggested that BTEX loading rates would be zero beyond 1994. Model PREDICT3 was run to illustrate this scenario, which is the least conservative of the three scenarios modeled for this site. For this simulation, BTEX loading rates were reduced to zero immediately after the 1994 time step. As before, the model was run to observe plume migration until the year 2025. Simulated BTEX concentrations for this model rapidly decrease, and the plume retreats rapidly. Predicted plumes for 1997 and 1998 are illustrated on Figures 5.17 and 5.18, respectively. For the 1999 time step, predicted concentrations all were zero.



LEGEND

Borehole/Sampling location name

Borehole

Well screen or sampling interval

Bottom of borehole

Approximate water table surface, September 1993 (Dashed where inferred)

Line of equal simulated total BTEX concentration (µg/L), Fall 1997

Contour Interval = Variable



VERTICAL EXAGGERATION = 5x

FIGURE 5.14

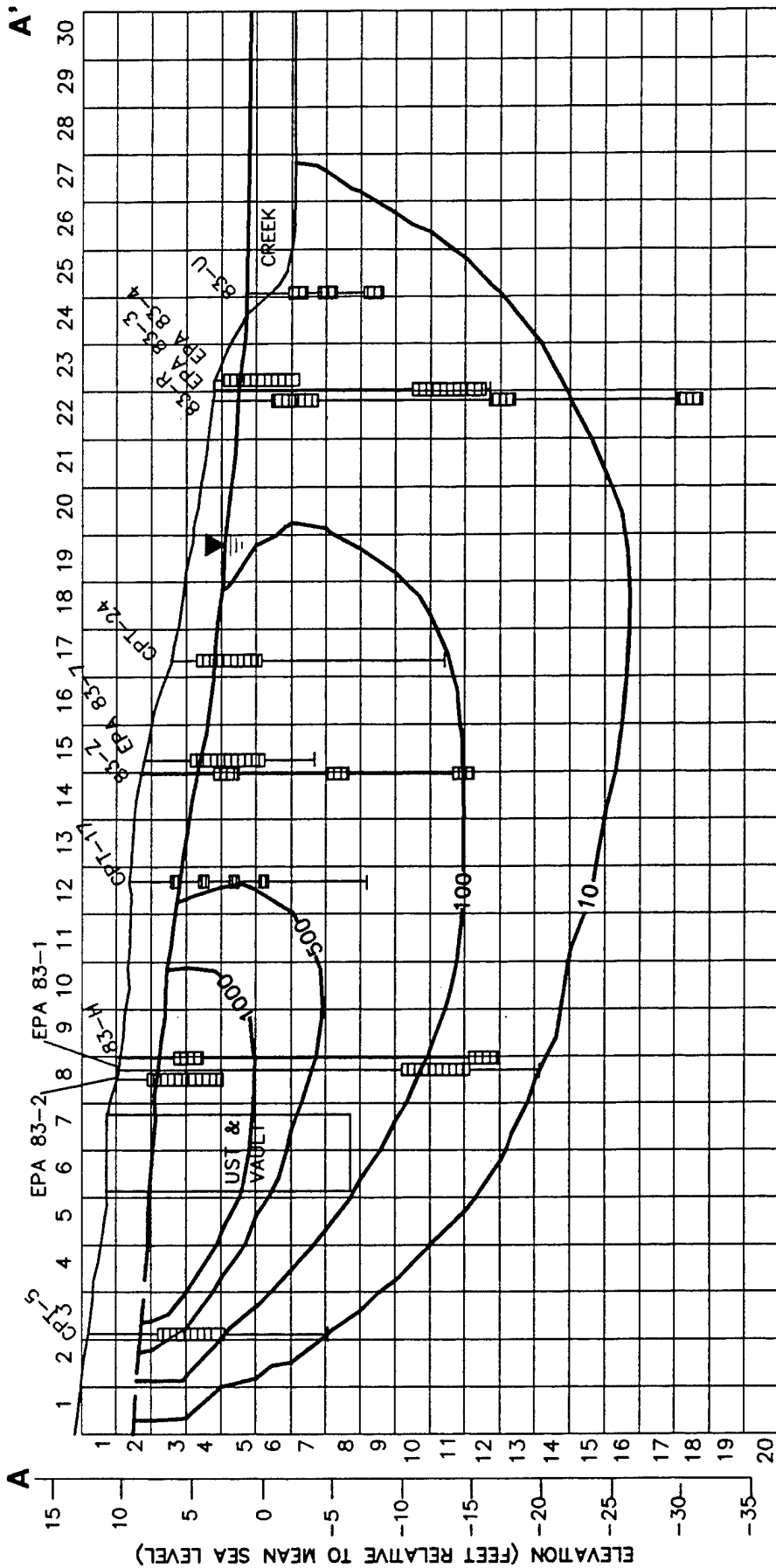
**PREDICTED BTEX
CONCENTRATIONS FOR 1997
MODEL PREDICT2**

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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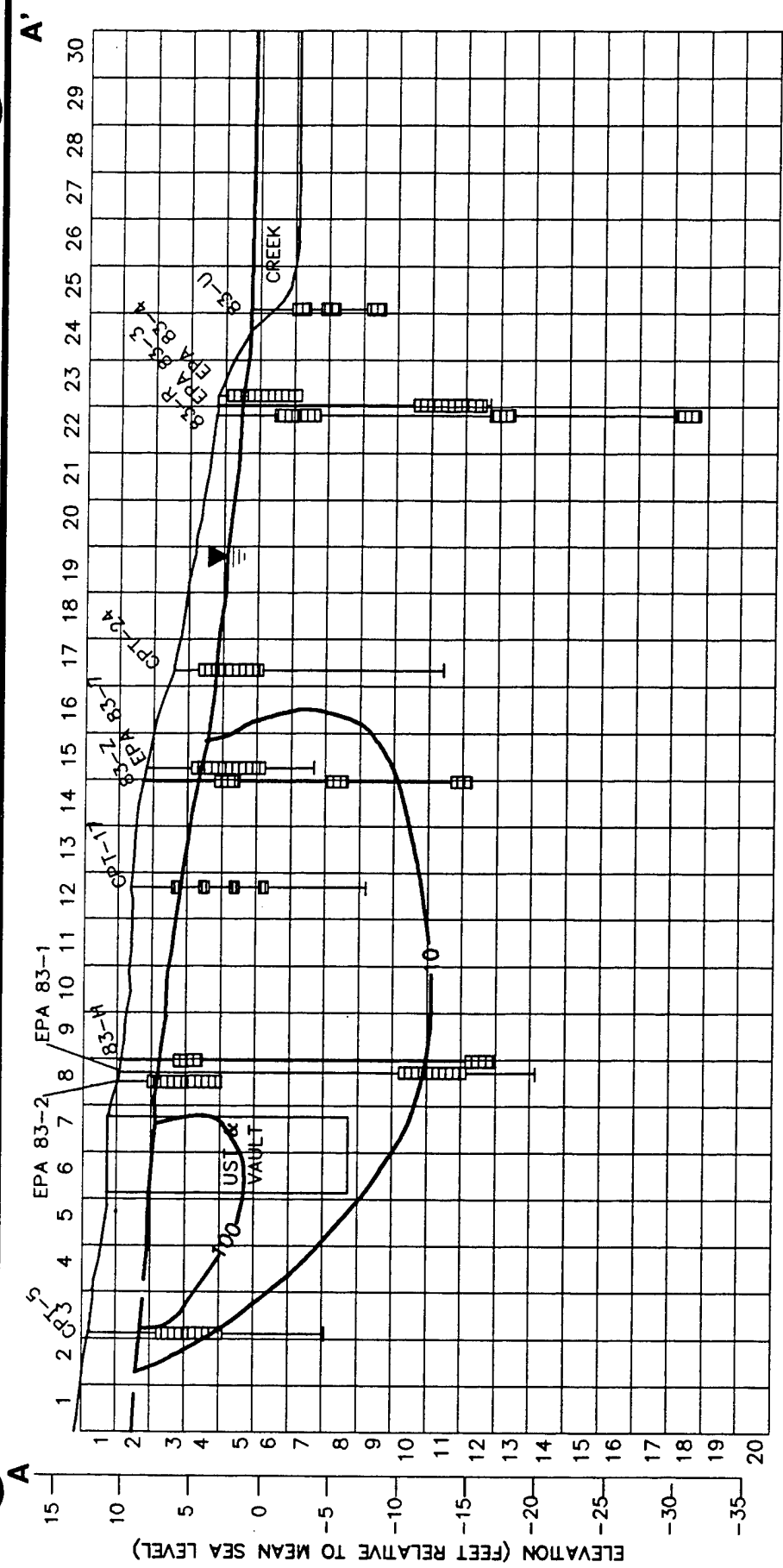


FIGURE 5.16

PREDICTED BTEX CONCENTRATIONS FOR 2003 MODEL PREDICT2

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida

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Contour Interval = Variable

Borehole/Sampling location name

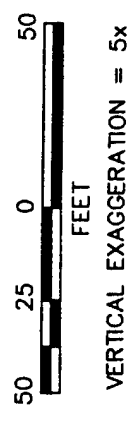
Borehole

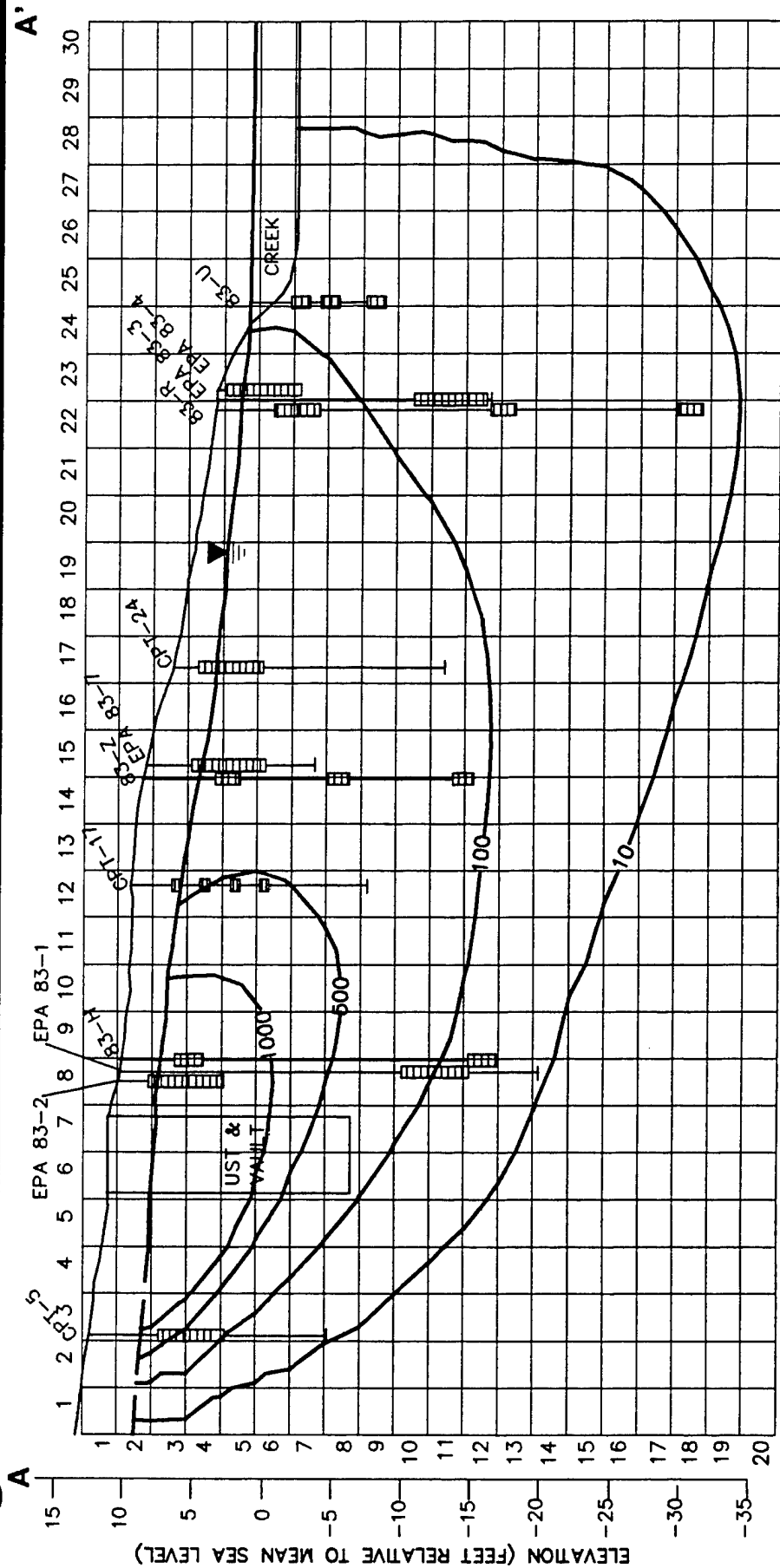
Well screen or sampling interval

Bottom of borehole

Approximate water table
surface, September 1993
(Dashed where inferred)

Line of equal simulated total BTEX
concentration (µg/L), Fall 2003





LEGEND

Borehole/Sampling location name

Borehole

Well screen or sampling interval

Bottom of borehole

Approximate water table surface, September 1993 (Dashed where inferred)

Line of equal simulated total BTEX concentration ($\mu\text{g/L}$), Fall 1997

Contour Interval = Variable



VERTICAL EXAGGERATION = 5x

FIGURE 5.17

PREDICTED BTEX CONCENTRATIONS FOR 1997 MODEL PREDICT3

POL Site SS-36

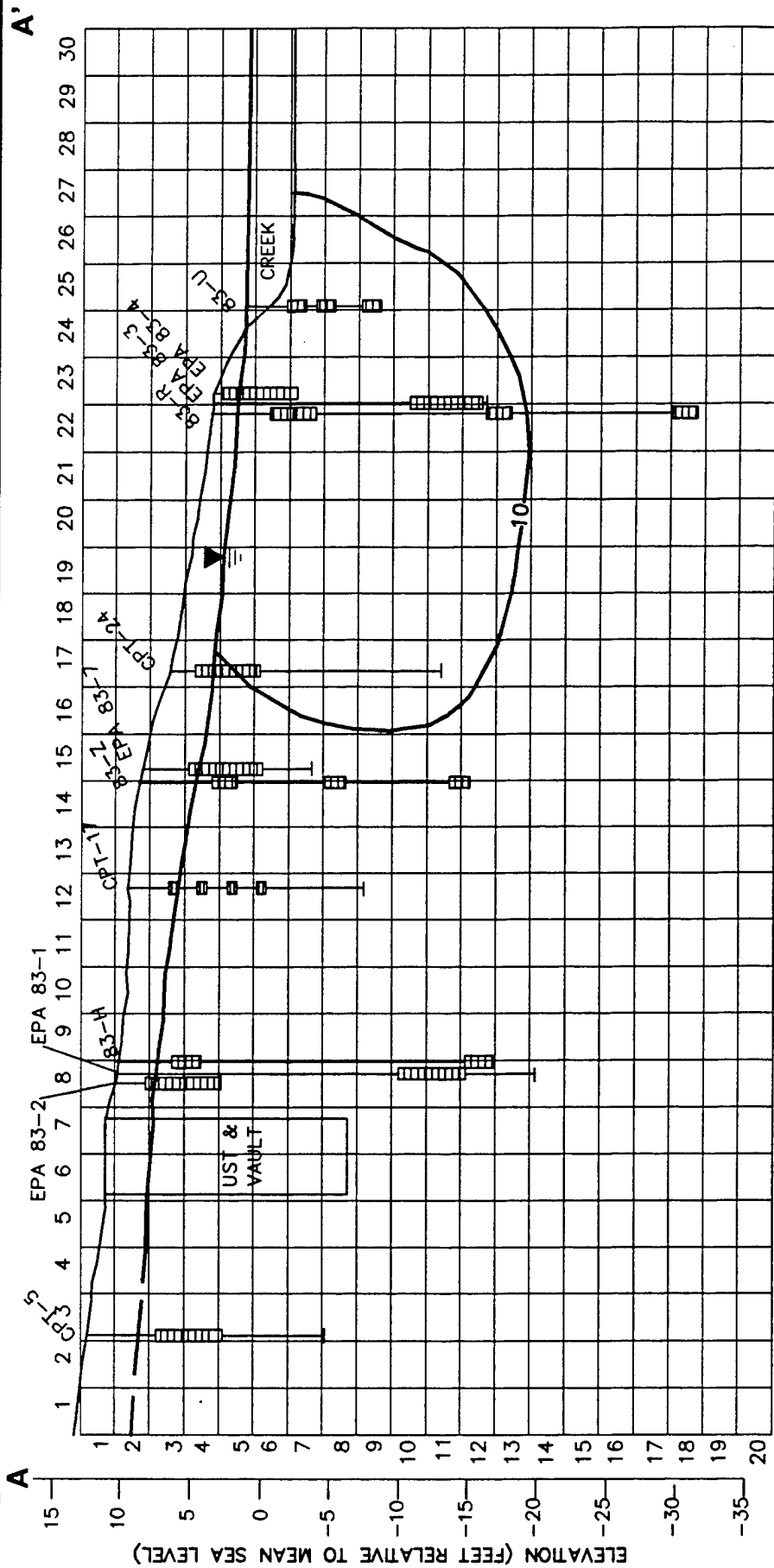
Intrinsic Remediation TS

Eglin Air Force Base, Florida



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LEGEND

Borehole/Sampling location name

Borehole

Well screen or sampling interval

Bottom of borehole

Approximate water table surface, September 1993 (Dashed where inferred)

Line of equal simulated total BTEX concentration ($\mu\text{g/L}$), Fall 1998

Contour Interval = Variable



FIGURE 5.18

PREDICTED BTEX CONCENTRATIONS FOR 1998 MODEL PREDICT3

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Intrinsic Remediation TS
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5.7 CONCLUSIONS AND DISCUSSION

The results of three model scenarios for the Eglin AFB study site suggest that the dissolved BTEX plume will not expand any further beyond its observed extents, and that BTEX concentrations migrating to the creek will not increase, even if BTEX loading rates did not decrease in the future. However, it is likely that the mass of BTEX entering site groundwater will continue to decrease, reaching levels that are too low to sustain BTEX concentrations at observed levels.

Model PREDICT1, the most conservative simulation, suggests that even if BTEX loading rates do not decrease further, the plume would rapidly stabilize. Although BTEX compounds would continue to entering the creek, concentrations would be lower than those observed in 1993. Given that no BTEX was detected in surface water in 1993, it is therefore unlikely that BTEX compounds will be detected in the surface water in the future. Results of model PREDICT2, which simulated a decreasing source, suggest that the plume will continue to shrink and that BTEX concentrations will drop below detectable levels in about the year 2004. The least conservative scenario (PREDICT3) suggested that BTEX concentrations would decrease below detectable concentrations by about 1999, assuming that no BTEX compounds were added to the system after 1994.

In all cases, model simulations are conservative for several reasons, including:

- 1) Aerobic respiration (near the creek, and probably in the vicinity of the water table), iron reduction, and methanogenesis all are occurring at this site; however, only the anaerobic processes are effectively simulated in the models. The biodegradation rate constant used in the calibrated model is within the range indicated by three different methods of analysis.
- 2) The rapid removal of BTEX compounds predicted by the simulations is largely the result of anaerobic biodegradation and sorption. As suggested by the configuration of the observed BTEX plumes, biodegradation in the shallowest part of the aquifer downgradient of the source area is further enhanced by the infiltration of electron-acceptor-rich precipitation and the interaction of surface water and groundwater near the creek. These processes could not be simulated with the models, so the model results are conservative in this respect.

- 3) The mean retardation coefficient for benzene (1.45) was used for model simulations. Minimum retardation coefficient values for the other BTEX compounds range from 1.26 to 1.65, and the averages ranged from 2.01 to 3.5. The use of a relatively low coefficient of retardation tends to increase the distance traveled by the simulated BTEX plume, but may provide a more accurate estimate of benzene transport.
- 4) Source area concentrations in the models remain higher than the observed concentrations until BTEX loading rates decrease well below those used for model calibration. This introduction of extra contaminant mass likely results in the predictions being conservative because additional BTEX mass must be biodegraded to produce the observed results.

Three simulations were run (rather than just one) in order to account for uncertainties associated with the assumptions of future site conditions and to provide a framework for any decision-making that might be based on the model results. The degradation and retreat of the BTEX plume observed in the simulations PREDICT2 and PREDICT3 is feasible, given the observed BTEX concentrations, the conservative assumptions made in constructing the simulation, and the strong evidence of biodegradation. Models PREDICT1 and PREDICT3 represent two endpoints in a continuum of probable scenarios at this site. PREDICT1 is a "worst-case" scenario in that it assumes BTEX dissolution into the aquifer will continue indefinitely at the same rates, while the rates should actually decrease due to weathering and degradation of the residual soil contamination and continuing dissolution of BTEX from the source area. Model PREDICT3 is a more optimistic prediction that assumes that BTEX partitioning into the dissolved phase ceased immediately after 1994. It is more likely that future site conditions will fall somewhere between those indicated by these two simulations, as illustrated by the simulation PREDICT2. In this case, the plume is predicted to persist until the year 2004 before BTEX concentrations are negligible.

SECTION 6

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the development and comparative analysis of groundwater remedial alternatives for the Eglin AFB study site at SS-36. The intent of this evaluation is to determine if intrinsic remediation is an appropriate and cost-effective remedial approach to consider when developing final remedial strategies for the site, especially when combined with other innovative and conventional remedial technologies

Section 6.1 presents the evaluation criteria used to evaluate groundwater remedial alternatives. Section 6.2 discusses the development of remedial alternatives considered as part of this demonstration project. Section 6.3 provides a brief description of each of these remedial alternatives. Section 6.4 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 6.5.

6.1 REMEDIAL ALTERNATIVE EVALUATION CRITERIA

The evaluation criteria used to identify appropriate remedial alternatives for shallow groundwater contamination at the site were adapted from those recommended by the USEPA (1988) for selecting remedies for Superfund sites [Office of Solid Waste and Emergency Response (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 focuses on the potential use of intrinsic remediation and source reduction technologies to reduce BTEX concentrations within the shallow groundwater to levels that meet regulatory action levels.

6.1.1 Long-Term Effectiveness and Permanence

Each remedial approach or remedial alternative (which can be a combination of remedial approaches or technologies such as intrinsic remediation and institutional controls) was analyzed

to determine how effectively it will minimize groundwater plume expansion so that groundwater quality standards can be achieved at a downgradient 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 groundwater is qualitatively assessed by conservatively estimating if a potential exposure pathway involving groundwater 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 potential for failure of the technology and the potential threats resulting from such a failure, also is evaluated.

6.1.2 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 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.

6.1.3 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 discount factor of 5 percent was assumed in present-worth calculations.

6.2 FACTORS INFLUENCING ALTERNATIVES DEVELOPMENT

Several factors were considered during the identification and screening of remedial technologies for addressing shallow groundwater contamination at the site. Factors considered included the objectives of the intrinsic remediation demonstration program; site contaminant, groundwater, and soil properties; present and future land use; and potential exposure pathways.

The following section briefly describes each of these factors and how they were used to narrow the list of potentially applicable remedial approaches and technologies to the final remedial alternatives considered for the site.

6.2.1 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 Eglin AFB study is to provide solid evidence of intrinsic remediation of dissolved fuel hydrocarbons so that this information can be used by the Base and its prime environmental contractor(s) to develop an effective groundwater 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 groundwater 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 in all contaminated media (e.g., vadose zone soil, soil gas, etc.), technologies have been evaluated based primarily on their potential impact on shallow groundwater and phreatic soils. Technologies that can reduce vadose zone contamination and partitioning of contaminants into groundwater also have been evaluated. Many source removal technologies evaluated in this section also will 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 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, bioventing, biosparging, groundwater pump and treat, and intrinsic remediation. Soil excavation, slurry walls, sheet piling, carbon adsorption, *ex situ* biological treatment, and onsite/offsite disposal are not attractive candidate technologies for this site.

6.2.2 Contaminant Properties

The site-related contaminants considered as part of this demonstration at the Eglin AFB POL Site SS-36 site are the BTEX compounds. The source of this contamination is weathered petroleum (i.e., MOGAS) present as residual contamination in capillary fringe and saturated soil in the vicinity of the UST beneath Building 763. The physiochemical characteristics of MOGAS

and the individual BTEX compounds will greatly influence the effectiveness and selection of a remedial technology.

Petroleum hydrocarbon mixtures, such as MOGAS, are composed of over 300 compounds with different physiochemical characteristics. MOGAS is classified as an LNAPL with a liquid density of 0.68 to 0.76 gram per cubic centimeter (g/cc) at 20°C (Wiedemeier *et al.*, 1995). Many compounds in MOGAS sorb very well to soil and are concentrated in the capillary fringe because the mixture is less dense than water. MOGAS is slightly soluble in water, with a maximum solubility of approximately 170 to 200 mg/L (IRP, 1987). MOGAS is also a primary substrate for biological metabolism. Simultaneous biodegradation of aliphatic, aromatic, and alicyclic hydrocarbons has been observed. In fact, mineralization rates of hydrocarbons in mixtures such as MOGAS or 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 groundwater, 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-m³/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 mg/L (Verschueren, 1983). Benzene is normally 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-m³/mol at 25°C (Pankow and Rosen, 1988; Hine and Mookerjee, 1975). Toluene sorbs more readily to soil media relative to benzene, but still is very mobile. The solubility of pure toluene in water at 20°C is approximately 515 mg/L at 20°C (Verschueren, 1983). Toluene has been shown to degrade to pyruvate, caetaldehyde, 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-m³/mol (Pankow and Rosen, 1988; Valsaraj, 1988). Ethylbenzene sorbs more strongly to

soils 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 mg/L at 20°C (Verschuere, 1983; Miller *et al.*, 1985). Ethylbenzene ultimately degrades 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-m³/mol at 25°C (Mackay and Wolkoff, 1973; Hine and Mookerjee, 1975; Pankow and Rosen, 1988). Of all of the BTEX compounds, xylenes sorb most strongly to soil, but still can leach from soil into the groundwater (Abdul *et al.*, 1987). Pure xylenes have water solubilities of 152 to 160 mg/L at 20°C (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Isnard and Lambert, 1988). Xylenes can degrade to carbon dioxide via pyruvate carbonyl intermediates (Hopper, 1978; Ribbons and Eaton, 1992).

On the basis of these physiochemical characteristics, intrinsic remediation, soil vapor extraction, bioventing, biosparging, groundwater extraction, and air stripping technologies could all be effective options for collecting, destroying, and/or treating BTEX contaminants at the Eglin AFB study site.

6.2.3 Site-Specific Conditions

Two general categories of site-specific characteristics were considered when identifying remedial technologies for comparative evaluation as part of this demonstration project. The first category was physical characteristics such as groundwater depth, 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.

6.2.3.1 Groundwater 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 groundwater flow and contaminant transport in the subsurface. The velocity of the groundwater and dissolved contamination is directly related to the hydraulic conductivity of the saturated zone. Hydraulic conductivity testing conducted in the vicinity of the site indicates a moderately high conductivity

within the sand unit present in the vicinity of the source area and dissolved plume. The average hydraulic conductivity estimated from these tests was 1.5×10^{-2} ft/min, within the range characteristic of sand or silty sand. The hydraulic conductivity at this site directly influences the fate and transport of contaminants. The shallow groundwater has migrated relatively rapidly, increasing the extent of contamination (i.e., the plume has expanded) but decreasing the average concentration within the aquifer through dilution and biodegradation.

Although high hydraulic conductivity can result in plume expansion and migration, this same characteristic also will enhance the effectiveness of other remedial technologies, such as groundwater extraction, biosparging, and intrinsic remediation. For example, it should be less expensive and time-consuming to capture and treat the contaminant plume using a network of extraction wells in areas of high hydraulic conductivity. Contaminant recovery also may be maximized when contaminants are not significantly sorbed to and retarded by phreatic soil. The effectiveness of biosparging may also be increased in highly conductive aquifers because of reduced entry pressures and increased radius of influence. Greater hydraulic conductivity would also increase the amount of contaminant mass traveling through a biosparging network. The DO introduced through biosparging also can enhance aerobic degradation of the dissolved contaminant mass.

The movement of contaminants within the subsurface away from the source also will increase the effectiveness of natural biodegradation processes by distributing the contaminant mass into areas containing additional microbe populations. In addition, because BTEX compounds are retarded relative to the advective flow velocity, relatively fresh groundwater containing DO and other electron acceptors will migrate through the plume area, further increasing biodegradation.

To satisfy the requirements for indigenous microbial activity and intrinsic remediation, the aquifer also must provide an adequate and available carbon or energy source, electron acceptors, essential nutrients, proper ranges of pH, temperature, and redox potential. Data collected as part of the field work phase of this TS and described in Sections 3 and 4 of this document indicate that this site is characterized by adequate and available carbon/energy sources and electron acceptors to support measurable biodegradation of fuel hydrocarbon contamination by indigenous microorganisms. DO, ferric iron, and carbon dioxide (which is utilized during methanogenesis) represent sources of electron acceptor capacity for the biodegradation of BTEX compounds at the site. 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 groundwater and phreatic soil at the site are not

likely to inhibit microorganism growth. In fact, the relatively high groundwater temperatures at the site likely have helped stimulate the relatively rapid biodegradation rates observed at this site.

Fuel hydrocarbon-degrading microorganisms are ubiquitous, and as many as 28 hydrocarbon-degrading isolates (bacteria and fungi) have been discovered in different soil environments (Davies and Westlake, 1977; Jones and Eddington, 1968). 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). Microbe addition was not considered a viable remedial technology for this site.

6.2.3.2 Potential Exposure Pathways

A pathways 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 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 TS includes determining if the approach will be sufficient and adequate to minimize plume expansion so that potential exposure pathways involving shallow groundwater and surface 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 area at this study site consists of the soil contaminated by LNAPL released during the 1988 spill from the UST near Building 763. There are several other fuel storage areas that are probable source areas within the POL site upgradient from this area. However, consideration of those sources is not within the scope of this study.

The Building 763 source area is bounded by surface water (including Weekly Bayou and Boggy Bayou) on the east and southeast, and by parks and recreation fields on the south and northeast. Dormitories are located approximately 1,750 feet northwest of the site, and office

buildings, warehouses, and parking lots are present west and southwest of the site. The groundwater plume originating from the source areas is migrating to the southeast, and has impacted groundwater in an area extending from the vicinity of Building 763 toward and underneath the small creek that feeds into Weekly Bayou (Figures 4.3 and 4.4). Groundwater is discharging to the creek. Because Weekly Bayou is contained within the boundaries of Eglin AFB, the current land use within and downgradient from the contaminant plume is industrial or undeveloped. There may be some recreational use of Boggy Bayou, but most of that body also is within Base boundaries.

Under reasonable current land use assumptions, potential receptors primarily consist of worker populations and possibly recreational users of the Bayous. Workers could be exposed to site-related contamination in phreatic soils or shallow groundwater if these materials are removed or exposed during future construction excavations or remedial activities. Recreational users of the Bayous, as well as ecological receptors, could be exposed to site-related contamination in surface water or sediments; however, given that surface water samples did not contain detectable concentrations of BTEX compounds, these exposure pathways are very unlikely to be completed. Groundwater from the shallow aquifer is not currently used to meet any potable supply demands at Eglin AFB. On-Base potable water demands are met by municipal supply wells screened in the Floridan Aquifer. Several wells screened in the shallow aquifer are used for irrigation needs at the Base, but these wells are all upgradient from the study site. Surface water is brackish and is not used for consumption. Exposure pathways involving other environmental media such as shallow soils and soil gas in the source area were not considered as part of this project, but should be considered in overall site remediation decisions.

Assumptions about hypothetical future land uses also must be made to ensure that the remedial technology or alternative considered for shallow groundwater at the site is adequate and sufficient to provide long-term protection. No changes in land use are anticipated in the foreseeable future, so the aforementioned land use assumptions are appropriate. Thus, likely potential future receptors include only worker populations. The potential future exposure pathways involving workers are identical to those under current conditions, provided shallow groundwater is not used to meet industrial water demands. 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 groundwater use be enforced in areas downgradient of the site until natural attenuation reduces contaminants to levels that pose no risk. If source removal technologies such as soil vapor extraction, bioventing, biosparging, or groundwater pump and treat 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 no BTEX compounds have been detected in surface water, and because modeling results suggest that surface water will not be further affected, restrictions or controls on surface water use do not appear to be necessary.

6.2.3.3 Remediation Goals for Shallow Groundwater

Site data and model results suggest that the BTEX plume is not likely to move beyond its observed extents, although contaminated groundwater will continue to discharge to the small creek that opens into Weekly Bayou. Therefore, the creek has been identified as the point of compliance (POC) for groundwater remedial activities because this appears to be the ultimate sink for future contaminant migration. This is a suitable location for monitoring of surface water, and for demonstrating compliance with protective water quality standards, such as promulgated groundwater maximum contaminant levels (MCLs) or surface water standards.

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 RAO for shallow groundwater and surface water within and downgradient of the Eglin AFB site is limited plume expansion to prevent exposure of downgradient receptors to concentrations of BTEX in groundwater or surface water at levels that exceed regulatory standards. This means that viable remedial alternatives must be able to achieve concentrations that minimize plume migration and/or expansion. The RAO for shallow groundwater at the POC is attainment of state target levels for petroleum-contaminated sites as listed in Chapter 62-770 FAC and summarized in Table 6.1. As noted in Section 4.3.1.2, concentrations of non-BTEX target compounds in site monitoring wells were all either below detection limits or well below target levels in Fall 1993.

In summary, available data suggest that there is no completed exposure pathway involving shallow groundwater or surface water under current conditions. Moreover, it is likely that no potential exposure pathways involving shallow groundwater would be complete under future land use assumptions, provided use of shallow groundwater as a potable or industrial source of water is prohibited by institutional controls within the plume area. Thus, institutional controls are likely to be a necessary component of any groundwater remediation strategy for this site. The required duration of these institutional controls may vary depending on the effectiveness of the

selected remedial technology at reducing contaminant mass and concentrations in the groundwater. Because surface water is brackish, controls on industrial or potable use should not be needed.

TABLE 6.1
POINT-OF-COMPLIANCE REMEDIATION GOALS
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

Compound	Groundwater Target Level ($\mu\text{g/L}$)
Benzene	1
Total Volatile Organic Aromatics	50
1,2-dichloroethane	3
1,2-dibromoethane	0.02
Lead	50
Methyl tert-butyl ether	50

6.2.4 Summary of Remedial Technology Screening

Several remedial approaches and technologies have been identified and screened for use in treating the shallow groundwater at the study site. Table 6.2 lists the initial remedial technologies considered as part of this demonstration study, and identifies those retained for detailed comparative analysis. Screening was conducted systematically by considering the program objectives of the AFCEE intrinsic remediation demonstration, physiochemical properties of the BTEX compounds, 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 for remediating shallow groundwater underlying and migrating from the site. The remedial approaches retained for development of remedial alternatives and comparative analysis include institutional controls, intrinsic remediation, LTM, and groundwater extraction and treatment (for plume containment).

TABLE 6.2
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

General Response Action	Technology Type	Process Option	Implementability	Retain
Long-Term Monitoring	Periodic Groundwater and Surface Water Monitoring	Confirmation Wells	Many wells and monitoring points are available to confirm the progress of remediation. Sufficient space for additional wells.	Yes
		Point-of-Compliance Sampling	Wells can be used to verify contaminants are not migrating any deeper in the aquifer; surface water samples will indicate if any BTEX compounds are reaching the creek.	Yes
Institutional Controls	Groundwater Use Control	Land Use Control/Regulate Well Permits	The majority of the plume area is currently within the base boundary and land use and groundwater use are under base jurisdiction. The leading edge of the plume extends beneath a surface water body within base boundaries.	Yes
		Seal/Abandon Existing Wells	No production wells are known to exist in the current or predicted plume area.	No
		Point-of-Use Treatment	No shallow groundwater is extracted from the plume area for any use.	No
		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	Site infrastructure (e.g., fuel lines) prevents installation of a suitable trench.	No
		Minimum Pumping/Gradient Control	Hydraulic conductivity of site soils favors pumping. High hydraulic conductivity of shallow aquifer will require relatively high pumping rates. Pumping may induce migration of contaminants from upgradient sources. Contamination downgradient of wells (e.g., beneath the creek) may not be contained or captured.	Yes
	Physical Controls	Slurry Walls/Grout Curtains	Limited effectiveness. Site infrastructure would limit installation.	No
		Sheet Piling	Limited effectiveness. Site infrastructure would limit installation.	No
	Reactive/Semi-Permeable Barriers	Biologically Active Zones	Degradation of BTEX can be stimulated by allowing groundwater to flow through a nutrient-rich barrier. New, unproven technology. Site infrastructure would prevent installation	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

General Response Action	Technology Type	Process Option	Implementability	Retain
<i>In Situ</i> Treatment	Biological	Oxygen and/or Nutrient Enhanced Biodegradation (Biosparging)	Differs from biologically active zone in that oxygen and/or nutrients are injected downgradient of plume to limit plume migration by enhancing biodegradation and reducing BTEX concentrations as the plume moves downgradient from the source area. Process appears to occur naturally in the vicinity of the groundwater/creek interface, and site data indicate that elsewhere anaerobic processes are sufficient to reduce BTEX mass.	No
	Chemical/Physical	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Sampling at the site 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 into air bubbles and into vadose zone. Could create vapor emissions requiring containment and/or permitting.	No
Aboveground Groundwater Treatment	Groundwater Extraction	Vertical Pumping Wells	Downgradient margin of groundwater plume is pumped by installing submersible pumps in wells. Could reduce contaminant concentrations upgradient of wells, possibly reducing the length of time required for natural attenuation processes to complete groundwater restoration in that area. Will create waste requiring treatment and disposal, and could induce migration of contaminants from upgradient sources.	Yes
		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 at higher flow rates. Potential permitting for air emissions.	Yes
		Activated Carbon	Cost-prohibitive for more concentrated BTEX. Creates a disposal problem.	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	No

TABLE 6.2 (Concluded)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

General Response Action	Technology Type	Process Option	Implementability	Retain
Aboveground Treatment	Direct Discharge to Industrial Waste Water Treatment Plant (IWWTP)		Viable option when an IWWTP is readily available and capable of handling BTEX, chlorinated solvent, and hydraulic loading.	No
Treated Groundwater 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 Groundwater 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
Source Removal/Soil Remediation	Discharge to Surface Waters	Storm Drains	Viable option. Generally requires NPDES or other discharge permit.	Yes
		Biological Landfarming	Excavation may not be feasible at this site. Soil remediation may be unnecessary for groundwater remediation.	No
	<i>In Situ</i>	Thermal Desorption	Excavation may not be feasible at this site. Soil remediation may be unnecessary for groundwater remediation.	No
		Bioventing	Air injection to stimulate biodegradation of fuel residuals. Evidence indicates significant natural weathering of residuals. Due to location of residuals in capillary fringe, bioventing may not be effective without dewatering.	No
		Soil Vapor Extraction	Vapor extraction has been successfully implemented at other sites. Soil remediation may be unnecessary for groundwater remediation. Evidence indicates significant natural weathering of residuals.	No

6.3 BRIEF DESCRIPTION OF REMEDIAL ALTERNATIVES

This section describes how remedial approaches and technologies retained from the screening process were combined into two remedial alternatives for the Eglin AFB site. Sufficient information on each remedial alternative is provided to facilitate a comparative analysis of effectiveness, implementability, and cost in Section 6.4.

6.3.1 Alternative 1 - Intrinsic Remediation and Institutional Controls with Long-Term 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 groundwater. 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 dispersion and infiltration), and volatilization. In some cases, intrinsic remediation will reduce dissolved contaminant concentrations below numerical concentration goals intended to be protective of human health and the environment. As indicated by the evidence of intrinsic remediation described in Section 4, these processes are occurring in the vicinity of Building 763 and the MOGAS spill and will continue to reduce contaminant mass in the plume area. In addition, evidence presented in Section 4 indicates that the remaining residual MOGAS is extremely weathered and will no longer be an effective source of dissolved BTEX. As a result, no additional source abatement need be considered.

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 permit restrictions on groundwater 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. Model scenarios PREDICT1 and PREDICT3 delineate the maximum and minimum threats posed by plume migration. Future plume migration and degradation will most likely result in conditions that fall between these limits, as suggested by the results of model PREDICT2. Given the evidence of degradation of the residual LNAPL, the results of model PREDICT2 should be considered in making decisions regarding groundwater monitoring and potential land use restrictions.

As a minimum, groundwater monitoring within the plume area would be conducted annually as part of this remedial technology to evaluate the progress of natural attenuation processes. Based on the potential plume migration suggested by model PREDICT2, it is unlikely that benzene concentrations exceeding the target level of 1 µg/L (Table 6.1) would persist beyond the year 2004 (this would be true even if it were assumed that model contaminant concentrations are all benzene rather than total BTEX). Under this scenario, it appears that dissolved BTEX concentrations in the vicinity of the creek should diminish to insignificant levels after the year 2001. Even if the results of the very conservative model PREDICT1 are considered, the plume will still shrink slightly, and BTEX concentrations near the creek will be lower than those observed in 1993 and 1994. Given that no BTEX compounds have been detected in surface water samples, it is therefore very unlikely that detectable concentrations of BTEX will impact the creek in the future.

Because the plume appears to have reached a downgradient exposure point (the creek), POC samples should be collected from two locations within the creek and from three nested wells on the plume centerline, beneath the groundwater/creek interface (e.g., in the vicinity of monitoring wells EPA 83-3 and 83-4, or Geoprobe® location 83-U). In addition, four LTM wells within and upgradient from the observed BTEX plume would be used to monitor the effectiveness of intrinsic remediation. LTM wells are further described in Section 7.2.1. Increasing BTEX concentrations at downgradient wells may require additional evaluation and modeling to assess BTEX migration and to determine the impact of additional BTEX migration on surface waters.

Public education on the selected alternative would be developed to inform Base personnel and residents of the scientific principles underlying source reduction and 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 groundwater and surface 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 intrinsic remediation and institutional controls at the site, and reevaluate the need for additional remedial actions at the site.

6.3.2 Alternative 2 - Groundwater Extraction and Treatment, Intrinsic Remediation, and Institutional Controls with Long-Term Groundwater Monitoring

This alternative is identical to Alternative 1 except that a groundwater extraction system would be installed along the eastern edge of the site. This system would intercept contaminated groundwater migrating from the Building 763 source area. An aboveground air stripper would be used as necessary to treat extracted contaminated groundwater before it is discharged into the sanitary sewer (or possibly into the creek). Although an interceptor trench or reactive barrier might be preferable, site constraints (e.g., infrastructure and flowing sands) prevent installation of sufficiently deep and wide trenches. Therefore, groundwater extraction wells would be used for plume containment. The small mass of dissolved BTEX contamination downgradient of the extraction system, along with residual and sorbed contamination throughout the remainder of the plume area, would be left for treatment by intrinsic remediation.

It is estimated that 2 wells, each pumped at a rate of 23 gallons per minute would be required to capture the contamination emanating from the MOGAS spill area. Proposed well locations are presented on Figure 6.1. Calculations used to arrive at the extraction well configuration are presented in Appendix E. It is assumed that the wells would operate for 2 years. Given the natural site groundwater and contaminant velocities, the increased velocities induced by pumping should be sufficient to intercept and extract a significant mass of the BTEX plume within 2 years. Increased partitioning during pumping will also remove additional BTEX from the remaining residual LNAPL. However, some BTEX will continue to partition from the source area and would be treated by natural attenuation processes.

The extracted groundwater may require treatment prior to release to storm drains adjacent to the site. Air stripping is the recommended method of treatment, as activated carbon produces waste that is expensive to dispose of or recycle. However, the system would produce air emissions and might require a permit for such emissions. As with Alternative 1, institutional controls and LTM would be required. POC and LTM samples would be collected in the same locations indicated in the previous section. Groundwater and surface water monitoring would also follow the same schedule.

6.4 EVALUATION OF ALTERNATIVES

This section provides a comparative analysis of each of the remedial alternatives based on the effectiveness, implementability, and cost criteria. This evaluation is summarized in Section 6.5.

6.4.1 Alternative 1 - Intrinsic Remediation and Institutional Controls with Long-Term Monitoring

6.4.1.1 Effectiveness

Section 5 of this document presents the results of the MODFLOW and MT3D[®] modeling completed to support the intrinsic remediation alternative at the Eglin AFB site. Three models (PREDICT1, PREDICT2, and PREDICT3) were used to illustrate the range of potential future conditions at the site. Model PREDICT1 predicted BTEX migration and degradation based on the assumption that BTEX loading rates used to produce the calibrated model indefinitely remain constant. Model PREDICT2 assumed that BTEX loading rates remain constant before decreasing to zero after the year 2000, and model PREDICT3 assumed that BTEX loading rates dropped to zero immediately after 1995. Results of model PREDICT1 are intended to illustrate a worst-case scenario, and results of PREDICT3 represent the most optimistic scenario. Model PREDICT2 was run as a conservative but more realistic approximation of future site conditions, given evidence of source degradation.

Results of PREDICT2 suggest that natural attenuation mechanisms will significantly limit contaminant migration and reduce contaminant mass and toxicity. Contaminant concentrations should not exceed the target levels listed in Table 6.1 at any POC sampling locations after the year 2004. Consideration of these results, along with the lack of detectable concentrations of BTEX compounds in surface water in 1993, indicates that detectable concentrations of MOGAS-related compounds are not likely to be present in the creek. Groundwater and surface water monitoring at the LTM and POC locations will ensure the protectiveness of this alternative. While this alternative would not cease to be protective if BTEX were detected in POC samples collected after the year 2004, 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 groundwater to the surface. Long-term land use restrictions will be required to ensure that shallow groundwater and surface water will not be pumped or removed for potable use within, and approximately 500 feet in all directions from, the existing BTEX plume. Existing health and safety plans should be enforced to reduce risks from additional excavation or 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. This alternative also satisfies program goals for cost effectiveness and waste minimization.

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 this Eglin AFB site using field data and the groundwater flow and contaminant transport models demonstrated that the BTEX plume migration will be significantly limited. The model sensitivity analysis completed for this site (Section 5) suggests that even under the most conservative (i.e., worst-case) conditions, the naturally occurring processes at the site should reduce contaminant migration so that it is unlikely that BTEX compounds will be detected in the creek water.

Apart from the administrative concerns associated with enforcement of long-term land use restrictions and long-term groundwater monitoring programs, this remedial alternative should provide reliable, continued protection. It is assumed for cost comparison purposes that dissolved benzene concentrations will exceed state standards throughout the plume for approximately 9 years under Alternative 1, and that sampling to verify this will last for 10 years.

6.4.1.2 Implementability

Alternative 1 is not technically difficult to implement. Installation of LTM and POC wells and annual groundwater and surface 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 also may be administrative concerns associated with long-term enforcement of groundwater and surface water use restrictions. Future land use within the source area may be impacted by leaving contaminated soil and groundwater 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 has been positive.

6.4.1.3 Cost

The cost of Alternative 1 is summarized in Table 6.3. Capital costs are limited to the construction of three new POC wells and one new LTM well. Included in the \$155,000 total present worth cost estimate for Alternative 1 are the costs of maintaining institutional controls and long-term groundwater monitoring for a total of 10 years.

TABLE 6.3
ALTERNATIVE 1 - COST ESTIMATE
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

<u>Capital Costs</u>	<u>Cost</u>
Design/Construct Three POC Wells and One LTM Well	\$16,800
<u>Operation, Maintenance and Monitoring Costs (Annual)</u>	<u>Annual Cost</u>
Conduct Annual Groundwater and Surface Water Monitoring at 9 locations (10 years)	\$8,200
Maintain Institutional Controls/Public Education (10 years)	\$5,000
Project Management and Reporting (10 years)	\$4,800
<u>Present Worth of Alternative 1</u> ^{a/}	\$155,000

^{a/} Based on an annual discount factor of 5 percent.

6.4.2 Alternative 2 - Groundwater Extraction and Treatment, Intrinsic Remediation and Institutional Controls with Long-Term Groundwater Monitoring

6.4.2.1 Effectiveness

The effectiveness of the intrinsic remediation, institutional controls, and LTM components of this alternative have been described under Alternative 1. Groundwater extraction and treatment is an established technology for reducing contaminant mass and controlling plume migration.

The goal of groundwater extraction would be to prevent additional migration of BTEX compounds to the receptor (the creek) and to reduce the mass of contamination in the system.

Extracted groundwater would likely require treatment prior to discharge. Air stripping is an effective technology for the removal of volatile constituents from water. It is likely that air emissions controls would not be required for the air stripper offgas due to the relatively low concentrations of BTEX compounds in site groundwater. A discharge permit would likely be required for the treated groundwater. As with Alternative 1, this alternative would require long-term land use restrictions and enforcement of health and safety plans to reduce risks from installing the pump-and-treat system and installing and monitoring LTM and POC wells.

Alternative 2 should provide reliable, continuous protection with little risk from temporary system failures. This alternative also complies with the program goals because intrinsic remediation remains the predominant decontamination method for the site. However, this remedial alternative will result in the generation of additional drill cuttings, groundwater, and other wastes requiring treatment and/or disposal. It is also possible that drawdown of the water table due to pumping will induce the migration of additional contamination through the study area from upgradient sources in the POL Yard. This could introduce additional contaminant mass into the study area and cause BTEX concentrations to rise, demanding additional LTM and POC sampling.

Although pumping will remove a greater mass of BTEX in a shorter time frame, some residual LNAPL may remain in the source area and continue to act as a source of dissolved BTEX. In addition, dissolved BTEX downgradient of the wells (especially beneath the creek) may not be captured due to preferential flow of water from the creek to the well. Therefore, on the basis of the results of model PREDICT2, it is assumed that dissolved BTEX concentrations will exceed state standards throughout the plume for approximately 9 years under Alternative 2, and that sampling will last for 10 years. Costs for installation of the extraction and treatment system are based on the conceptual design discussed in Section 6.3.2.

6.4.2.2 Implementability

Installing and operating a groundwater extraction system to limit BTEX migration at the study site will present additional implementability concerns. Installation involves standard drilling practices for wells, limited shallow excavation for piping and manifold connections, and construction of an air stripper. Implementation in and around the POL yard could disrupt fueling operations. Groundwater extraction pumps and air stripping equipment are readily available, and

the technology used to construct these systems is proven and reliable. The technical and administrative implementability concerns associated with the intrinsic remediation and LTM component of this alternative are similar to those discussed in Alternative 1. Installation and operation of a full-scale groundwater extraction and treatment system would require an increased commitment of man-hours and other resources to maintain and monitor the system.

6.4.2.3 Cost

The estimated capital and operating costs of Alternative 2 are shown in Table 6.4. The total present worth cost of Alternative 2 is \$257,000. The cost of Alternative 2 is increased relative to the cost of Alternative 1 by the addition of groundwater extraction and treatment. It is assumed that the groundwater extraction system would operate for 2 years after installation. Annual LTM would continue for 10 years to ensure that intrinsic remediation is reducing BTEX concentrations below standards throughout the plume and to verify that additional contamination does not reach the POC locations.

6.5 RECOMMENDED REMEDIAL APPROACH

Two remedial alternatives have been evaluated for remediation of the shallow groundwater at the Eglin AFB study site. Components of the alternatives evaluated include groundwater extraction and treatment, intrinsic remediation with LTM, and institutional controls. Table 6.5 summarizes the results of the evaluation based upon effectiveness, implementability, and cost criteria. On the basis of this evaluation, the Air Force recommends Alternative 1 as achieving the best combination of risk reduction and cost effectiveness.

Both alternatives make maximum use of intrinsic remediation mechanisms to reduce plume migration and toxicity. Alternative 2 would provide additional protection against further plume migration, but would still rely on intrinsic remediation mechanisms to reduce plume toxicity downgradient of the bioventing system. Implementation of Alternative 2 would not decrease the time frame for remediation, would require a greater capital expenditure, and could induce the migration of additional contamination into the study site from upgradient sources.

Both of the remedial alternatives are implementable, and both alternatives effectively reduce potential hydrocarbon migration and toxicity. Both alternatives should be acceptable to the public and regulatory agencies because they are protective of human health and the environment and reduce soil and groundwater contamination in a relatively short time frame. Implementation

of either alternative will require land use and groundwater use controls to be enforced for at least 10 years, along with annual groundwater monitoring for the same period.

TABLE 6.4
ALTERNATIVE 2 - COST ESTIMATE
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AFB, FLORIDA

<u>Capital Costs</u>	<u>Cost</u>
Design/Construct Three POC Wells and One LTM Well	\$16,800
Design/Construct Groundwater Extraction System, Including ___ wells, Submersible Pumps, Piping, and Air Stripper System	\$63,500
<u>Operation, Maintenance and Monitoring Costs (Annual)</u>	<u>Annual Cost</u>
Operate/Maintain Groundwater Extraction System (2 years)	\$17,600
Extraction System Reporting/Project Management (2 years)	\$2,900
Conduct Annual Groundwater and Surface Water Monitoring at 9 locations (10 years)	\$8,200
Maintain Institutional Controls/Public Education (10 years)	\$5,000
Project Management and Reporting (10 years)	\$4,800
<u>Present Worth of Alternative 2 ^{a/}</u>	\$257,000

^{a/} Based on an annual discount factor of 5 percent.

The final evaluation criterion used to compare each of the two remedial alternatives was cost. The additional cost of Alternative 2 over Alternative 1 is not justified by the minimal additional protection it provides. In addition, operation of such a system could to cause additional contamination from the upgradient source areas to migrate through the site and towards the creek. Therefore, Alternative 1 is recommended.

TABLE 6.5
SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUNDWATER REMEDIATION
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 1			
- Intrinsic Remediation - Long-Term Monitoring - Institutional Controls	Contaminant mass, volume, and toxicity will be significantly reduced and plume migration should be halted. Standards for BTEX not likely to be exceeded at POC wells.	Readily implementable. Long-term management, groundwater use controls and monitoring required for an estimated 10 years. Minimal exposure of site workers if excavation is carefully controlled in source area. If standards are exceeded at POCs after 2005, additional remedial work may be required.	\$155,000
Alternative 2			
- Groundwater Extraction and Treatment - Intrinsic Remediation - Long-Term Monitoring - Institutional Controls	Similar to Alternative 1, with the addition of a groundwater extraction and air-stripper treatment system. Contaminant mass, volume, and toxicity could be reduced more rapidly than in Alternative 1. Less likely that standards will be exceeded at POC. Could induce migration of contaminants onto site from upgradient sources	Readily implementable. Installation of groundwater extraction system should present no problems. Groundwater extraction and treatment estimated to continue for 2 years. Long-term management, groundwater controls, and monitoring required for an estimated 10 years. If standards are exceeded at POC after 2005, additional remedial work may be required.	\$257,000

7.2 MONITORING NETWORKS

Two separate sets of sampling locations will be utilized at the site as part of the intrinsic remediation with LTM remedial alternative. The first set will consist of four LTM wells located in and upgradient from the observed BTEX plume to verify the results of the modeling effort and to ensure that natural attenuation rates are sufficient to minimize plume expansion. This network of wells will consist of three existing wells and one proposed well screened within the shallow aquifer to provide short-term confirmation and verification of the quantitative groundwater modeling results. The second set of sampling locations will consist of two surface water sampling stations and one set of three nested groundwater monitoring wells (the POCs for this demonstration project). The purpose of the POCs is to verify that no contaminant concentrations exceeding state target levels migrate beyond the area under institutional control. The LTM and POC samples should be analyzed for the parameters listed in Tables 7.1 and 7.2, respectively, in addition to the parameters that are specified in Chapter 62-770, FAC.

7.2.1 Long-Term Monitoring Wells

At four locations, groundwater wells within and upgradient from the BTEX contaminant plume will be used to monitor the effectiveness of intrinsic remediation in reducing total contaminant mass and minimizing contaminant migration at the study site. One well upgradient from the existing plume will be monitored to assess the effects of upgradient contaminant sources on site geochemistry and contaminant distribution. Of the remaining wells, typically one is placed within the anaerobic treatment zone, one is placed in the aerobic treatment zone, and one is placed downgradient of the aerobic treatment zone. However, because the plume terminates at the creek (where there is an aerobic treatment zone), wells will not be placed in this manner. Instead, one set of two nested wells near the plume core and one well at a downgradient location within the BTEX plume will be monitored.

At three of the locations, existing wells will be used for this purpose. Wells EPA 83-1 and EPA 83-2 will be used to monitor conditions near the plume core, and monitoring well EPA 83-7 will be used for monitoring further downgradient within the plume. For monitoring upgradient from the MOGAS plume, one new permanent well should be installed. Figure 7.1 identifies the proposed locations of the new well and the existing wells to be used for LTM.

TABLE 7.1
LONG-TERM MONITORING ANALYTICAL PROTOCOL
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

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	Every Year for 10 Years	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	Same as above.	Every Year for 10 Years	Collect 100 mL of water in a glass container	Field
Temperature	E170.1	Field only	Metabolism rates for microorganisms depend on temperature	Every Year for 10 Years	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to Method A4500 for a comparable laboratory procedure	The oxygen concentration is an indicator of biodegradation conditions; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Every Year for 10 Years	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 ^{d/}	Aerobic and anaerobic processes are pH-sensitive	Every Year for 10 Years	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 groundwater system	Every Year for 10 Years	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 E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Every Year for 10 Years	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base

TABLE 7.1 (CONCLUDED)
LONG-TERM MONITORING ANALYTICAL PROTOCOL
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

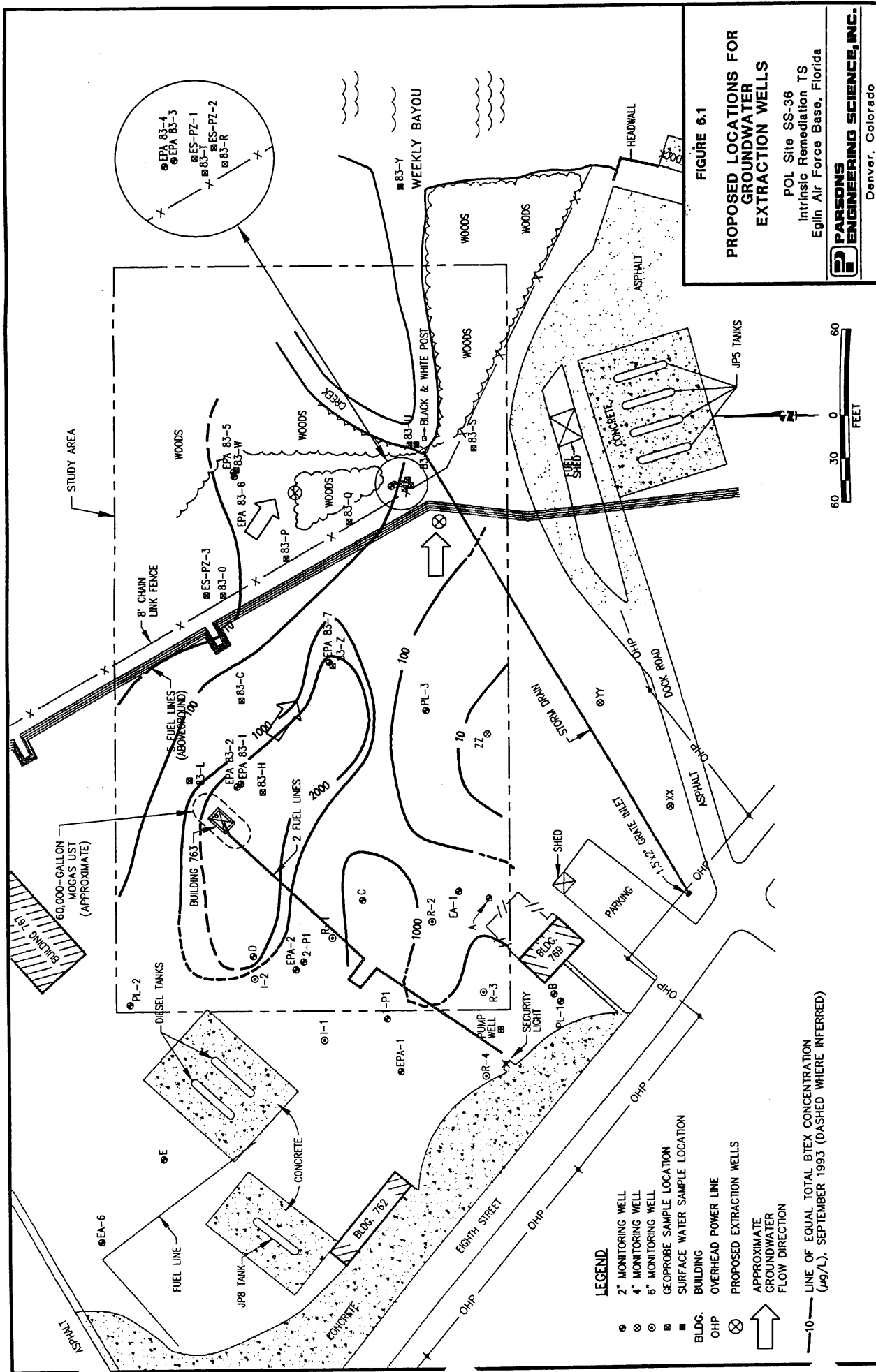
Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Sulfate (SO_4^{2-})	IC method E300 or method SW9056 or HACH SulfaVer 4 method	Method E300 is a Handbook method; method SW9056 is an equivalent procedure. HACH method is Photometric	Substrate for anaerobic microbial respiration	Every Year for 10 Years	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base or field (for HACH method)
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 groundwater influences and is influenced by biologically mediated reactions; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Every Year for 10 Years	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Methane, Ethane, and Ethene	RSKSOP-114 modified to analyze water samples for methane by headspace sampling with dual thermal conductivity and flame ionization detection.	Method published and used by the USEPA Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis). The presence of ethane and ethene suggest that cometabolism of vinyl chloride is occurring.	Every Year for 10 Years	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	Every Year for 10 Years	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤ 2	Fixed-base

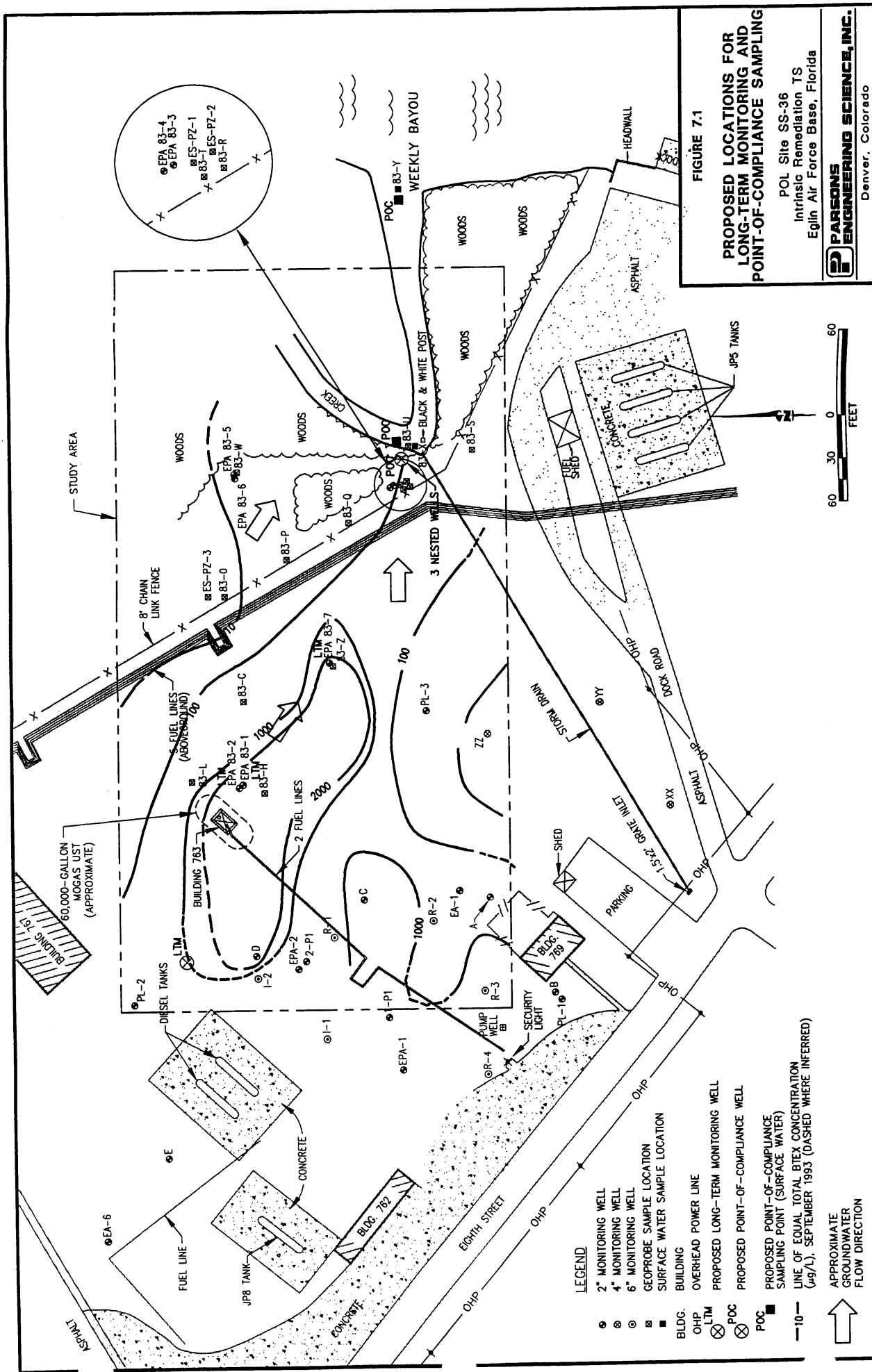
a/ Protocol methods are presented by Wiedemeier *et al.* (1995).

TABLE 7.2
POINT-OF-COMPLIANCE MONITORING ANALYTICAL PROTOCOL
POL SITE SS-36
INTRINSIC REMEDIATION TS
EGLIN AIR FORCE BASE, FLORIDA

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	Every Year for 10 Years	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is an indicator of biodegradation conditions; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Every Year for 10 Years	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	Every Year for 10 Years	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 groundwater system	Every Year for 10 Years	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 groundwater influences and is influenced by biologically mediated reactions; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Every Year for 10 Years	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Lead	SW7421 or 239.2	Standard methods	Lead must be measured for regulatory compliance	Every Year for 10 Years	Collect 100–250 mL of water in a glass or plastic container; add nitric acid to pH ≤2	Fixed-base
1,2-dichloroethane and EDB	Purge and trap GC method SW8010	Handbook method	Halogenated hydrocarbon concentrations must be measured for regulatory compliance	Every Year for 10 Years	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	Fixed-base
Aromatic hydrocarbons (BTX), plus MTBE	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTX are the primary target analytes for monitoring natural attenuation; BTX and MTBE concentrations must also be measured for regulatory compliance	Every Year for 10 Years	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.* (1995).





This network will supplement the POC wells to provide early confirmation of model predictions and to allow additional response time if necessary. The new LTM well will be constructed with a 10-foot screen, with approximately 8 feet of the screen below the water table. All LTM wells will be sampled and analyzed for the parameters listed in Table 7.1 to verify the effectiveness of the intrinsic remediation remedial alternative.

7.2.2 Point-of-Compliance Sampling

A nested set of three POC monitoring wells will be installed as close as possible to the creek bank, immediately west of Geoprobe[®] sample location 83-U. Figure 7.1 shows the proposed location of this well nest. In addition to groundwater sampling from this well nest, surface water samples should be collected at two locations in the creek. One location should be as near as possible to the well nest, and one location should be at the mouth of the creek. The purpose of the POC sampling is to verify that no contaminated water exceeding target levels migrates beyond the area under institutional control. Although model results suggest that the contaminant plume will should recede and BTEX loading to the creek should decrease, POC sampling is the technical mechanism used to demonstrate protection of human health and the environment and compliance with site-specific numerical remediation goals. Surface water samples and groundwater samples will be analyzed for the parameters listed in Table 7.2 and the parameters required by Chapter 62-770, FAC to assure that the selected remedy is providing the anticipated level of risk reduction and site remediation.

As with the LTM wells, the POC wells will also be screened in the same hydrogeologic unit as the contaminant plume. Data presented in this report concerning the nature and extent of contamination at the site suggest that 5-foot screens at the groundwater surface, 15 feet below the groundwater surface, and 30 feet below the groundwater surface will provide sufficient vertical resolution regarding the fate of the contaminant plume at that POC. Figure 7.2 is a proposed groundwater monitoring well completion diagram for both the LTM wells and the POC wells.

7.3 GROUNDWATER AND SURFACE WATER SAMPLING

To ensure that sufficient contaminant removal is occurring at the Eglin AFB site to meet site-specific remediation goals, the long-term groundwater and surface water monitoring plan

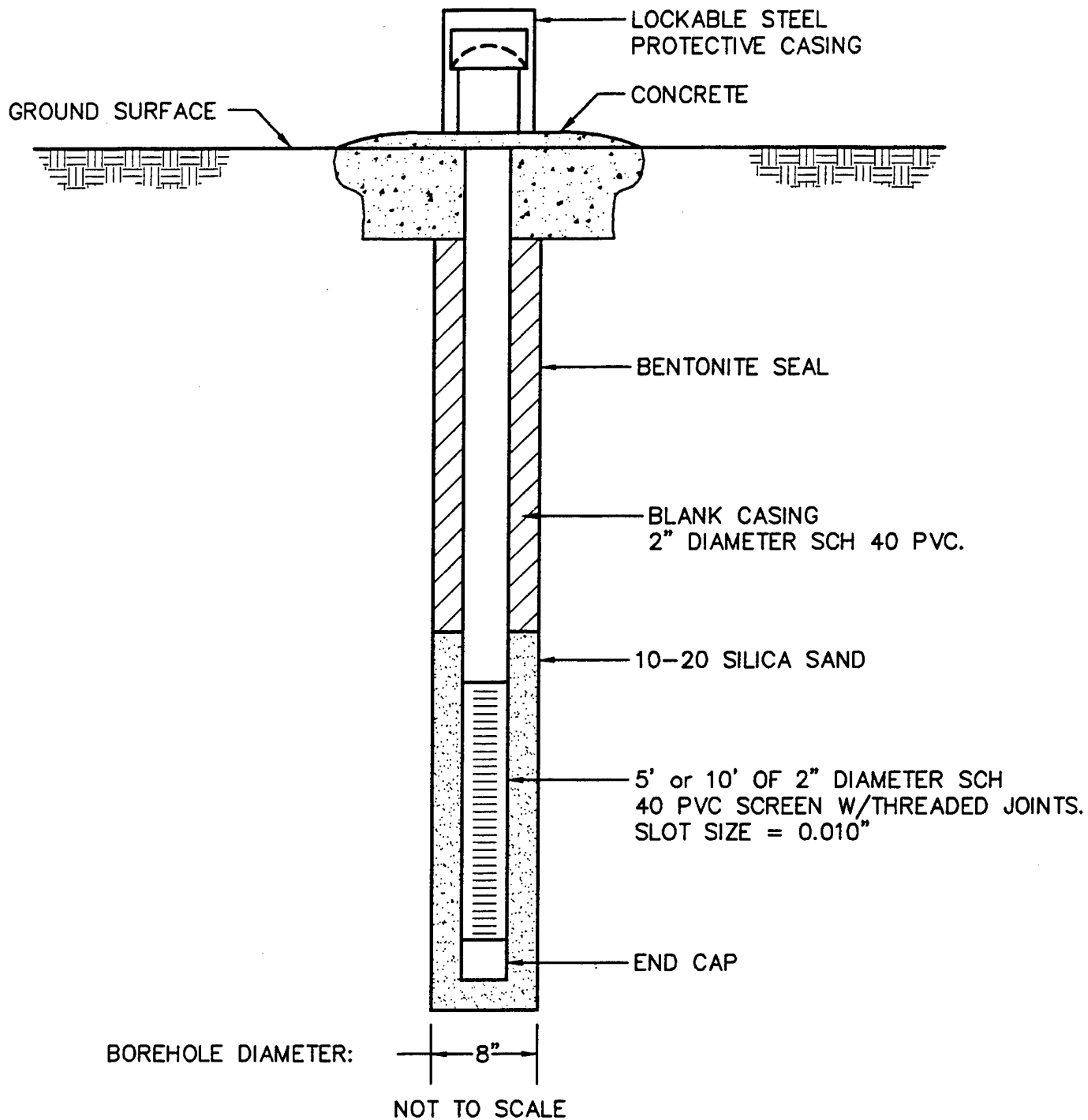


FIGURE 7.2

**PROPOSED MONITORING WELL
COMPLETION DIAGRAM**

POL Site SS-36
Intrinsic Remediation TS
Eglin Air Force Base, Florida



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includes a comprehensive sampling and analysis plan. LTM and POC samples should be collected 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 target levels for BTEX compounds that are intended to be protective of human health and the environment.

7.3.1 Analytical Protocol

All samples in the LTM program will be analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of intrinsic remediation at the site. At monitoring wells, water level measurements should be made during each sampling event. Groundwater and surface water samples should be analyzed for the parameters listed in Tables 7.1 and 7.2 (as well as any other analyses required by Chapter 62-770, FAC). A site-specific sampling and analysis plan should be prepared prior to initiating the LTM program.

7.3.2 Sampling Frequency

Each of the LTM and POC sampling points will be sampled once each year for 10 years. If the data collected during this time period support the anticipated effectiveness of the intrinsic remediation alternative at this site, the sampling frequency for all wells in the LTM program could be reduced to once every other year for the remainder of the 10-year sampling period, or sampling could be eliminated outright. If the data collected at any time during the monitoring period indicate the need for additional remedial activities at the site, the sampling frequency should be adjusted accordingly.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of a TS conducted to evaluate the use of intrinsic remediation with LTM for remediation of fuel-hydrocarbon-contaminated groundwater in the vicinity of Building 763 at POL Site SS-36, Eglin AFB, Florida. Specifically, the finite-difference groundwater flow model code MODFLOW and the contaminant transport code MT3D[®] were used in conjunction with site-specific geologic, hydrologic, and laboratory analytical data to simulate the migration and biodegradation of MOGAS-related fuel hydrocarbon compounds dissolved in groundwater. To collect the data necessary for the intrinsic remediation demonstration, Parsons ES and USEPA RSKERL researchers collected soil and groundwater samples from the site. Physical and chemical data collected under this program were supplemented (where necessary) with data collected during previous site characterization events. From this data, three lines of evidence have been used to document the occurrence of intrinsic remediation: 1) geochemical evidence; 2) documented loss of contaminant mass at the field scale; and 3) laboratory microcosm studies.

Comparison of BTEX, electron acceptor, and biodegradation byproduct isopleth maps for the Eglin AFB study site provides strong qualitative evidence of biodegradation of BTEX compounds. BTEX concentrations at monitoring wells decreased significantly between 1993 and 1994 sampling events, indicating a loss of contaminant mass. Geochemical data strongly suggest that biodegradation of fuel hydrocarbons is occurring at the site via the anaerobic processes of iron reduction and methanogenesis, as well as by aerobic respiration (in the vicinity of the creek). It appears that the aerobic respiration near the creek is rapidly consuming hydrocarbons that migrate to that area, preventing detectable concentrations of BTEX compounds from entering the surface water. This is evidenced by patterns of BTEX and DO distribution, and by the non-detection of BTEX compounds in surface water samples.

USEPA RSKERL researchers also performed a microcosm study using site soils; this study provided evidence of microbial degradation of BTEX compounds and a lower bound

on degradation rates. BTEX and TMB data also were used to calculate degradation rates. In addition, partitioning calculations using residual soil BTEX and TPH concentrations provided evidence of significant weathering of the remaining residual LNAPL.

Site-specific geologic, hydrologic, and laboratory analytical data then were used in the numerical groundwater flow and contaminant transport models to simulate the effects of advection, dispersion, sorption, 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 sediments similar to those found at the site. Conservative aquifer parameters were used to construct the models for this study, and therefore, the model results presented herein are very conservative.

For one simulation (model PREDICT1), it was assumed that conditions at the end of the calibrated model would persist for the duration of the simulation. This worst-case scenario suggests that the plume would recede slightly from the Fall 1994 plume configuration before BTEX migration halts and the plume stabilizes as a result of natural attenuation. Model PREDICT3 assumed that BTEX loading in the source areas would cease after 1995, producing an optimistic prediction of rapid plume degradation (within 5 years). Finally, the simulation PREDICT2 assumed that BTEX loading rates would remain constant for 5 more years before reducing to zero. This simulation suggested that the plume would persist for about 10 more years before natural attenuation reduces concentrations below regulatory levels of concern. Given the available evidence of continued source degradation, this is likely the most appropriate scenario to use for evaluation of future site conditions.

The results of this TS suggest that natural attenuation of BTEX compounds is occurring at the Eglin AFB site to the extent that the dissolved concentrations of these compounds in groundwater will continue to decline, reaching levels below current regulatory guidelines in about 9 years. The study results also indicate that the creek, which is a potential exposure point for dissolved contamination at this site, has not been impacted by contamination resulting from the 1988 MOGAS release. Given the rates of BTEX plume migration and degradation predicted by the model scenario PREDICT2, and that there are no identifiable impacts to the downgradient receptor, the recommended remedial option for BTEX-impacted groundwater at the site is intrinsic remediation, institutional controls, and LTM. Construction activities in the plume area and potable groundwater/surface water use in and

downgradient from the plume area should be restricted for a period of approximately 10 years.

To verify the results of the modeling effort, and to ensure that natural attenuation rates are sufficient to protect potential downgradient receptors, groundwater from monitoring wells EPA 83-1, EPA 83-2, EPA 83-7, and one additional proposed LTM well should be sampled annually and analyzed for the parameters listed in Table 7.1 (as well as parameters specified in Chapter 62-770, FAC). In addition, POC samples should be collected from a nested set of three POC groundwater monitoring wells to be installed near the creek, as well as from two locations in the creek. POC samples should be collected annually and analyzed for the parameters listed in Table 7.2 (as well as parameters specified in Chapter 62-770, FAC). Figure 7.1 shows suggested locations for POC and LTM sampling. Sampling should continue annually for 10 years. If the concentrations of dissolved BTEX or other target analytes in the POC samples exceed state target levels, additional evaluation or corrective action may be necessary at this site.

SECTION 9

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APPENDIX A

BORING LOGS, CPT LOGS, WELL COMPLETION DIAGRAMS, WELL DEVELOPMENT RECORDS, AND HYDRAULIC CONDUCTIVITY TESTING RESULTS

BORING NO.:	EPA-83-1	CONTRACTOR:	DATE SPUD:	9/20/93
CLIENT:	AFCEE	RIG TYPE:	DATE CMPL.:	9/20/93
JOB NO.:	722450.03	DRLG METHOD:	ELEVATION:	12.84 ft msl
LOCATION:	SITE SS-36	BORING DIA.:	TEMP:	90
GEOLOGIST:	TW	DRLG FLUID:	WEATHER:	CLEAR AND HOT
COMMENTS:				

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample	Sample	Penet Res*	PID(ppm)	WKSPC PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	- 1 -			Sand, light gray near surface, becomes reddish brown (Fe3+) by 12", damp, very well sorted quartz sand, well rounded grains, strong HC odor at about 2'	0-1	CONTINUOUS CORE	PH				
				1-2	PH		8				
				2-3	PH		1000				
				3-4	PH						
				4-5	PH		341				
	5			5-6	PH		572				
				6-7	1/1		181				
				7-8	3/3		170				
				8-9	3/5		22				
				9-10	23/26		437				
	10			10-11	2/3		131				
				11-12	15/24		352				
				12-13	6/8		833				
				13-14	30/33		182				
				14-15	3/7		17				
	15			15-16	24/23		333				
				16-17			291				
				17-18	1/4		521				
				18-19	6/12		179				
	20			19-20	19/21		210				
				20-21	5/9		320				
				21-22	10/18		81				
				22-23	10/7		20				
				23-24	4/16		260				
	25			24-25	1/1		10				
				25-26	2/5		55				
				26-27	3/8		17				
				27-28	5/5		51				
				28-29	2/2		38				
	30			29-30	5/5		12				
35											

* Penetration Resistance, blows per 6"/per 6"

NOTES

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above
PH - Sampler Post Holed

SAMPLE TYPE

D — DRIVE
C — CORE
G — GRAB



Water level drilled

GEOLOGIC BORING LOG

Site SS-36
Intrinsic Remediation Demonstration
Eqlin AFB, Florida



**PARSONS
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Denver, Colorado

Sheet 1 of 1

BORING NO.:	<u>EPA-83-3</u>	CONTRACTOR:	<u>LAYNE ENVIRONMENTAL SERVICES</u>	DATE SPUD:	<u>9/21/93</u>
CLIENT:	<u>AFCEE</u>	RIG TYPE:	<u>CME-55</u>	DATE CMPL.:	<u>9/21/93</u>
JOB NO.:	<u>722450.03</u>	DRLG METHOD:	<u>HOLLOW STEM AUGER</u>	ELEVATION:	<u>5.77 ft msl</u>
LOCATION:	<u></u>	BORING DIA.:	<u>8.25"</u>	TEMP:	<u>90</u>
GEOLOGIST:	<u>TW</u>	DRLG FLUID:	<u>NONE</u>	WEATHER:	<u>CLEAR AND HOT</u>
COMMENTS:	<u></u>				

[illegible]

* Penetration Resistance, Blows per 6"/per 6"

NOTES

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above
PH - Sampler Post Holed

SAMPLE TYPE

D — DRIVE
C — CORE
G — GRAB



GEOLOGIC BORING LOG

Site SS-36
Intrinsic Remediation Demonstration
Eqlin AFB, Florida



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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: EPA-83-7 CONTRACTOR: LAYNE ENVIRONMENTAL SERVICES DATE SPUD: 9/23/93
 CLIENT: AFCEE RIG TYPE: CME-55 DATE CMPL.: 9/23/93
 JOB NO.: 722450.03 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 10.68 ft msl
 LOCATION: SITE SS-36 BORING DIA.: 8.25" TEMP: 90
 GEOLOGIST: TW DRLG FLUID: NONE WEATHER: CLEAR AND HOT
 COMMENTS: Pushed split spoon sampler to depth(post holed)

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
	1			White to light gray, moderately sorted fine grained sand, slight silt content, almost 100% quartz, upper 10" to 1' is stained with Fe3+ which imparts a reddish-brown color, damp, roots, no odor	0.5-1		CONTINUOUS CORE		0			
					1-1.5				0			
					1.5-2				0			
					2-2.5				0			
					2.5-3				1			
				Same as above, becomes saturated at about 4.5' bgs odor of long chain hydrocarbons	3-4				4			
	5			Same as above but stronger odor and darker gray color	4-5				410			
					5-6				-			
					6-7				1000?			
					7-8				50			
				Becomes a dark gray color, some clay, fair to medium grained, moderately sorted sand, sheen observed on water in split spoon	8-9				250			
	10				9-10				191			
					10-11				1000?			
				Peat at 10.75', clay dark brown with large amounts of root material, TD at 11', strong odor								
	15											
	20											
	25											
	30											
	35											

NOTES

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



Water level drilled

GEOLOGIC BORING LOG

Site SS-36
 Intrinsic Remediation Demonstration
 Eglin AFB, Florida



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Note on Cone Penetrometer Logs

In order to use these logs, you must translate the coordinates printed on the log sheets to the new numbering scheme using the enclosed table entitled "Cone Penetrometer Locations".

The enclosed map displays the locations of all cone holes at the POL facility except CPT-1 which is far off site.

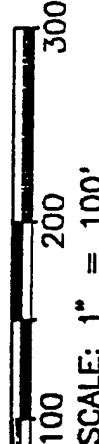
If you have any questions, contact

Howard Sweed
Rice University
(713) 527-4656.

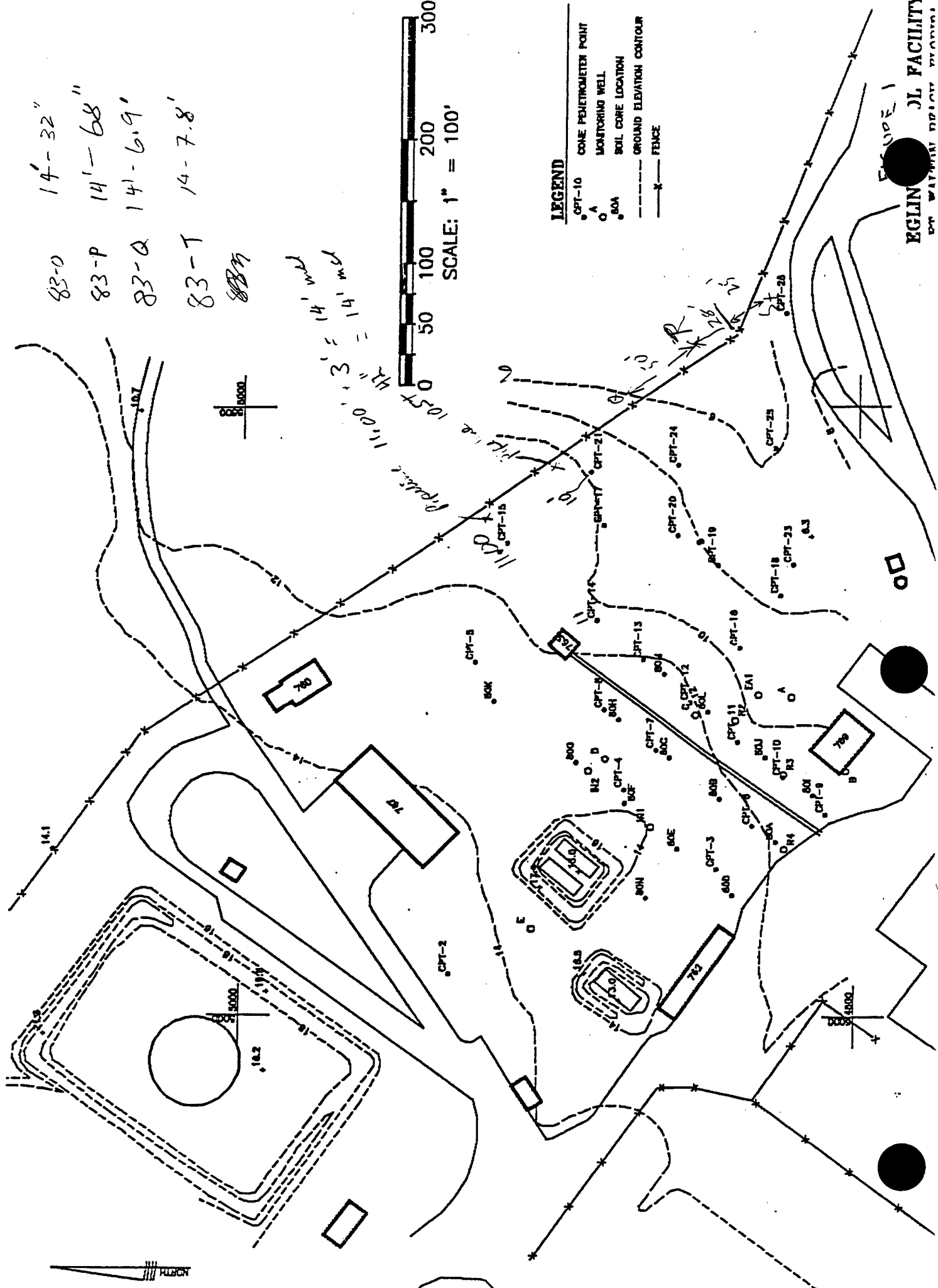
83-0 14'-32"
 83-P 14'-68"
 83-Q 14'-6.9'
 83-T 14'-7.8'

83-3

11.00
 10.57
 42" = 14' mud
 14' mud



- LEGEND**
- CPT-10 CONE PENETROMETER POINT
 - A MONITORING WELL
 - B04 SOIL CORE LOCATION
 - - - GROUND ELEVATION CONTOUR
 - - - FENCE



EGLON J1 FACILITY
 BY WATKINS DESIGN GROUP

Eglin AFB - Cone Penetrometer Locations

ID#	Cone Log Coordinates	
	x	y
CPT-1	No log available	
CPT-2	-100.00	200.00
CPT-3	150.00	100.00
CPT-4	150.00	200.00
CPT-5	150.00	350.00
CPT-6	200.00	100.00
CPT-7	200.00	200.00
CPT-8	200.00	250.00
CPT-9	250.00	50.00
CPT-10	250.00	100.00
CPT-11	250.00	150.00
CPT-12	250.00	200.00
CPT-13	250.00	250.00
CPT-14	250.00	300.00
CPT-15	250.00	400.00
CPT-16	300.00	200.00
CPT-17	300.00	350.00
CPT-18	350.00	200.00
CPT-19	350.00	250.00
CPT-20	350.00	300.00
CPT-21	350.00	400.00
CPT-22	400.00	0.00
CPT-23	400.00	200.00
CPT-24	400.00	350.00
CPT-25	450.00	300.00
CPT-26	550.00	400.00

80C
- 80H

EGLIN AFB

CONTRACTOR : TERRA TECH.

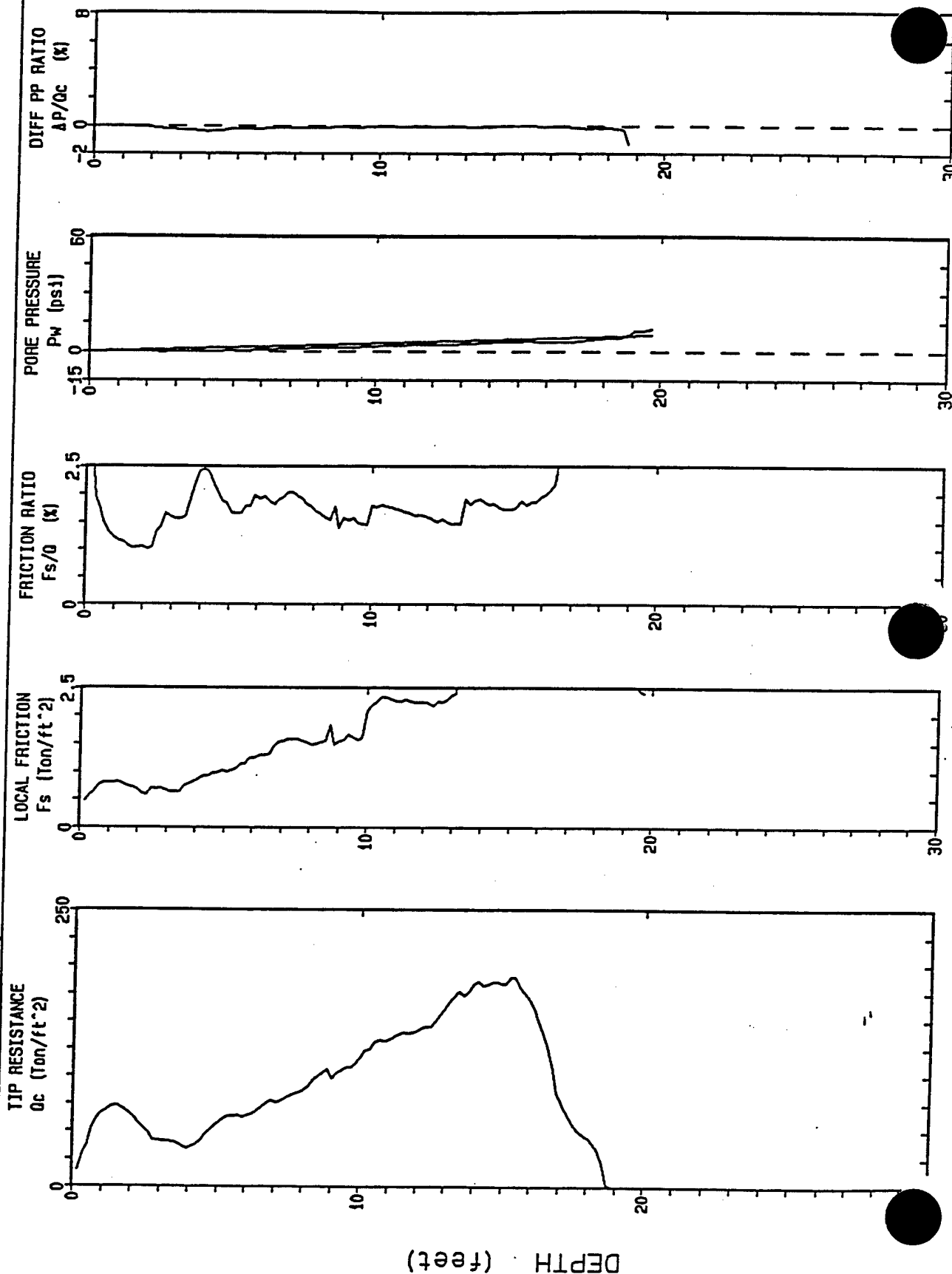
LOCATION : ~~100-200~~
-100,200

DATE : 1 03-24-93

ELEVATION : UNKNOWN

SOUNDING NO. : 1 Pg 1 / 1

TERRA JOB NO. : 93-1003



Contractor : TERRA TECH.

Location : -100-200

Job No. : 93-1003

Unit Wt. (avg) : 100 pcf

Test Date : 03-24-93

Elevation : UNKNOWN

Water table (meters) : 1

CPT-2

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	38.64	0.65	1.67	0.02	silty sand to sandy silt	>90	>48	12	UNDEFINED
0.50	1.64	70.28	0.79	1.12	0.06	sand to silty sand	>90	>48	17	UNDEFINED
0.75	2.46	60.72	0.66	1.09	0.10	silty sand to sandy silt	80-90	>48	19	UNDEFINED
1.00	3.28	42.82	0.67	1.56	0.14	silty sand to sandy silt	70-80	44-46	14	UNDEFINED
1.25	4.10	37.06	0.77	2.08	0.17	sandy silt to clayey silt	UNDFND	UNDFD	14	3.07
1.50	4.92	46.82	0.96	2.05	0.19	sandy silt to clayey silt	UNDFND	UNDFD	18	3.88
1.75	5.74	62.48	1.08	1.72	0.20	silty sand to sandy silt	70-80	44-46	20	UNDEFINED
2.00	6.56	66.64	1.28	1.92	0.22	silty sand to sandy silt	70-80	44-46	21	UNDEFINED
2.25	7.38	77.42	1.54	1.99	0.23	silty sand to sandy silt	80-90	46-48	25	UNDEFINED
2.50	8.20	86.32	1.53	1.77	0.25	silty sand to sandy silt	80-90	46-48	28	UNDEFINED
2.75	9.02	100.74	1.59	1.58	0.26	silty sand to sandy silt	80-90	46-48	32	UNDEFINED
3.00	9.84	107.04	1.61	1.50	0.28	sand to silty sand	80-90	46-48	26	UNDEFINED
3.25	10.66	125.44	2.25	1.79	0.29	silty sand to sandy silt	>90	46-48	40	UNDEFINED
3.50	11.48	135.04	2.28	1.69	0.31	sand to silty sand	>90	46-48	32	UNDEFINED
3.75	12.30	141.20	2.23	1.58	0.33	sand to silty sand	>90	46-48	34	UNDEFINED
4.00	13.12	155.02	2.32	1.50	0.34	sand to silty sand	>90	46-48	37	UNDEFINED
4.25	13.94	176.10	3.32	1.88	0.36	sand to silty sand	>90	46-48	42	UNDEFINED
4.50	14.76	184.26	3.28	1.78	0.37	sand to silty sand	>90	46-48	44	UNDEFINED
4.75	15.58	184.98	3.36	1.82	0.39	sand to silty sand	>90	46-48	44	UNDEFINED
5.00	16.40	158.86	3.20	2.01	0.40	silty sand to sandy silt	>90	46-48	>50	UNDEFINED
5.25	17.22	93.10	3.24	3.48	0.42	sandy silt to clayey silt	UNDFND	UNDFD	36	7.68
5.50	18.04	50.98	2.88	5.64	0.43	clay	UNDFND	UNDFD	49	4.17
5.75	18.86	19.16	2.84	14.81	0.45	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.00	19.69	0.00	2.55	0.00	0.46	undefined	UNDFND	UNDFD	UDF	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

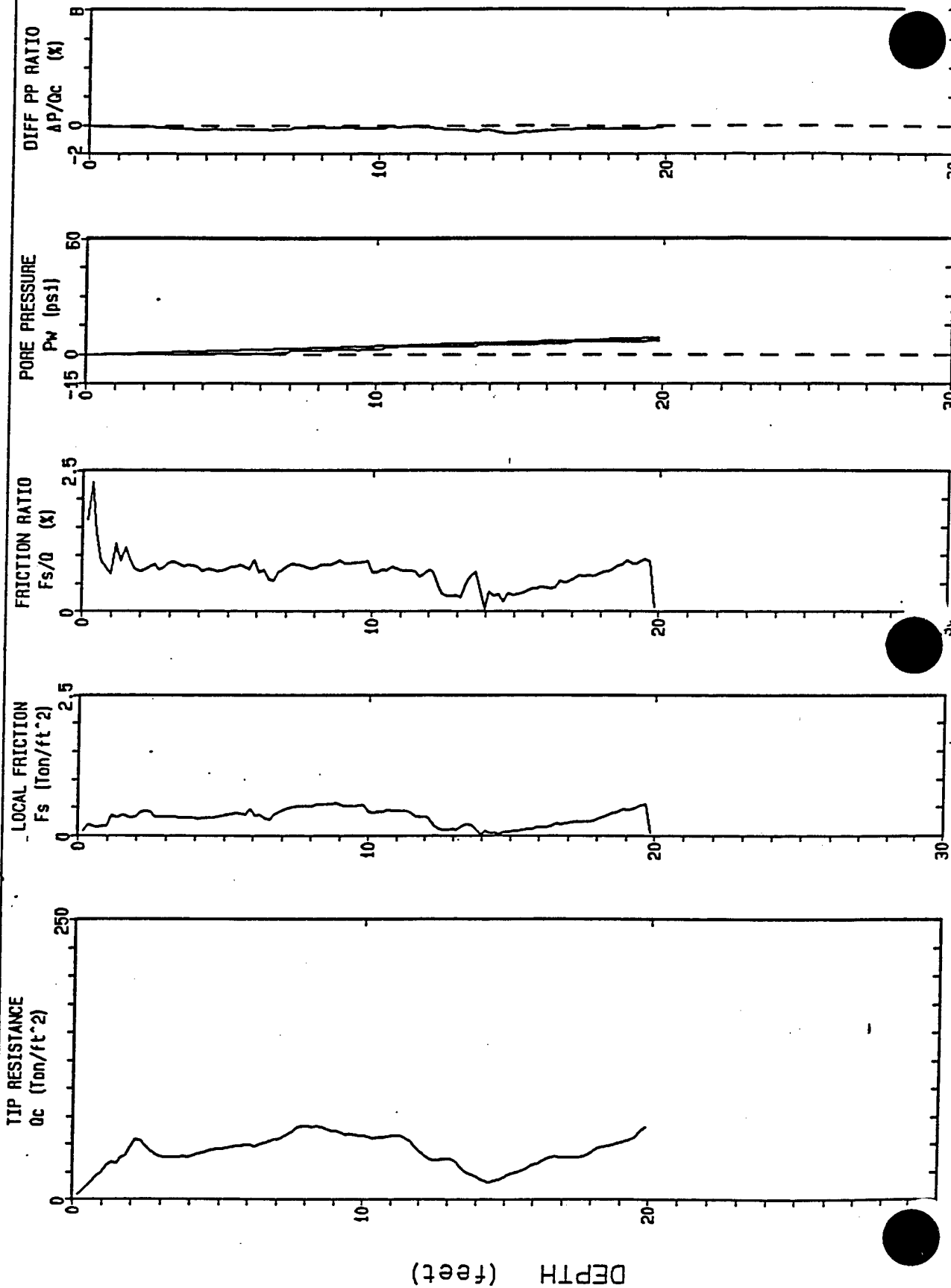
PHI - Robertson and Campanella 1983

Su: Nk= 12

** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH. SOUNDING NO. : 1 Pg 1 / 1
LOCATION : 100-50 ¹⁰⁰50,100 DATE : 7 03-24-93 TERRA JOB NO. : 93-1003
ELEVATION : UNKNOWN



Contractor : TERRA TECH.

Test Date : 03-24-93

Location : 150-50

Elevation : UNKNOWN

Job No. : 93-1003

Water table (meters) : 1

Unit Wt. (avg) : 100 pcf

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	12.70	0.15	1.20	0.02	sandy silt to clayey silt	UNDFND	UNDFD	5	1.05
0.50	1.64	31.84	0.31	0.99	0.06	silty sand to sandy silt	70-80	46-48	10	UNDEFINED
0.75	2.46	49.04	0.38	0.78	0.10	silty sand to sandy silt	70-80	46-48	16	UNDEFINED
1.00	3.28	40.56	0.34	0.83	0.14	silty sand to sandy silt	60-70	44-46	13	UNDEFINED
1.25	4.10	38.82	0.31	0.80	0.17	silty sand to sandy silt	60-70	44-46	12	UNDEFINED
1.50	4.92	44.02	0.33	0.75	0.19	silty sand to sandy silt	60-70	44-46	14	UNDEFINED
1.75	5.74	47.66	0.38	0.80	0.20	silty sand to sandy silt	60-70	44-46	15	UNDEFINED
2.00	6.56	49.76	0.35	0.70	0.22	sand to silty sand	60-70	44-46	12	UNDEFINED
2.25	7.38	56.02	0.45	0.80	0.23	sand to silty sand	70-80	44-46	13	UNDEFINED
2.50	8.20	65.08	0.52	0.80	0.25	sand to silty sand	70-80	44-46	16	UNDEFINED
2.75	9.02	63.86	0.55	0.86	0.26	sand to silty sand	70-80	44-46	15	UNDEFINED
3.00	9.84	59.52	0.52	0.88	0.28	sand to silty sand	70-80	44-46	14	UNDEFINED
3.25	10.66	56.88	0.42	0.74	0.29	sand to silty sand	60-70	42-44	14	UNDEFINED
3.50	11.48	57.60	0.43	0.74	0.31	sand to silty sand	60-70	42-44	14	UNDEFINED
3.75	12.30	44.54	0.29	0.66	0.33	silty sand to sandy silt	50-60	42-44	14	UNDEFINED
4.00	13.12	36.18	0.10	0.28	0.34	sand to silty sand	50-60	40-42	9	UNDEFINED
4.25	13.94	26.80	0.13	0.48	0.36	silty sand to sandy silt	40-50	38-40	9	UNDEFINED
4.50	14.76	17.58	0.05	0.30	0.37	silty sand to sandy silt	<40	36-38	6	UNDEFINED
4.75	15.58	23.84	0.08	0.34	0.39	silty sand to sandy silt	<40	38-40	8	UNDEFINED
5.00	16.40	32.52	0.14	0.43	0.40	silty sand to sandy silt	40-50	40-42	10	UNDEFINED
5.25	17.22	38.48	0.22	0.57	0.42	silty sand to sandy silt	50-60	40-42	12	UNDEFINED
5.50	18.04	40.22	0.27	0.66	0.43	silty sand to sandy silt	50-60	40-42	13	UNDEFINED
5.75	18.86	48.88	0.40	0.81	0.45	silty sand to sandy silt	50-60	40-42	16	UNDEFINED
6.00	19.69	56.02	0.50	0.89	0.46	sand to silty sand	60-70	40-42	13	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT.PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 150-200

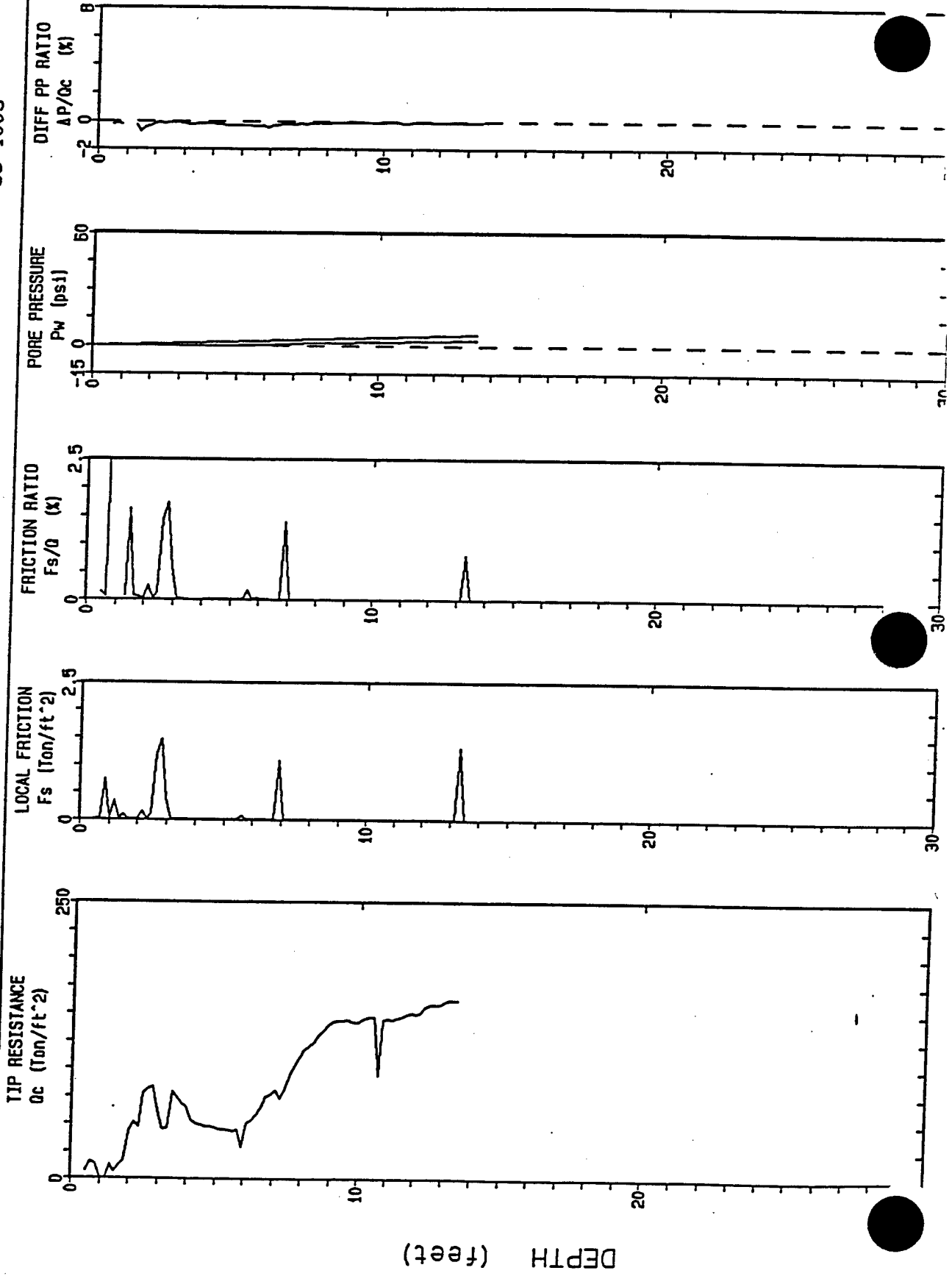
DATE : 1 03-22-93

ELEVATION : UNKNOWN

SOUNDING NO. :

TERRA JOB NO. : 93-1003

Pg 1 / 1



Contractor : TERRA TECH.
Location : 150-200
Job No. : 93-1003
Unit Wt. (avg) : 100 pcf

Test Date : 03-22-93
Elevation : UNKNOWN
Water table (meters) : 1

CPT-4

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.82	2.69	7.16	0.22	3.10	0.07	clay	UNDFND	UNDFD	7	.59
1.64	5.38	18.10	0.03	0.15	0.18	silty sand to sandy silt	40-50	40-42	6	UNDEFINED
2.46	8.07	68.56	0.58	0.85	0.23	sand to silty sand	70-80	44-46	16	UNDEFINED
3.28	10.76	61.58	0.08	0.14	0.28	sand to silty sand	70-80	44-46	15	UNDEFINED
4.10	13.45	57.60	0.01	0.02	0.33	sand to silty sand	60-70	42-44	14	UNDEFINED
4.92	16.14	46.60	0.01	0.02	0.38	sand to silty sand	50-60	40-42	11	UNDEFINED
5.74	18.83	42.80	0.02	0.06	0.43	sand to silty sand	50-60	40-42	10	UNDEFINED
6.56	21.52	65.96	0.22	0.34	0.48	sand to silty sand	60-70	42-44	16	UNDEFINED
7.38	24.21	86.50	0.01	0.01	0.53	sand	70-80	42-44	17	UNDEFINED
8.20	26.90	120.56	0.01	0.01	0.58	sand	70-80	44-46	23	UNDEFINED
9.02	29.59	140.80	0.01	0.01	0.63	sand	80-90	44-46	27	UNDEFINED
9.84	32.28	143.74	0.01	0.01	0.68	sand	80-90	44-46	28	UNDEFINED
10.66	34.97	135.54	0.01	0.01	0.73	sand	70-80	42-44	26	UNDEFINED
11.48	37.66	147.54	0.01	0.01	0.78	sand	80-90	42-44	28	UNDEFINED
12.30	40.35	154.16	0.01	0.01	0.83	sand	80-90	42-44	30	UNDEFINED
13.12	43.04	160.58	0.27	0.17	0.89	sand	80-90	42-44	31	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985) PHI - Robertson and Campanella 1983 Su: Nk= 12

*** For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ***

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 150-350

DATE : 4 03-24-93

ELEVATION : UNKNOWN

SOUNDING NO. : 1

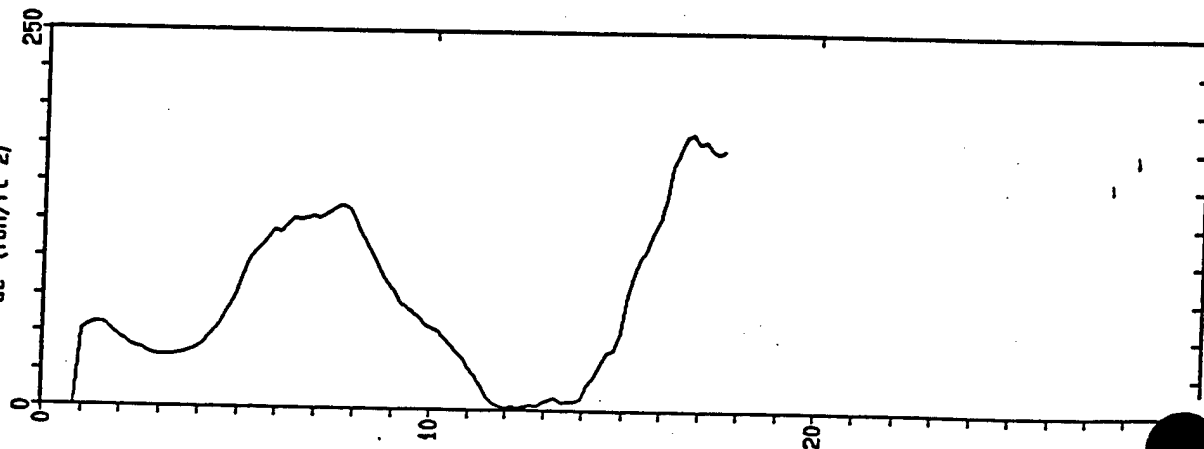
TERRA JOB NO. : 93-1003

Pg 1 / 1

93-1003

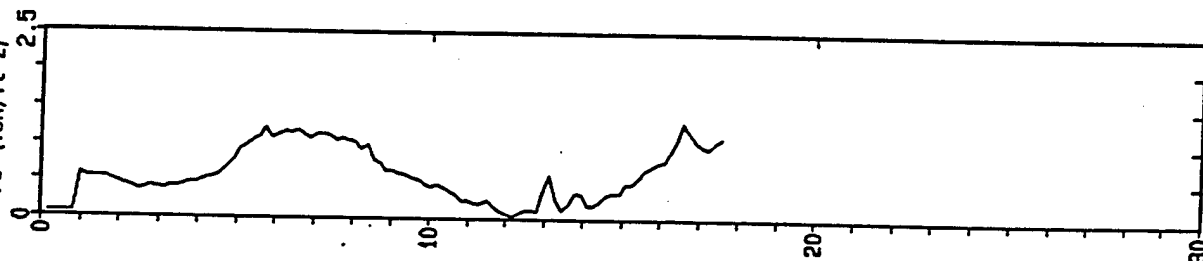
TIP RESISTANCE

Q_c (Ton/ft²)



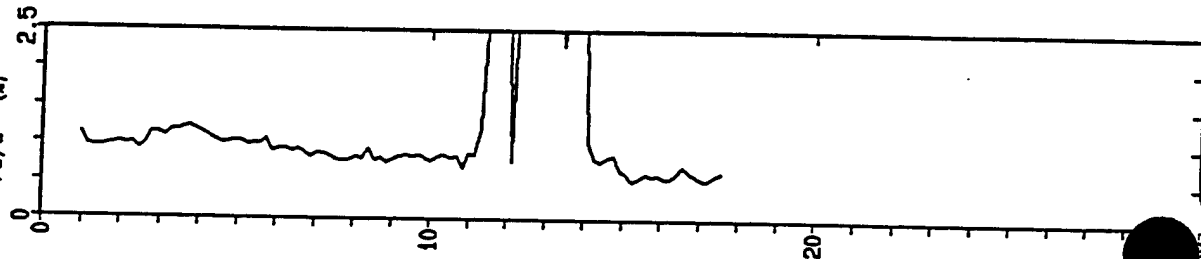
LOCAL FRICTION

F_s (Ton/ft²)



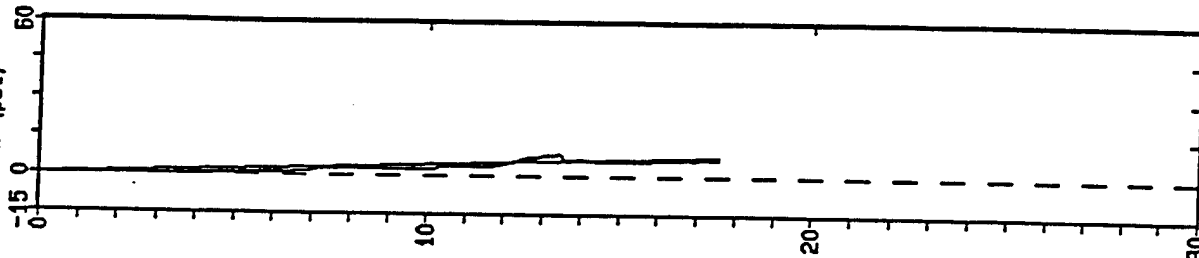
FRICTION RATIO

F_s/Q_c (%)



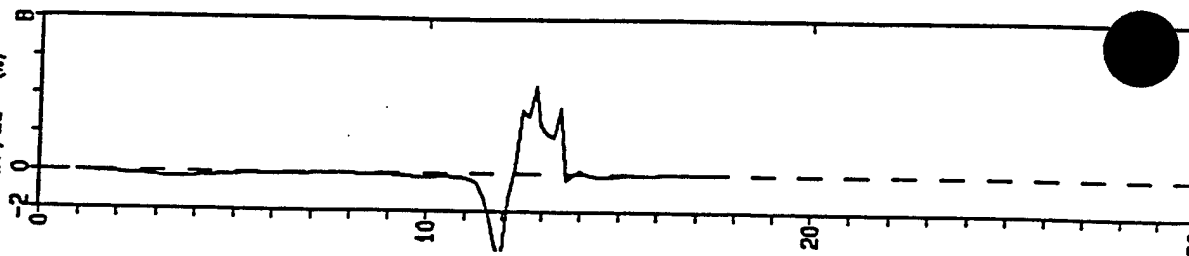
PORE PRESSURE

P_w (psf)



DIFF PP RATIO

$\Delta P/Q_c$ (%)



DEPTH (feet)

Contractor : TERRA TECH.

Location : 150-350

Job No. : 93-1003

Unit Wt. (avg) : 100 pcf

Test Date : 03-24-93

Elevation : UNKNOWN

Water table (meters) : 1

CPT-5

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	0.00	0.06	0.00	0.02	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.50	1.64	54.78	0.54	0.99	0.06	silty sand to sandy silt	80-90	>48	17	UNDEFINED
0.75	2.46	44.56	0.44	0.98	0.10	silty sand to sandy silt	70-80	46-48	14	UNDEFINED
1.00	3.28	35.68	0.40	1.11	0.14	silty sand to sandy silt	60-70	44-46	11	UNDEFINED
1.25	4.10	38.80	0.46	1.19	0.17	silty sand to sandy silt	60-70	44-46	12	UNDEFINED
1.50	4.92	60.72	0.63	1.04	0.19	silty sand to sandy silt	70-80	46-48	19	UNDEFINED
1.75	5.74	102.50	1.05	1.03	0.20	sand to silty sand	>90	46-48	25	UNDEFINED
2.00	6.56	122.16	1.13	0.93	0.22	sand to silty sand	>90	>48	29	UNDEFINED
2.25	7.38	128.10	1.11	0.86	0.23	sand	>90	>48	25	UNDEFINED
2.50	8.20	127.58	1.02	0.80	0.25	sand	>90	46-48	24	UNDEFINED
2.75	9.02	91.52	0.76	0.83	0.26	sand to silty sand	80-90	46-48	22	UNDEFINED
3.00	9.84	64.38	0.54	0.84	0.28	sand to silty sand	70-80	44-46	15	UNDEFINED
3.25	10.66	47.50	0.39	0.83	0.29	silty sand to sandy silt	60-70	42-44	15	UNDEFINED
3.50	11.48	22.26	0.23	1.02	0.31	sandy silt to clayey silt	UNDFND	UNDFD	9	1.80
3.75	12.30	2.58	0.08	3.02	0.33	clay	UNDFND	UNDFD	2	.16
4.00	13.12	4.18	0.25	5.98	0.34	clay	UNDFND	UNDFD	4	.29
4.25	13.94	6.78	0.25	3.75	0.36	clay	UNDFND	UNDFD	6	.50
4.50	14.76	30.28	0.26	0.85	0.37	silty sand to sandy silt	40-50	40-42	10	UNDEFINED
4.75	15.58	84.90	0.50	0.58	0.39	sand to silty sand	70-80	44-46	20	UNDEFINED
5.00	16.40	144.08	0.83	0.58	0.40	sand	>90	46-48	28	UNDEFINED
5.25	17.22	179.38	1.08	0.60	0.42	sand	>90	46-48	34	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

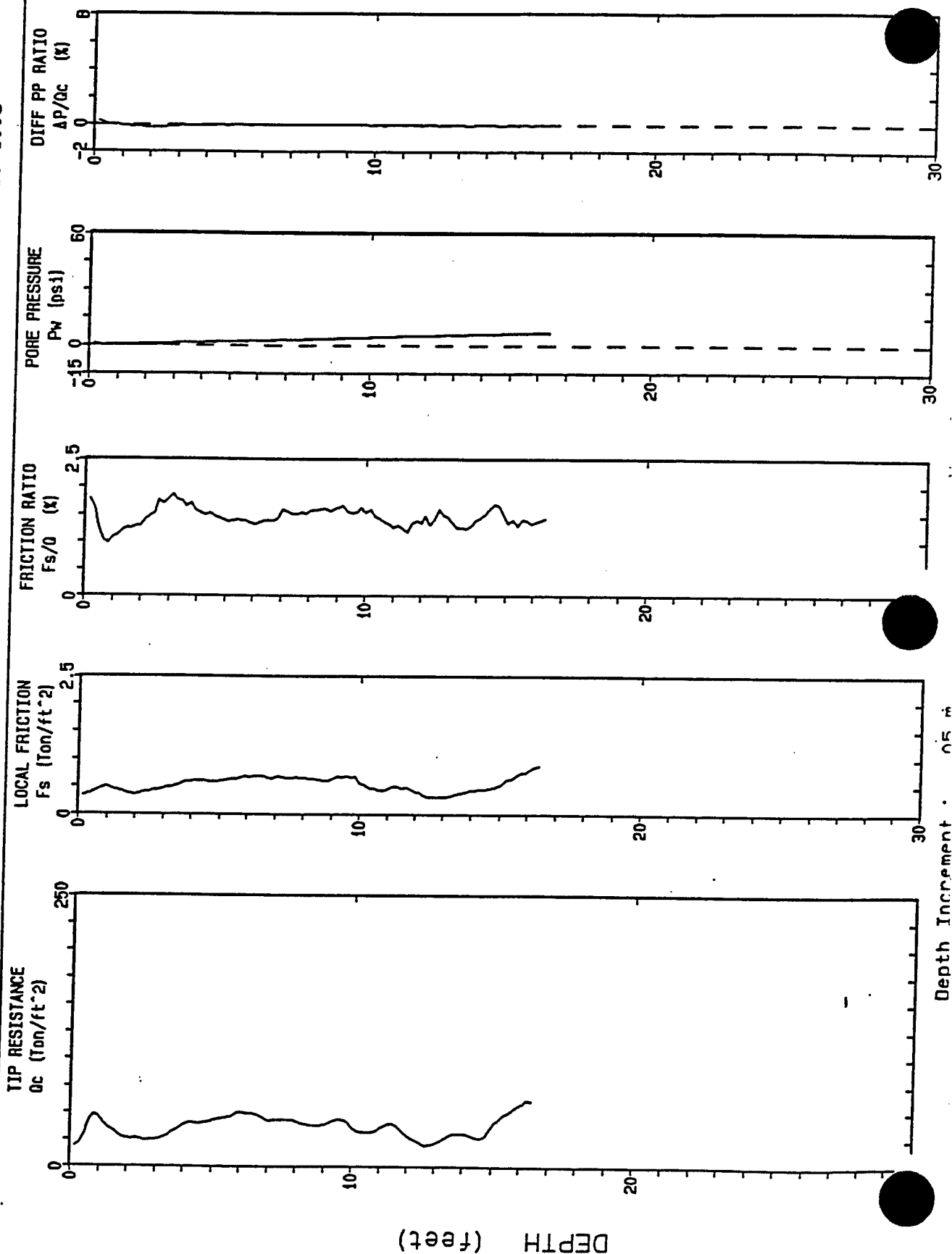
* Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.
 LOCATION : 200-100

DATE : 0 03-25-93
 ELEVATION : UNKNOWN

SOUNDING NO. :
 TERRA JOB NO. : 93-1003



Depth Increment : 0.5 ft

EGLIN AFB - RICE UNIVERSITY

Contractor : TERRA TECH.

Location : 200-100

Job No. : 93-1003

Unit Wt. (avg) : 100 pcf

Test Date : 03-25-93

Elevation : UNKNOWN

Water table (meters) : 1

CPT 6

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	32.52	0.40	1.23	0.02	silty sand to sandy silt	>90	>48	10	UNDEFINED
0.50	1.64	37.08	0.44	1.18	0.06	silty sand to sandy silt	70-80	>48	12	UNDEFINED
0.75	2.46	26.80	0.38	1.40	0.10	sandy silt to clayey silt	UNDFND	UNDFD	10	2.22
1.00	3.28	25.74	0.46	1.78	0.14	sandy silt to clayey silt	UNDFND	UNDFD	10	2.13
1.25	4.10	34.62	0.57	1.63	0.17	sandy silt to clayey silt	UNDFND	UNDFD	13	2.87
1.50	4.92	40.72	0.60	1.47	0.19	silty sand to sandy silt	60-70	44-46	13	UNDEFINED
1.75	5.74	45.24	0.63	1.40	0.20	silty sand to sandy silt	60-70	44-46	14	UNDEFINED
2.00	6.56	49.78	0.68	1.37	0.22	silty sand to sandy silt	60-70	44-46	16	UNDEFINED
2.25	7.38	44.20	0.66	1.50	0.23	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
2.50	8.20	42.46	0.66	1.54	0.25	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
2.75	9.02	38.66	0.62	1.60	0.26	silty sand to sandy silt	50-60	42-44	12	UNDEFINED
3.00	9.84	42.82	0.68	1.58	0.28	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
3.25	10.66	33.24	0.49	1.48	0.29	silty sand to sandy silt	50-60	40-42	11	UNDEFINED
3.50	11.48	37.42	0.47	1.26	0.31	silty sand to sandy silt	50-60	40-42	12	UNDEFINED
3.75	12.30	30.10	0.41	1.38	0.33	sandy silt to clayey silt	UNDFND	UNDFD	12	2.45
4.00	13.12	21.76	0.32	1.46	0.34	sandy silt to clayey silt	UNDFND	UNDFD	8	1.76
4.25	13.94	29.26	0.38	1.30	0.36	silty sand to sandy silt	40-50	40-42	9	UNDEFINED
4.50	14.76	28.90	0.46	1.58	0.37	sandy silt to clayey silt	UNDFND	UNDFD	11	2.34
4.75	15.58	44.04	0.61	1.38	0.39	silty sand to sandy silt	50-60	40-42	14	UNDEFINED
5.00	16.40	58.64	0.81	1.38	0.40	silty sand to sandy silt	60-70	42-44	19	UNDEFINED

Dr All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 200-200

DATE : 2 03-22-93

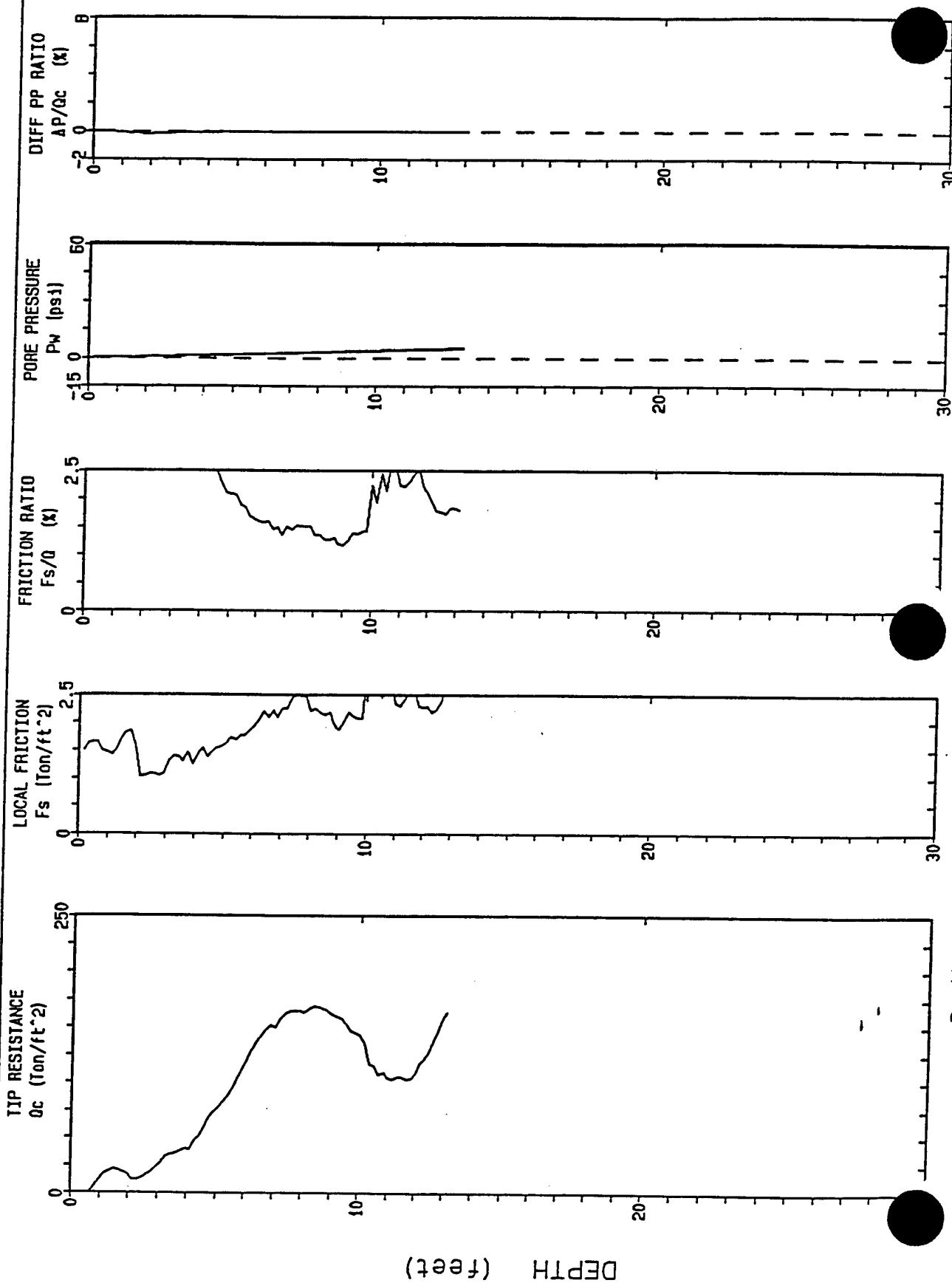
ELEVATION : UNKNOWN

SOUNDING NO. :

TERRA JOB NO. :

Pg 1 / 1

93-1003



Contractor : TERRA TECH.

Location : 200-200

Job No. : 93-1003

Unit Wt. (avg) : 100 pcf

Test Date : 03-22-93

Elevation : UNKNOWN

Water table (meters) : 1

CPT-7

DEPTH meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	1.22	1.59	130.33	0.02	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.50	1.64	18.46	1.60	8.65	0.06	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.75	2.46	14.96	1.31	8.77	0.10	undefined	UNDFND	UNDFD	UDF	UNDEFINED
1.00	3.28	24.00	1.18	4.92	0.14	clay	UNDFND	UNDFD	23	1.98
1.25	4.10	37.42	1.37	3.65	0.17	clayey silt to silty clay	UNDFND	UNDFD	18	3.10
1.50	4.92	60.36	1.50	2.49	0.19	sandy silt to clayey silt	UNDFND	UNDFD	23	5.01
1.75	5.74	90.30	1.72	1.90	0.20	silty sand to sandy silt	80-90	46-48	29	UNDEFINED
2.00	6.56	128.94	2.03	1.58	0.22	sand to silty sand	>90	>48	31	UNDEFINED
2.25	7.38	154.00	2.27	1.47	0.23	sand to silty sand	>90	>48	37	UNDEFINED
2.50	8.20	164.42	2.39	1.45	0.25	sand to silty sand	>90	>48	39	UNDEFINED
2.75	9.02	165.64	2.07	1.25	0.26	sand to silty sand	>90	>48	40	UNDEFINED
3.00	9.84	152.26	2.09	1.38	0.28	sand to silty sand	>90	>48	36	UNDEFINED
3.25	10.66	123.52	2.81	2.27	0.29	silty sand to sandy silt	>90	46-48	39	UNDEFINED
3.50	11.48	105.46	2.49	2.36	0.31	silty sand to sandy silt	80-90	46-48	34	UNDEFINED
3.75	12.30	110.84	2.33	2.10	0.33	silty sand to sandy silt	80-90	46-48	35	UNDEFINED
4.00	13.12	146.16	2.63	1.80	0.34	sand to silty sand	>90	46-48	35	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

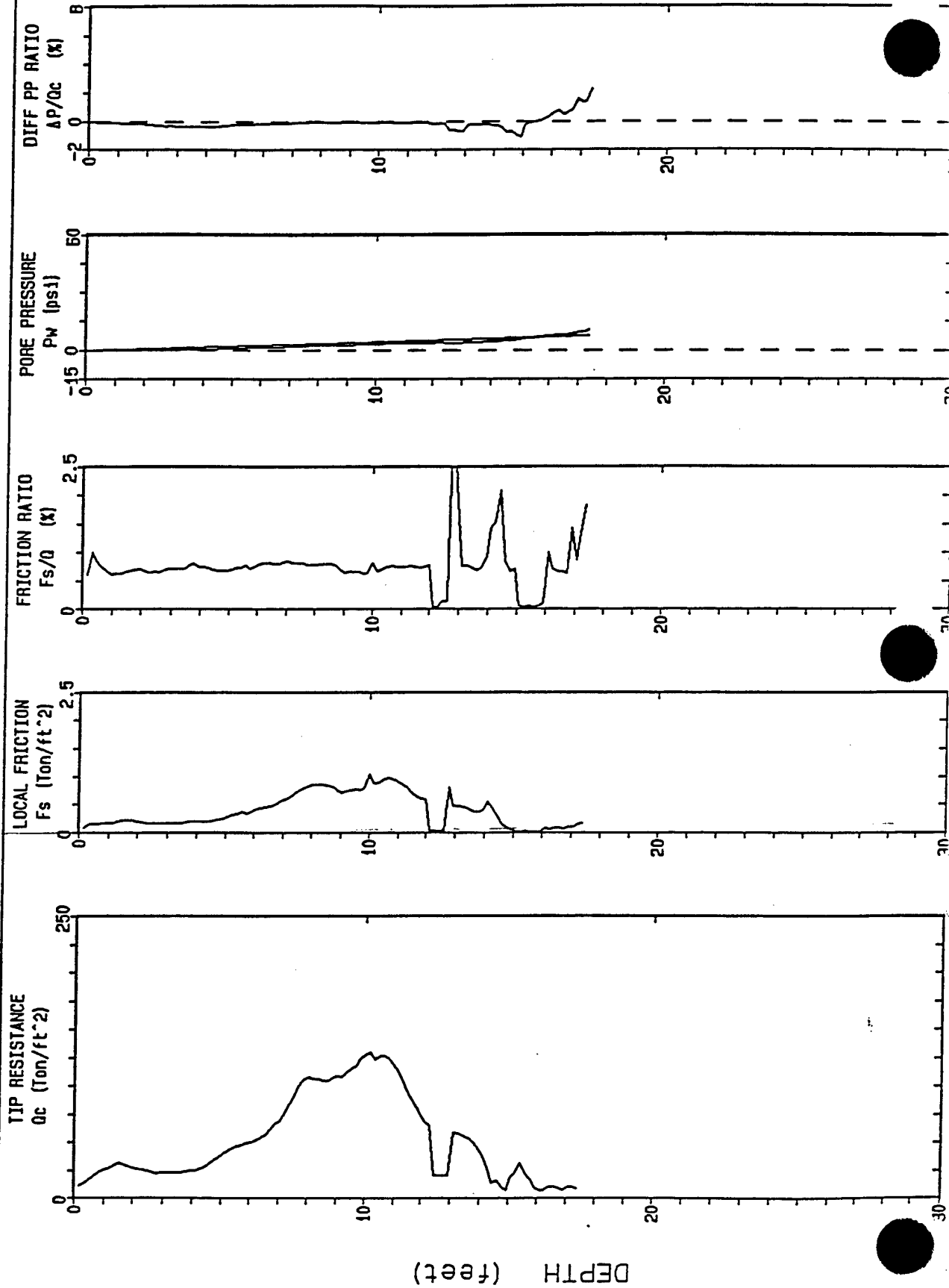
*** For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ***

EGLIN AFB

CONTRACTOR : TERRA TECH.
LOCATION : 200-250

DATE : 1 03-25-93
ELEVATION : UNKNOWN

SOUNDING NO. : 2 Pg 1 / 1
TERRA JOB NO. : 93-1003



Contractor : TERRA TECH.

Location : 200-250

Job No. : 93-1003

Net. Unit Wt. (avg) : 100 pcf

Test Date : 03-25-93

Elevation : UNKNOWN

Water table (meters) : 1

CPT-8

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	17.04	0.13	0.77	0.02	sandy silt to clayey silt	UNDFND	UNDFD	7	1.41
0.50	1.64	28.90	0.19	0.65	0.06	silty sand to sandy silt	70-80	46-48	9	UNDEFINED
0.75	2.46	27.14	0.19	0.69	0.10	silty sand to sandy silt	60-70	44-46	9	UNDEFINED
1.00	3.28	23.50	0.17	0.71	0.14	silty sand to sandy silt	50-60	42-44	8	UNDEFINED
1.25	4.10	24.36	0.19	0.76	0.17	silty sand to sandy silt	50-60	42-44	8	UNDEFINED
1.50	4.92	31.32	0.22	0.70	0.19	silty sand to sandy silt	50-60	42-44	10	UNDEFINED
1.75	5.74	44.52	0.33	0.73	0.20	silty sand to sandy silt	60-70	44-46	14	UNDEFINED
2.00	6.56	52.90	0.42	0.80	0.22	sand to silty sand	70-80	44-46	13	UNDEFINED
2.25	7.38	71.34	0.59	0.83	0.23	sand to silty sand	70-80	44-46	17	UNDEFINED
2.50	8.20	102.32	0.81	0.79	0.25	sand to silty sand	80-90	46-48	25	UNDEFINED
2.75	9.02	106.14	0.80	0.75	0.26	sand to silty sand	80-90	46-48	25	UNDEFINED
3.00	9.84	115.70	0.76	0.66	0.28	sand	80-90	46-48	22	UNDEFINED
3.25	10.66	126.50	0.94	0.75	0.29	sand	>90	46-48	24	UNDEFINED
3.50	11.48	110.84	0.84	0.76	0.31	sand to silty sand	80-90	46-48	27	UNDEFINED
3.75	12.30	74.84	0.38	0.51	0.33	sand to silty sand	70-80	44-46	18	UNDEFINED
4.00	13.12	28.56	0.36	1.25	0.34	silty sand to sandy silt	40-50	40-42	9	UNDEFINED
4.25	13.94	52.20	0.40	0.77	0.36	sand to silty sand	60-70	42-44	13	UNDEFINED
4.50	14.76	21.38	0.30	1.38	0.37	sandy silt to clayey silt	UNDFND	UNDFD	8	1.72
4.75	15.58	20.70	0.02	0.10	0.39	silty sand to sandy silt	<40	36-38	7	UNDEFINED
5.00	16.40	10.28	0.04	0.41	0.40	sandy silt to clayey silt	UNDFND	UNDFD	4	.79
5.25	17.22	9.56	0.09	0.96	0.42	clayey silt to silty clay	UNDFND	UNDFD	5	.72

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

*** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ***

EGLIN AFB

CONTRACTOR : TERRA TECH.

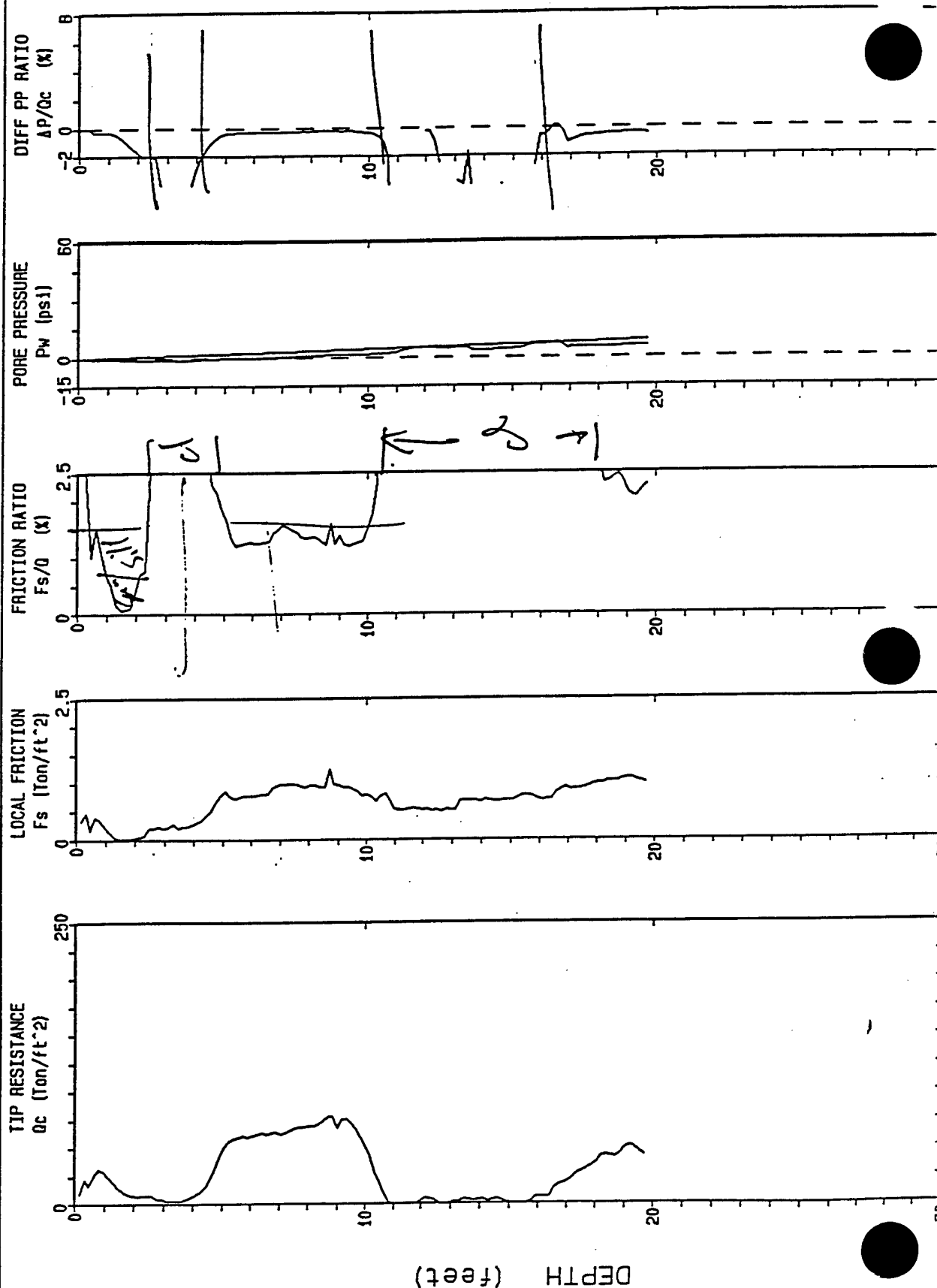
LOCATION : 250-50

DATE : 2 03-24-93

ELEVATION : UNKNOWN

SOUNDING NO. : 1 Pg 1 / 1

TERRA JOB NO. : 93-1003



Contractor : TERRA TECH.

Test Date : 03-24-93

Location : 250-50

Elevation : UNKNOWN

Job No. : 93-1003

Water table (meters) : 1

Opt. Unit Wt. (avg) : 100 pcf

CPT-91

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	21.22	0.34	1.60	0.02	sandy silt to clayey silt	UNDFND	UNDFD	8	1.76
0.50	1.64	19.66	0.08	0.39	0.06	silty sand to sandy silt	60-70	44-46	6	UNDEFINED
0.75	2.46	7.82	0.07	0.90	0.10	sensitive fine grained	UNDFND	UNDFD	4	.64
1.00	3.28	4.32	0.22	5.19	0.14	clay	UNDFND	UNDFD	4	.34
1.25	4.10	4.86	0.24	4.98	0.17	clay	UNDFND	UNDFD	5	.38
1.50	4.92	24.22	0.55	2.25	0.19	sandy silt to clayey silt	UNDFND	UNDFD	9	1.99
1.75	5.74	57.58	0.77	1.34	0.20	silty sand to sandy silt	70-80	44-46	18	UNDEFINED
2.00	6.56	61.92	0.79	1.28	0.22	silty sand to sandy silt	70-80	44-46	20	UNDEFINED
2.25	7.38	63.70	0.96	1.51	0.23	silty sand to sandy silt	70-80	44-46	20	UNDEFINED
2.50	8.20	68.90	0.95	1.38	0.25	silty sand to sandy silt	70-80	44-46	22	UNDEFINED
2.75	9.02	74.12	1.00	1.35	0.26	silty sand to sandy silt	70-80	44-46	24	UNDEFINED
3.00	9.84	69.76	0.87	1.25	0.28	silty sand to sandy silt	70-80	44-46	22	UNDEFINED
3.25	10.66	30.26	0.76	2.50	0.29	sandy silt to <u>clayey silt</u>	UNDFND	UNDFD	12	2.47
3.50	11.48	0.18	0.56	308.89	0.31	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.75	12.30	2.42	0.53	21.82	0.33	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.00	13.12	1.04	0.51	49.23	0.34	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.25	13.94	3.12	0.68	21.73	0.36	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.50	14.76	3.28	0.68	20.73	0.37	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.75	15.58	0.18	0.73	403.33	0.39	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.00	16.40	5.22	0.71	13.64	0.40	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.25	17.22	18.80	0.88	4.66	0.42	clay	UNDFND	UNDFD	18	1.49
5.50	18.04	32.00	0.94	2.93	0.43	clayey silt to silty clay	UNDFND	UNDFD	15	2.59
5.75	18.86	43.14	1.03	2.38	0.45	sandy silt to clayey silt	UNDFND	UNDFD	17	3.51
6.00	19.69	48.74	1.05	2.15	0.46	sandy silt to clayey silt	UNDFND	UNDFD	19	3.98

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

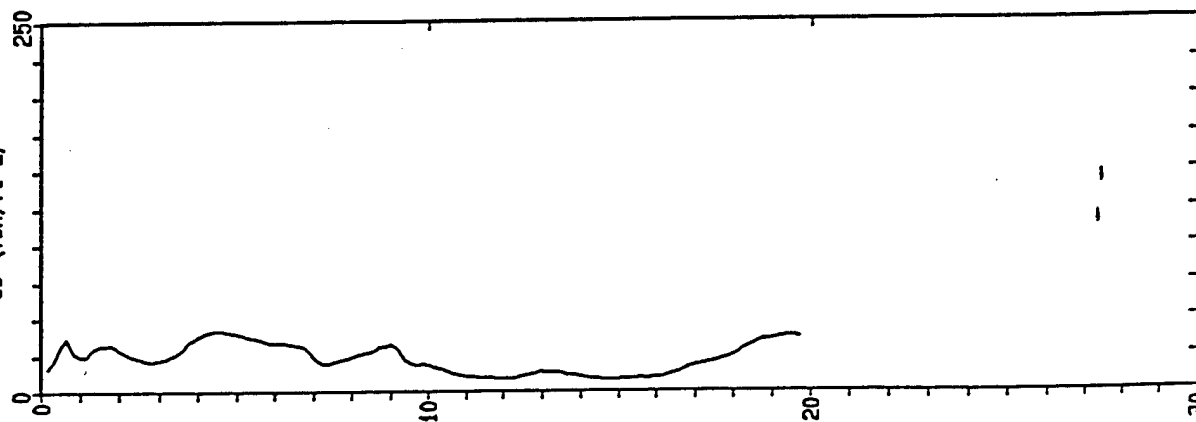
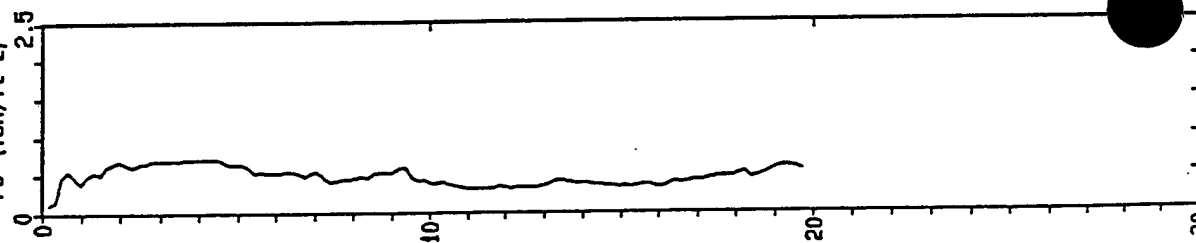
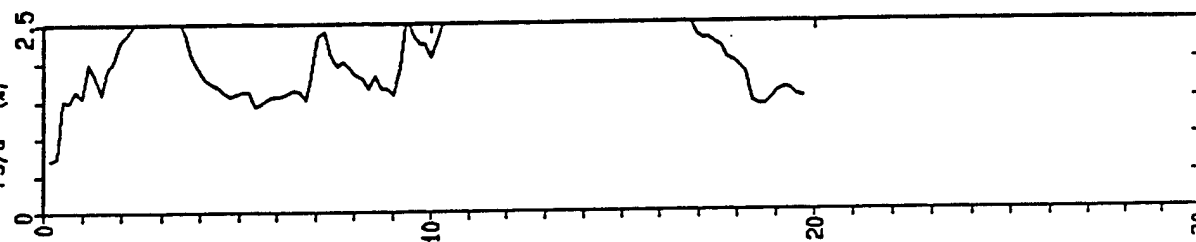
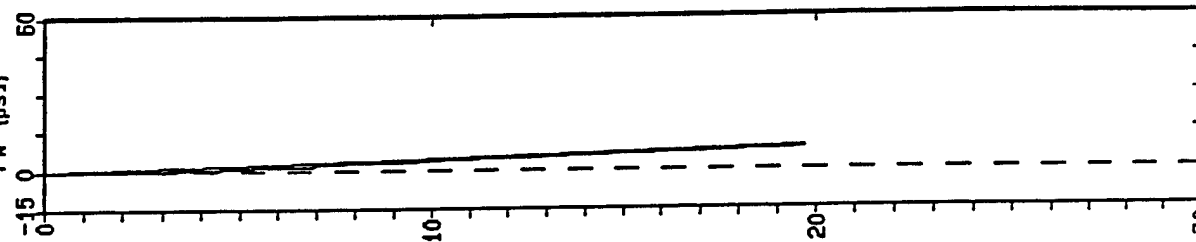
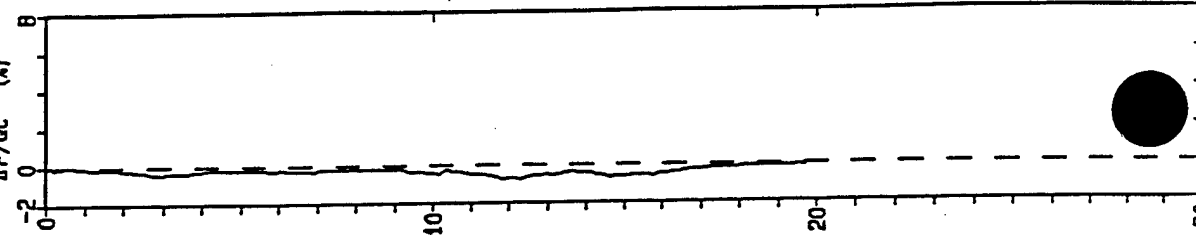
LOCATION : 250-100

DATE : 0 03-23-93

ELEVATION : UNKNOWN

SOUNDING NO. : 1 Pg 1 / 1

TERRA JOB NO. : 93-1003

TIP RESISTANCE
 Q_c (Ton/ft²)LOCAL FRICTION
 F_s (Ton/ft²)FRICTION RATIO
 F_s/Q_c (%)PORE PRESSURE
 P_w (psi)DIFF PP RATIO
 $\Delta P/Q_c$ (%)

DEPTH (feet)

EGLIN AFB - RICE UNIVERSITY

Contractor : TERRA TECH.
 Location : 250-100
 No. : 93-1003
 Unit Wt. (avg) : 100 pcf

Test Date : 03-23-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-16

DEPTH (meters)	DEPTH (feet)	qc (avg) (tsf)	fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	26.78	0.35	1.31	0.02	sandy silt to clayey silt	UNDFND	UNDFD	10	2.23
0.50	1.64	28.20	0.50	1.78	0.06	sandy silt to clayey silt	UNDFND	UNDFD	11	2.34
0.75	2.46	27.34	0.65	2.38	0.10	sandy silt to clayey silt	UNDFND	UNDFD	10	2.27
1.00	3.28	22.30	0.68	3.04	0.14	clayey silt to silty clay	UNDFND	UNDFD	11	1.84
1.25	4.10	33.24	0.70	2.12	0.17	sandy silt to clayey silt	UNDFND	UNDFD	13	2.75
1.50	4.92	41.08	0.68	1.65	0.19	silty sand to sandy silt	60-70	44-46	13	UNDEFINED
1.75	5.74	36.54	0.56	1.54	0.20	silty sand to sandy silt	60-70	42-44	12	UNDEFINED
2.00	6.56	32.56	0.52	1.60	0.22	sandy silt to clayey silt	UNDFND	UNDFD	12	2.68
2.25	7.38	23.82	0.47	1.98	0.23	sandy silt to clayey silt	UNDFND	UNDFD	9	1.95
2.50	8.20	23.16	0.44	1.91	0.25	sandy silt to clayey silt	UNDFND	UNDFD	9	1.89
2.75	9.02	29.60	0.50	1.68	0.26	sandy silt to clayey silt	UNDFND	UNDFD	11	2.43
3.00	9.84	21.74	0.49	2.26	0.28	sandy silt to clayey silt	UNDFND	UNDFD	8	1.77
3.25	10.66	15.32	0.38	2.45	0.29	clayey silt to silty clay	UNDFND	UNDFD	7	1.23
3.50	11.48	10.26	0.32	3.08	0.31	silty clay to clay	UNDFND	UNDFD	7	.80
3.75	12.30	8.88	0.33	3.72	0.33	clay	UNDFND	UNDFD	9	.69
4.00	13.12	12.18	0.35	2.84	0.34	silty clay to clay	UNDFND	UNDFD	8	.96
4.25	13.94	11.84	0.40	3.38	0.36	silty clay to clay	UNDFND	UNDFD	8	.93
4.50	14.76	8.52	0.36	4.25	0.37	clay	UNDFND	UNDFD	8	.65
4.75	15.58	8.70	0.35	4.02	0.39	clay	UNDFND	UNDFD	8	.66
5.00	16.40	10.10	0.36	3.60	0.40	clay	UNDFND	UNDFD	10	.77
5.25	17.22	16.72	0.41	2.45	0.42	clayey silt to silty clay	UNDFND	UNDFD	8	1.32
5.50	18.04	22.62	0.47	2.07	0.43	sandy silt to clayey silt	UNDFND	UNDFD	9	1.81
5.75	18.86	32.20	0.49	1.53	0.45	sandy silt to clayey silt	UNDFND	UNDFD	12	2.60
6.00	19.69	36.70	0.59	1.60	0.46	silty sand to sandy silt	40-50	40-42	12	UNDEFINED

Dr - All sands (Jamolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 250-150

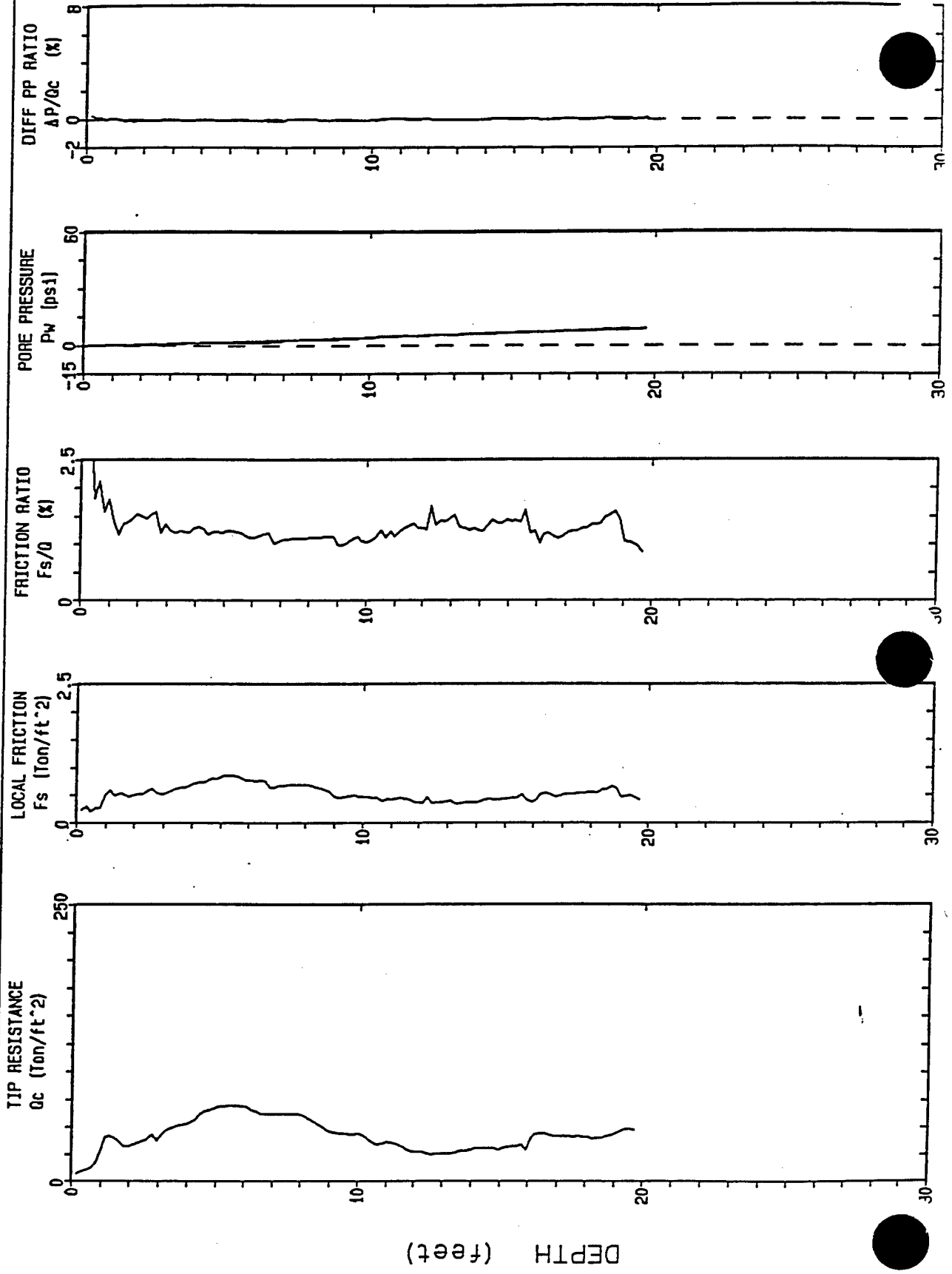
DATE : 9 03-23-93

ELEVATION : UNKNOWN

SOUNDING NO. :

TERRA JOB NO. : 93-1003

Pg 1 / 1



Contractor : TERRA TECH.

Test Date : 03-23-93

Location : 250-150

Elevation : UNKNOWN

ob No. : 93-1003

Water table (meters) : 1

Est. Unit Wt. (avg) : 100 pcf

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	11.14	0.25	2.21	0.02	clayey silt to silty clay	UNDFND	UNDFD	5	.92
0.50	1.64	37.24	0.52	1.41	0.06	silty sand to sandy silt	70-80	>48	12	UNDEFINED
0.75	2.46	34.28	0.52	1.51	0.10	silty sand to sandy silt	60-70	46-48	11	UNDEFINED
1.00	3.28	42.28	0.56	1.32	0.14	silty sand to sandy silt	60-70	44-46	13	UNDEFINED
1.25	4.10	52.20	0.66	1.26	0.17	silty sand to sandy silt	70-80	44-46	17	UNDEFINED
1.50	4.92	63.18	0.77	1.22	0.19	silty sand to sandy silt	70-80	46-48	20	UNDEFINED
1.75	5.74	69.24	0.84	1.21	0.20	silty sand to sandy silt	70-80	46-48	22	UNDEFINED
2.00	6.56	65.94	0.77	1.16	0.22	silty sand to sandy silt	70-80	44-46	21	UNDEFINED
2.25	7.38	61.96	0.66	1.07	0.23	silty sand to sandy silt	70-80	44-46	20	UNDEFINED
2.50	8.20	61.26	0.68	1.12	0.25	silty sand to sandy silt	70-80	44-46	20	UNDEFINED
2.75	9.02	51.30	0.57	1.12	0.26	silty sand to sandy silt	60-70	42-44	16	UNDEFINED
3.00	9.84	44.20	0.47	1.07	0.28	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
3.25	10.66	39.16	0.44	1.12	0.29	silty sand to sandy silt	50-60	42-44	13	UNDEFINED
3.50	11.48	34.98	0.44	1.25	0.31	silty sand to sandy silt	50-60	40-42	11	UNDEFINED
3.75	12.30	28.52	0.39	1.38	0.33	sandy silt to clayey silt	UNDFND	UNDFD	11	2.32
4.00	13.12	25.92	0.37	1.44	0.34	sandy silt to clayey silt	UNDFND	UNDFD	10	2.10
4.25	13.94	28.02	0.36	1.28	0.36	sandy silt to clayey silt	UNDFND	UNDFD	11	2.27
4.50	14.76	30.50	0.41	1.36	0.37	silty sand to sandy silt	40-50	40-42	10	UNDEFINED
4.75	15.58	31.16	0.46	1.46	0.39	sandy silt to clayey silt	UNDFND	UNDFD	12	2.53
5.00	16.40	38.28	0.45	1.18	0.40	silty sand to sandy silt	50-60	40-42	12	UNDEFINED
5.25	17.22	42.56	0.50	1.17	0.42	silty sand to sandy silt	50-60	40-42	14	UNDEFINED
5.50	18.04	41.26	0.54	1.31	0.43	silty sand to sandy silt	50-60	40-42	13	UNDEFINED
5.75	18.86	40.72	0.61	1.49	0.45	silty sand to sandy silt	50-60	40-42	13	UNDEFINED
6.00	19.69	47.24	0.47	0.99	0.46	silty sand to sandy silt	50-60	40-42	15	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 250-200

DATE : 3 03-22-93

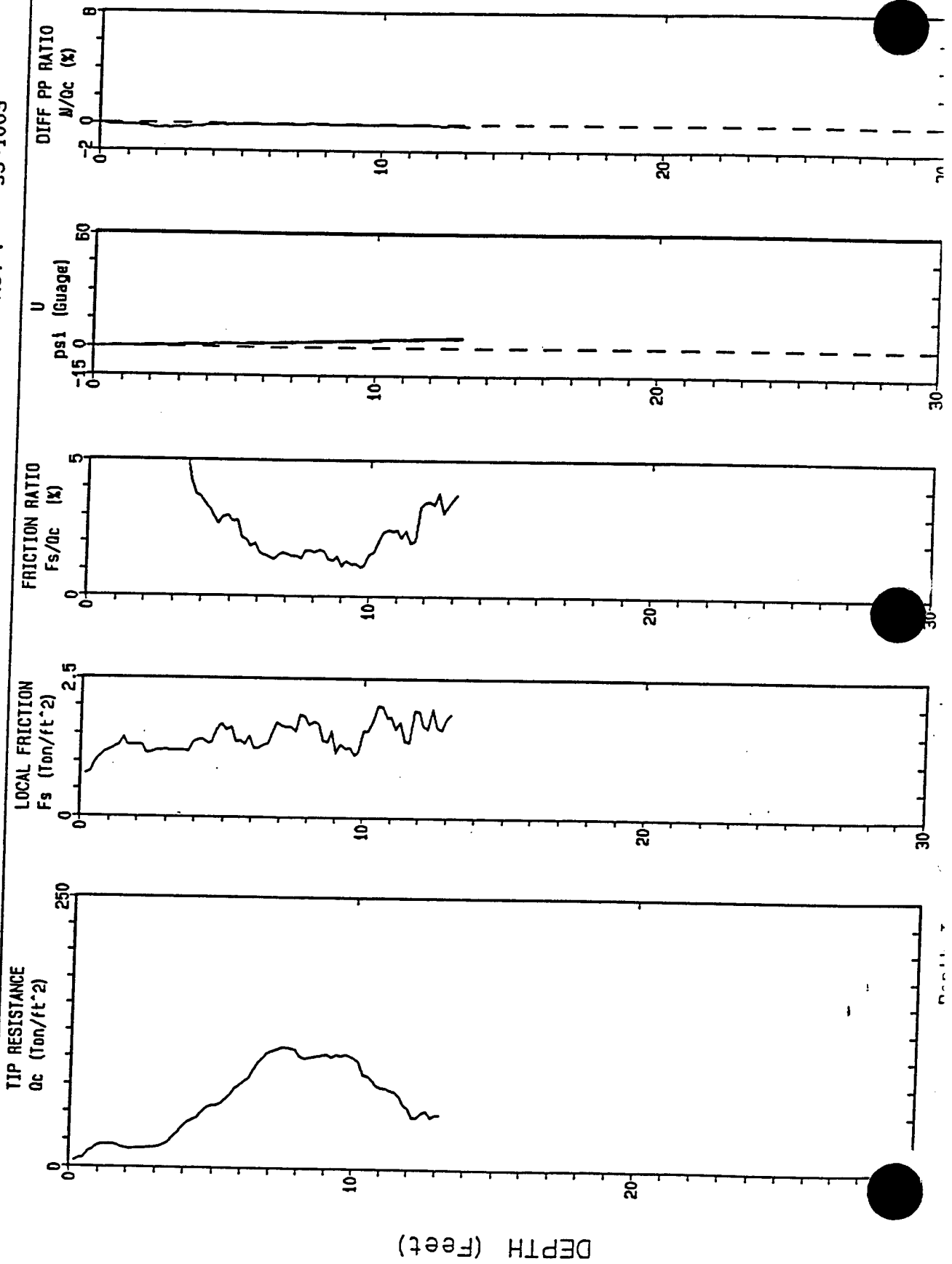
ELEVATION : UNKNOWN

SOUNDING NO. :

TERRA JOB NO. :

Pg 1 / 1

93-1003



Contractor : TERRA TECH.
Location : 250-200
Job No. : 93-1003
Unit Wt. (avg) : 100 pcf

Test Date : 03-22-93
Elevation : UNKNOWN
Water table (meters) : 1

CPT-12

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	10.24	0.95	9.32	0.02	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.50	1.64	20.54	1.30	6.31	0.06	clay	UNDFND	UNDFD	20	1.70
0.75	2.46	17.40	1.23	7.09	0.10	clay	UNDFND	UNDFD	17	1.44
1.00	3.28	18.80	1.20	6.37	0.14	clay	UNDFND	UNDFD	18	1.55
1.25	4.10	32.00	1.26	3.94	0.17	clayey silt to silty clay	UNDFND	UNDFD	15	2.65
1.50	4.92	49.74	1.47	2.96	0.19	sandy silt to clayey silt	UNDFND	UNDFD	19	4.12
1.75	5.74	62.96	1.46	2.31	0.20	sandy silt to clayey silt	UNDFND	UNDFD	24	5.22
2.00	6.56	84.04	1.32	1.58	0.22	silty sand to sandy silt	80-90	46-48	27	UNDEFINED
2.25	7.38	105.62	1.64	1.55	0.23	sand to silty sand	80-90	46-48	25	UNDEFINED
2.50	8.20	105.28	1.73	1.64	0.25	silty sand to sandy silt	80-90	46-48	34	UNDEFINED
2.75	9.02	101.80	1.43	1.41	0.26	sand to silty sand	80-90	46-48	24	UNDEFINED
3.00	9.84	102.14	1.23	1.21	0.28	sand to silty sand	80-90	46-48	24	UNDEFINED
3.25	10.66	89.28	1.78	2.00	0.29	silty sand to sandy silt	80-90	44-46	29	UNDEFINED
3.50	11.48	72.22	1.67	2.31	0.31	silty sand to sandy silt	70-80	44-46	23	UNDEFINED
3.75	12.30	54.48	1.70	3.12	0.33	sandy silt to clayey silt	UNDFND	UNDFD	21	4.49
4.00	13.12	50.12	1.77	3.54	0.34	clayey silt to silty clay	UNDFND	UNDFD	24	4.12

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 250-250

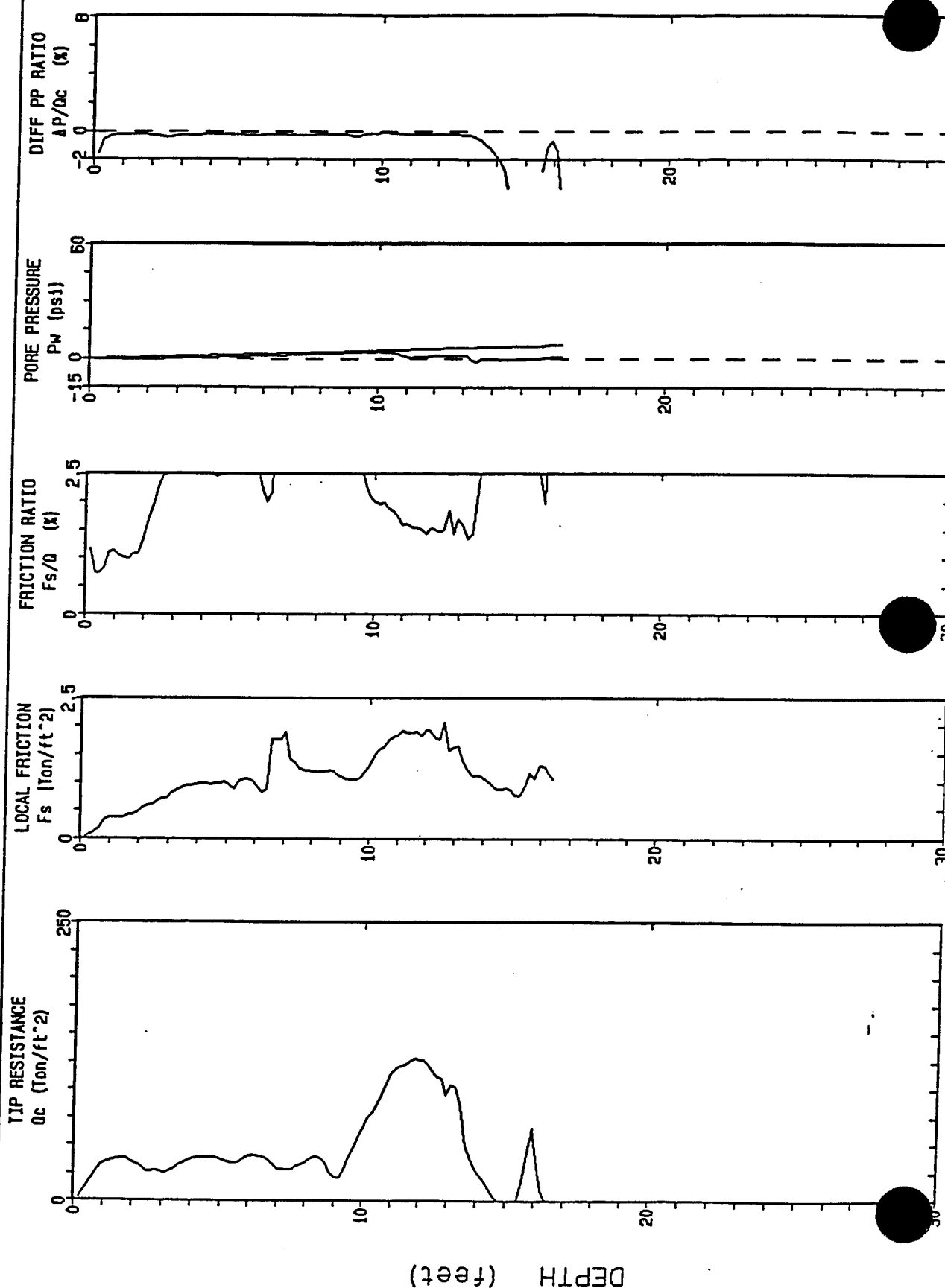
DATE : 8 03-23-93

ELEVATION : UNKNOWN

SOUNDING NO. :

TERRA JOB NO. : 93-1003

Pg 1 / 1



0

Contractor : TERRA TECH.

Test Date : 03-23-93

Location : 250-250

Elevation : UNKNOWN

Job No. : 93-1003

Water table (meters) : 1

Sat. Unit Wt. (avg) : 100 pcf

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	15.50	0.14	0.92	0.02	sandy silt to clayey silt	UNDFND	UNDFD	6	1.29
0.50	1.64	36.02	0.38	1.04	0.06	silty sand to sandy silt	70-80	>48	12	UNDEFINED
0.75	2.46	32.74	0.53	1.61	0.10	sandy silt to clayey silt	UNDFND	UNDFD	13	2.72
1.00	3.28	26.86	0.74	2.77	0.14	clayey silt to silty clay	UNDFND	UNDFD	13	2.22
1.25	4.10	34.10	0.94	2.76	0.17	sandy silt to clayey silt	UNDFND	UNDFD	13	2.82
1.50	4.92	39.02	0.98	2.51	0.19	sandy silt to clayey silt	UNDFND	UNDFD	15	3.23
1.75	5.74	34.96	0.99	2.83	0.20	sandy silt to clayey silt	UNDFND	UNDFD	13	2.89
2.00	6.56	40.04	1.08	2.70	0.22	sandy silt to clayey silt	UNDFND	UNDFD	15	3.31
2.25	7.38	30.80	1.64	5.32	0.23	clay	UNDFND	UNDFD	30	2.53
2.50	8.20	33.06	1.21	3.67	0.25	clayey silt to silty clay	UNDFND	UNDFD	16	2.72
2.75	9.02	32.02	1.18	3.67	0.26	clayey silt to silty clay	UNDFND	UNDFD	15	2.63
3.00	9.84	38.78	1.09	2.81	0.28	sandy silt to clayey silt	UNDFND	UNDFD	15	3.19
3.25	10.66	80.22	1.55	1.93	0.29	silty sand to sandy silt	70-80	44-46	26	UNDEFINED
3.50	11.48	116.92	1.87	1.60	0.31	sand to silty sand	80-90	46-48	28	UNDEFINED
3.75	12.30	125.66	1.88	1.49	0.33	sand to silty sand	80-90	46-48	30	UNDEFINED
4.00	13.12	107.36	1.73	1.62	0.34	silty sand to sandy silt	80-90	44-46	34	UNDEFINED
4.25	13.94	60.74	1.18	1.94	0.36	silty sand to sandy silt	60-70	42-44	19	UNDEFINED
4.50	14.76	11.66	0.92	7.92	0.37	clay	UNDFND	UNDFD	11	.91
4.75	15.58	3.48	0.88	25.40	0.39	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.00	16.40	29.92	1.17	3.90	0.40	clayey silt to silty clay	UNDFND	UNDFD	14	2.42

All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 250-300

DATE : 7 03-23-93

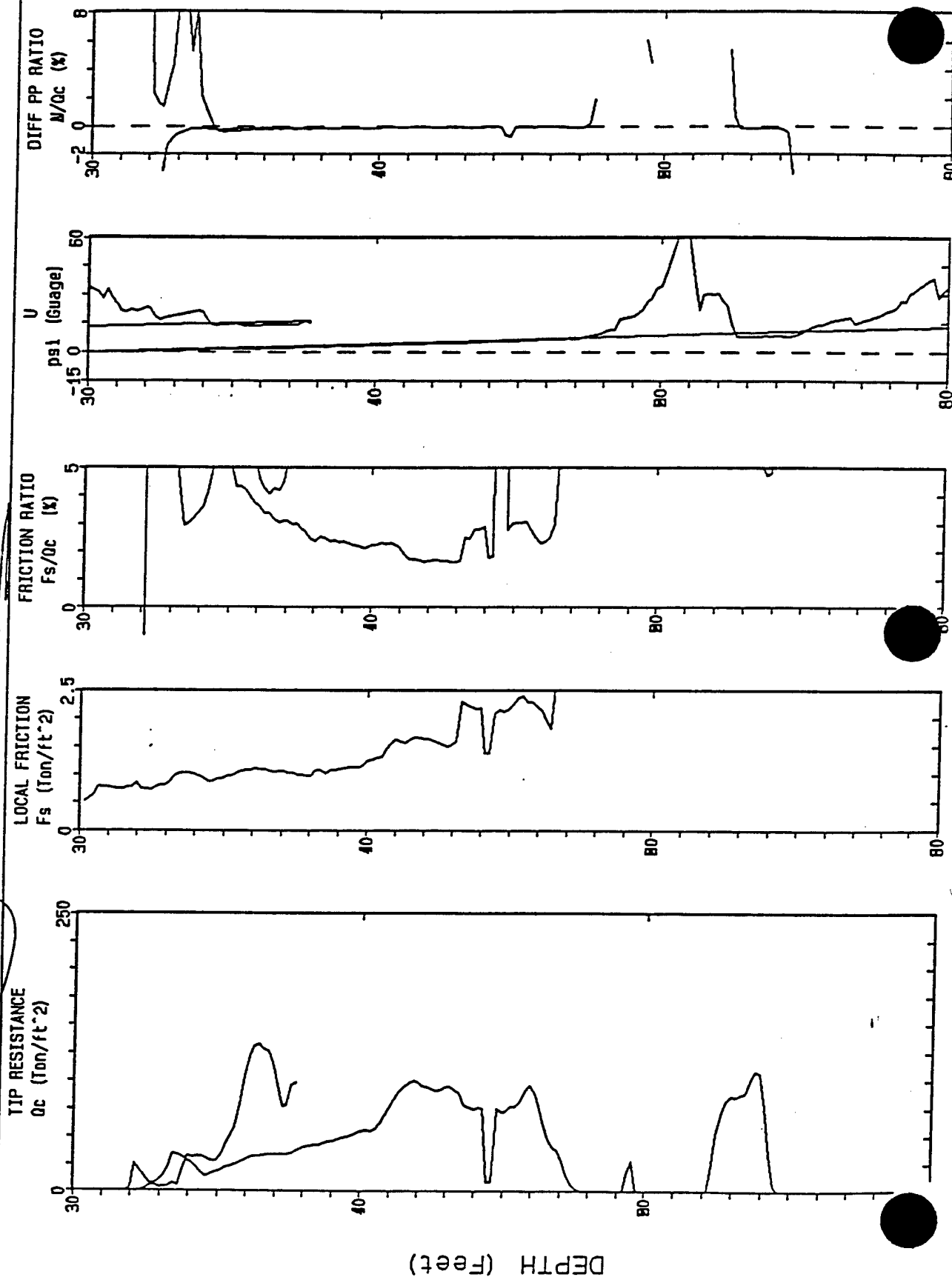
ELEVATION : UNKNOWN

SOUNDING NO. :

TERRA JOB NO. :

Pg 2 / 2

93-1003



Contractor : TERRA TECH.

Test Date : 03-23-93

Location : 250-300

Elevation : UNKNOWN

Job No. : 93-1003

Water table (meters) : 1

Unit Wt. (avg) : 100 pcf

CPT-14

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	0.00	0.66	0.00	0.02	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.50	1.64	0.00	0.75	0.00	0.06	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.75	2.46	0.34	0.76	224.12	0.10	undefined	UNDFND	UNDFD	UDF	UNDEFINED
1.00	3.28	11.32	0.85	7.47	0.14	clay	UNDFND	UNDFD	11	.93
1.25	4.10	31.50	1.01	3.22	0.17	clayey silt to silty clay	UNDFND	UNDFD	15	2.60
1.50	4.92	17.58	0.91	5.16	0.19	clay	UNDFND	UNDFD	17	1.44
1.75	5.74	23.48	1.02	4.35	0.20	silty clay to clay	UNDFND	UNDFD	15	1.93
2.00	6.56	31.34	1.09	3.48	0.22	clayey silt to silty clay	UNDFND	UNDFD	15	2.58
2.25	7.38	33.90	1.04	3.07	0.23	clayey silt to silty clay	UNDFND	UNDFD	16	2.79
2.50	8.20	38.64	1.00	2.59	0.25	sandy silt to clayey silt	UNDFND	UNDFD	15	3.18
2.75	9.02	44.36	1.07	2.41	0.26	sandy silt to clayey silt	UNDFND	UNDFD	17	3.66
3.00	9.84	50.80	1.13	2.22	0.28	sandy silt to clayey silt	UNDFND	UNDFD	19	4.19
3.25	10.66	57.58	1.32	2.29	0.29	sandy silt to clayey silt	UNDFND	UNDFD	22	4.75
3.50	11.48	82.66	1.60	1.93	0.31	silty sand to sandy silt	70-80	44-46	26	UNDEFINED
3.75	12.30	96.92	1.64	1.69	0.33	silty sand to sandy silt	80-90	44-46	31	UNDEFINED
4.00	13.12	93.08	1.55	1.66	0.34	silty sand to sandy silt	80-90	44-46	30	UNDEFINED
4.25	13.94	82.30	2.23	2.70	0.36	sandy silt to clayey silt	UNDFND	UNDFD	32	6.80
4.50	14.76	49.08	1.83	3.73	0.37	clayey silt to silty clay	UNDFND	UNDFD	24	4.03
4.75	15.58	76.38	2.30	3.01	0.39	sandy silt to clayey silt	UNDFND	UNDFD	29	6.30
5.00	16.40	83.16	2.09	2.51	0.40	sandy silt to clayey silt	UNDFND	UNDFD	32	6.86
5.25	17.22	34.08	2.64	7.75	0.42	clay	UNDFND	UNDFD	33	2.77
5.50	18.04	1.92	2.73	142.19	0.43	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.75	18.86	0.00	4.03	0.00	0.45	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.00	19.69	9.04	5.83	64.47	0.46	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.25	20.51	0.00	4.54	0.00	0.48	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.50	21.33	0.00	4.35	0.00	0.50	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.75	22.15	0.00	5.00	0.00	0.51	undefined	UNDFND	UNDFD	UDF	UNDEFINED
7.00	22.97	62.48	5.14	8.23	0.53	undefined	UNDFND	UNDFD	UDF	UNDEFINED
7.25	23.79	94.66	5.20	5.49	0.54	very stiff fine grained (*)	UNDFND	UNDFD	>50	UNDEFINED
7.50	24.61	44.70	5.00	11.19	0.56	undefined	UNDFND	UNDFD	UDF	UNDEFINED
7.75	25.43	0.00	4.42	0.00	0.57	undefined	UNDFND	UNDFD	UDF	UNDEFINED
8.00	26.25	0.00	4.16	0.00	0.59	undefined	UNDFND	UNDFD	UDF	UNDEFINED
8.25	27.07	0.00	4.12	0.00	0.60	undefined	UNDFND	UNDFD	UDF	UNDEFINED
8.50	27.89	0.00	4.16	0.00	0.62	undefined	UNDFND	UNDFD	UDF	UNDEFINED
8.75	28.71	0.00	4.42	0.00	0.63	undefined	UNDFND	UNDFD	UDF	UNDEFINED
9.00	29.53	0.00	4.33	0.00	0.65	undefined	UNDFND	UNDFD	UDF	UNDEFINED
9.25	30.35	0.00	4.39	0.00	0.66	undefined	UNDFND	UNDFD	UDF	UNDEFINED
9.50	31.17	0.00	4.53	0.00	0.68	undefined	UNDFND	UNDFD	UDF	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

(*) overconsolidated or cemented

Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

DEPTH meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
9.75	31.99	0.70	4.75	678.29	0.70	undefined	UNDFND	UNDFD	UDF	UNDEFINE
10.00	32.81	14.78	4.74	32.08	0.71	undefined	UNDFND	UNDFD	UDF	UNDEFINE
10.25	33.63	5.02	4.70	93.59	0.73	undefined	UNDFND	UNDFD	UDF	UNDEFINE
10.50	34.45	29.94	4.83	16.12	0.74	undefined	UNDFND	UNDFD	UDF	UNDEFINE
10.75	35.27	32.56	4.73	14.54	0.76	undefined	UNDFND	UNDFD	UDF	UNDEFINE
11.00	36.09	83.18	5.23	6.29	0.77	very stiff fine grained (*)	UNDFND	UNDFD	>50	UNDEFINE
11.25	36.91	126.68	5.41	4.27	0.79	very stiff fine grained (*)	UNDFND	UNDFD	>50	UNDEFINE
11.50	37.73	89.08	5.31	5.96	0.80	very stiff fine grained (*)	UNDFND	UNDFD	>50	UNDEFINE

Dr - All sands (Jamiolkowski et al. 1985) PHI - Robertson and Campanella 1983 Su: Nk= 12

(*) overconsolidated or cemented

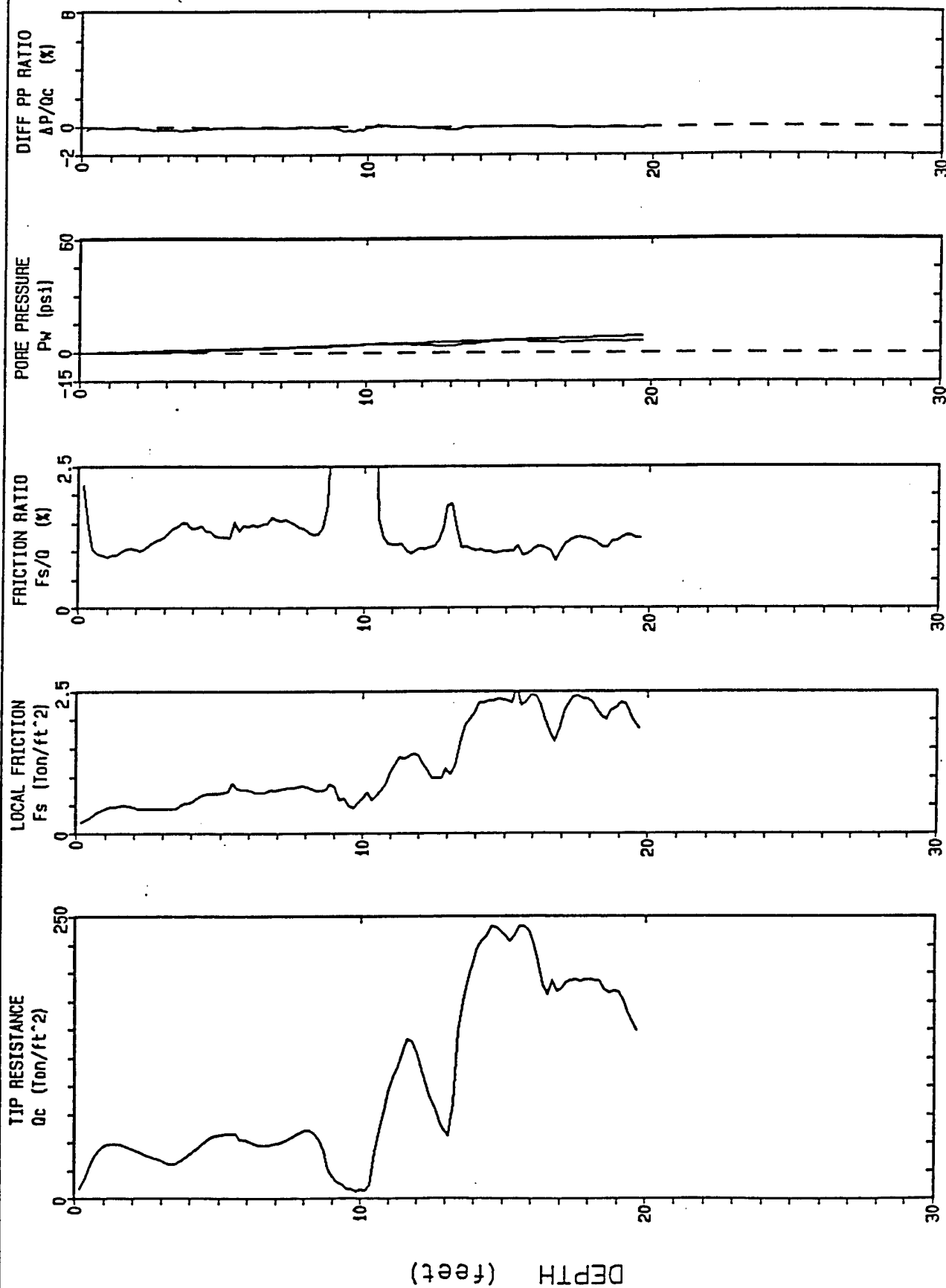
*** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) **

EGLIN AFB

CONTRACTOR : TERRA TECH.
LOCATION : 250-400

DATE : 3 03-24-93
ELEVATION : UNKNOWN

SOUNDING NO. : -- 1 Pg 1 / 1
TERRA JOB NO. : 93-1003



Depth Increment : .05 m

Max Depth : 19.69 ft

Contractor : TERRA TECH.

Test Date : 03-24-93

Location : 250-400

Elevation : UNKNOWN

Job No. : 93-1003

Water table (meters) : 1

Tot. Unit Wt. (avg) : 100 pcf

CPT-25

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	26.44	0.29	1.11	0.02	silty sand to sandy silt	80-90	>48	8	UNDEFIN
0.50	1.64	48.18	0.47	0.97	0.06	silty sand to sandy silt	80-90	>48	15	UNDEFIN
0.75	2.46	42.46	0.45	1.06	0.10	silty sand to sandy silt	70-80	46-48	14	UNDEFIN
1.00	3.28	34.12	0.43	1.27	0.14	silty sand to sandy silt	60-70	44-46	11	UNDEFIN
1.25	4.10	35.52	0.52	1.46	0.17	silty sand to sandy silt	60-70	44-46	11	UNDEFIN
1.50	4.92	51.84	0.69	1.34	0.19	silty sand to sandy silt	70-80	44-46	17	UNDEFIN
1.75	5.74	57.08	0.78	1.37	0.20	silty sand to sandy silt	70-80	44-46	18	UNDEFIN
2.00	6.56	49.92	0.74	1.48	0.22	silty sand to sandy silt	60-70	44-46	16	UNDEFIN
2.25	7.38	49.94	0.78	1.56	0.23	silty sand to sandy silt	60-70	44-46	16	UNDEFIN
2.50	8.20	58.64	0.82	1.39	0.25	silty sand to sandy silt	70-80	44-46	19	UNDEFIN
2.75	9.02	40.20	0.80	1.99	0.26	sandy silt to clayey silt	UNDFND	UNDFD	15	3.
3.00	9.84	10.28	0.54	5.23	0.28	clay	UNDFND	UNDFD	10	.
3.25	10.66	25.94	0.67	2.60	0.29	sandy silt to clayey silt	UNDFND	UNDFD	10	2.
3.50	11.48	105.60	1.17	1.10	0.31	sand to silty sand	80-90	46-48	25	UNDEFIN
3.75	12.30	125.98	1.30	1.03	0.33	sand to silty sand	80-90	46-48	30	UNDEFIN
4.00	13.12	71.84	1.03	1.43	0.34	silty sand to sandy silt	70-80	44-46	23	UNDEFIN
4.25	13.94	162.54	1.78	1.09	0.36	sand	>90	46-48	31	UNDEFIN
4.50	14.76	233.36	2.34	1.00	0.37	sand	>90	>48	45	UNDEFIN
4.75	15.58	234.56	2.37	1.01	0.39	sand	>90	>48	45	UNDEFIN
5.00	16.40	220.82	2.31	1.05	0.40	sand	>90	>48	42	UNDEFIN
5.25	17.22	187.24	1.94	1.04	0.42	sand	>90	46-48	36	UNDEFIN
5.50	18.04	193.48	2.38	1.23	0.43	sand	>90	46-48	37	UNDEFIN
5.75	18.86	187.90	2.13	1.13	0.45	sand	>90	46-48	36	UNDEFIN
6.00	19.69	166.70	2.12	1.27	0.46	sand to silty sand	>90	46-48	40	UNDEFIN

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02)

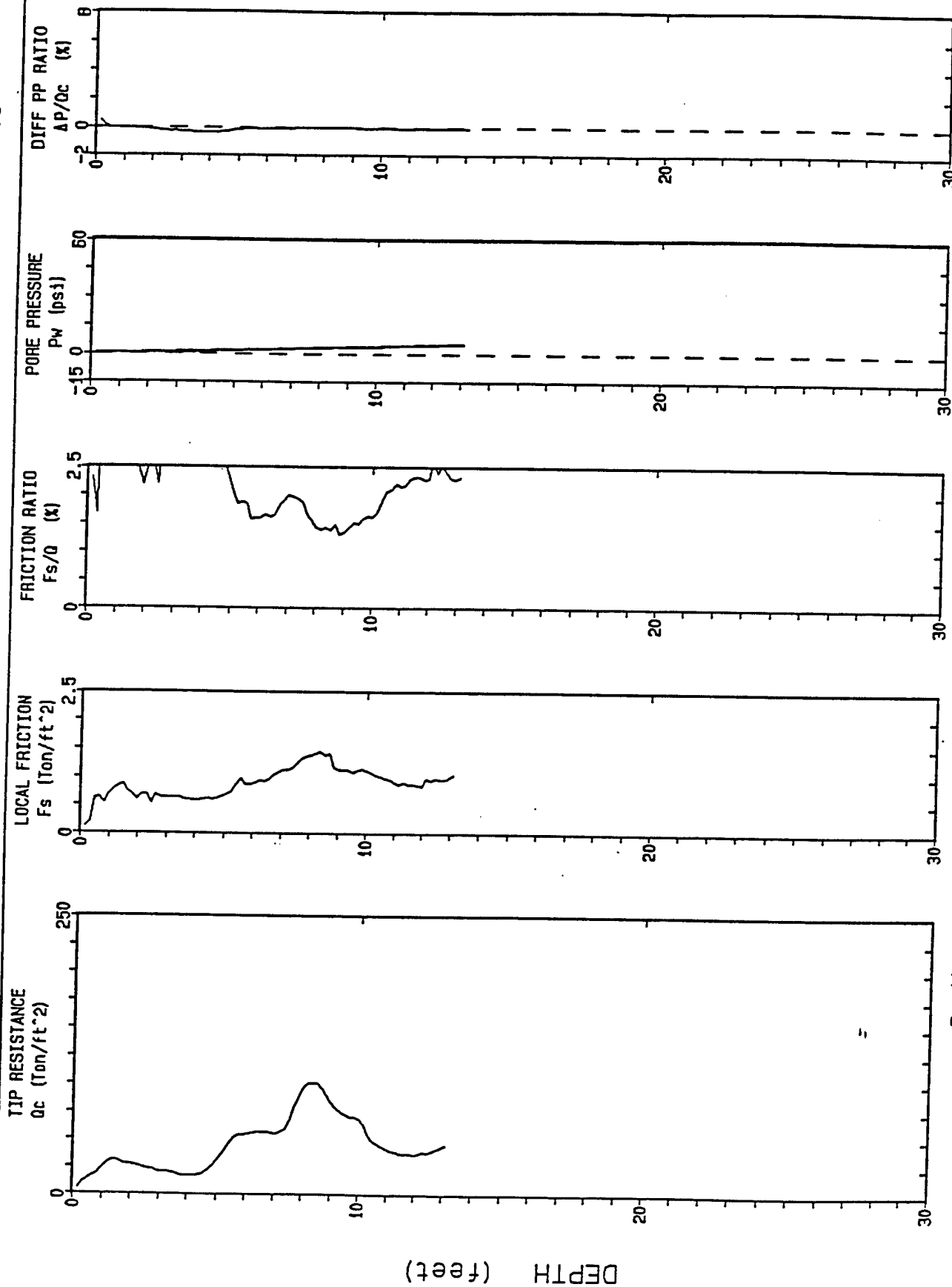
EGLIN AFB

CONTRACTOR : TERRA TECH.
LOCATION : 300-200

DATE : 6 03-22-93
ELEVATION : UNKNOWN

SOUNDING NO. :
TERRA JOB NO. : 93-1003

Pg 1 / 1



Depth Increment : .05 m

Max Depth : 13.12 ft

Contractor : TERRA TECH.

Test Date : 03-22-93

Location : 300-200

Elevation : UNKNOWN

ob No. : 93-1003

Water table (meters) : 1

Tot. Unit Wt. (avg) : 100 pcf

CFT-16

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su tsf
0.25	0.82	12.88	0.42	3.26	0.02	silty clay to clay	UNDFND	UNDFD	8	1.0
0.50	1.64	28.38	0.78	2.76	0.06	clayey silt to silty clay	UNDFND	UNDFD	14	2.2
0.75	2.46	26.62	0.64	2.42	0.10	sandy silt to clayey silt	UNDFND	UNDFD	10	2.2
1.00	3.28	21.94	0.64	2.93	0.14	clayey silt to silty clay	UNDFND	UNDFD	11	1.8
1.25	4.10	18.26	0.60	3.30	0.17	clayey silt to silty clay	UNDFND	UNDFD	9	1.5
1.50	4.92	21.40	0.62	2.92	0.19	clayey silt to silty clay	UNDFND	UNDFD	10	1.7
1.75	5.74	45.08	0.83	1.83	0.20	silty sand to sandy silt	60-70	44-46	14	UNDEFINE
2.00	6.56	56.36	0.92	1.63	0.22	silty sand to sandy silt	70-80	44-46	18	UNDEFINE
2.25	7.38	57.40	1.11	1.93	0.23	silty sand to sandy silt	70-80	44-46	18	UNDEFINE
2.50	8.20	86.14	1.35	1.56	0.25	silty sand to sandy silt	80-90	46-48	28	UNDEFINE
2.75	9.02	94.30	1.31	1.39	0.26	sand to silty sand	80-90	46-48	23	UNDEFINE
3.00	9.84	73.26	1.12	1.53	0.28	silty sand to sandy silt	70-80	44-46	23	UNDEFINE
3.25	10.66	56.18	1.04	1.85	0.29	silty sand to sandy silt	60-70	42-44	18	UNDEFINE
3.50	11.48	40.38	0.90	2.23	0.31	sandy silt to clayey silt	UNDFND	UNDFD	15	3.3
3.75	12.30	37.58	0.90	2.38	0.33	sandy silt to clayey silt	UNDFND	UNDFD	14	3.0
4.00	13.12	41.76	0.99	2.36	0.34	sandy silt to clayey silt	UNDFND	UNDFD	16	3.4

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

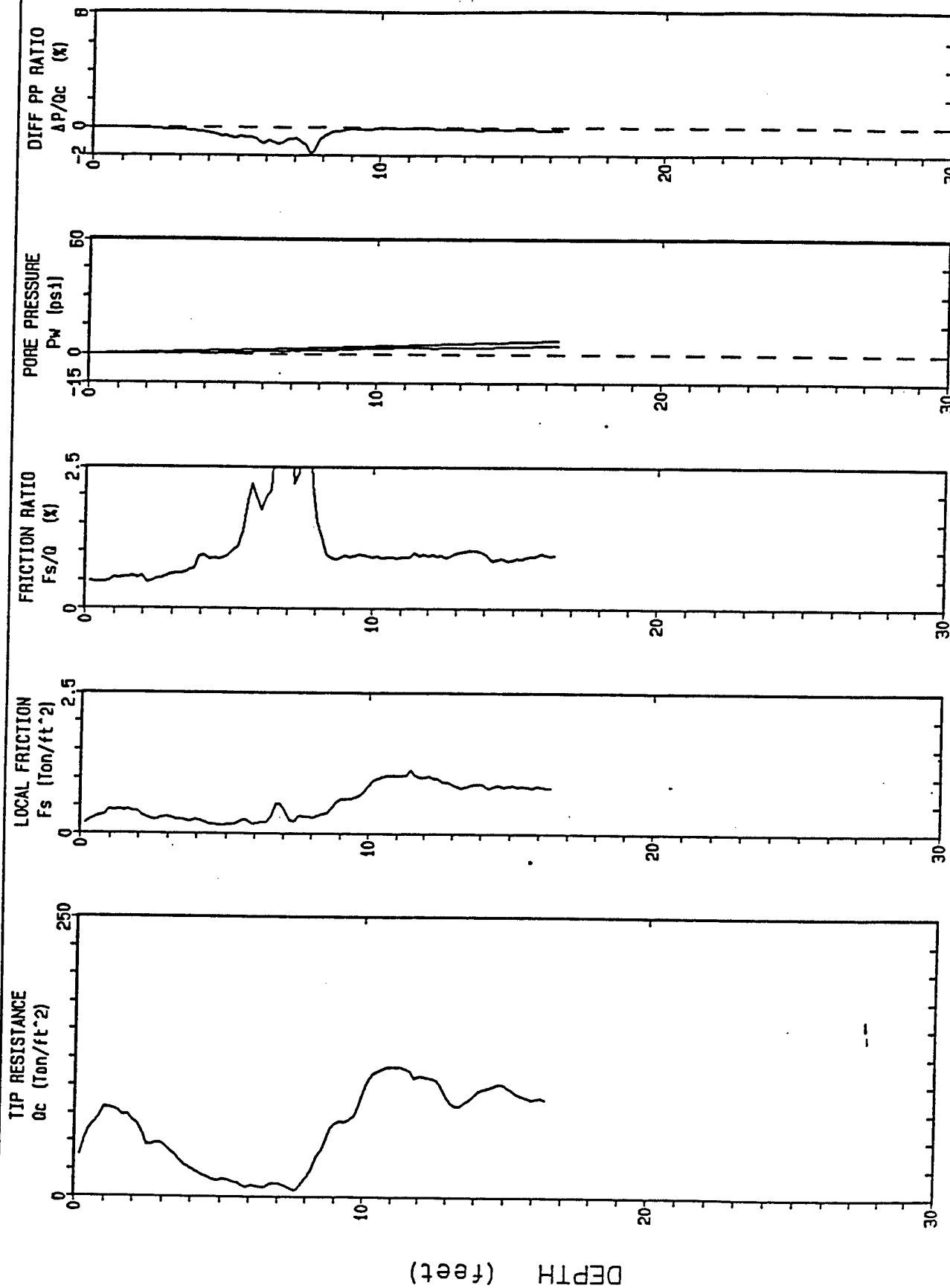
**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (V

EGLIN AFB

CONTRACTOR : TERRA TECH.
LOCATION : 300-350

DATE : 3 03-26-93
ELEVATION : UNKNOWN

SOUNDING NO. : 2 Pg 1 / 1
TERRA JOB NO. : 93-1003



Depth Increment : .05 m

Max Depth : 16.40 ft

EGLIN AFB - RICE UNIVERSITY

Contractor : TERRA TECH.
Location : 300-350
Job No. : 93-1003
Tot. Unit Wt. (avg) : 100 pcf

Test Date : 03-26-93
Elevation : UNKNOWN
Water table (meters) : 1

CPT-17

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	U tsf
0.25	0.82	57.76	0.27	0.47	0.02	sand to silty sand	>90	>48	14	UNDEFINE
0.50	1.64	77.96	0.43	0.55	0.06	sand to silty sand	>90	>48	19	UNDEFINE
0.75	2.46	62.64	0.33	0.52	0.10	sand to silty sand	80-90	>48	15	UNDEFINE
1.00	3.28	46.10	0.27	0.59	0.14	sand to silty sand	70-80	44-46	11	UNDEFINE
1.25	4.10	30.30	0.23	0.77	0.17	silty sand to sandy silt	50-60	42-44	10	UNDEFINE
1.50	4.92	17.94	0.16	0.89	0.19	sandy silt to clayey silt	UNDFND	UNDFD	7	1.4
1.75	5.74	13.92	0.20	1.45	0.20	sandy silt to clayey silt	UNDFND	UNDFD	5	1.1
2.00	6.56	9.30	0.20	2.19	0.22	clayey silt to silty clay	UNDFND	UNDFD	4	.7
2.25	7.38	11.14	0.39	3.46	0.23	silty clay to clay	UNDFND	UNDFD	7	.8
2.50	8.20	13.94	0.30	2.15	0.25	clayey silt to silty clay	UNDFND	UNDFD	7	1.1
2.75	9.02	51.86	0.47	0.91	0.26	silty sand to sandy silt	60-70	42-44	17	UNDEFINE
3.00	9.84	71.88	0.67	0.93	0.28	sand to silty sand	70-80	44-46	17	UNDEFINE
3.25	10.66	107.36	0.98	0.91	0.29	sand to silty sand	80-90	46-48	26	UNDEFINE
3.50	11.48	116.24	1.07	0.92	0.31	sand to silty sand	80-90	46-48	28	UNDEFINE
3.75	12.30	108.58	1.02	0.94	0.33	sand to silty sand	80-90	46-48	26	UNDEFINE
4.00	13.12	97.08	0.92	0.94	0.34	sand to silty sand	80-90	44-46	23	UNDEFINE
4.25	13.94	85.80	0.86	1.01	0.36	sand to silty sand	70-80	44-46	21	UNDEFINE
4.50	14.76	97.78	0.85	0.87	0.37	sand to silty sand	80-90	44-46	23	UNDEFINE
4.75	15.58	95.86	0.85	0.89	0.39	sand to silty sand	70-80	44-46	23	UNDEFINE
5.00	16.40	88.74	0.83	0.94	0.40	sand to silty sand	70-80	44-46	21	UNDEFINE

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) *

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 350-200

DATE : 5 03-22-93

ELEVATION : UNKNOWN

SOUNDING NO. : -- Pg 1 / 1

TERRA JOB NO. : 93-1003

TIP RESISTANCE

Q_c (Ton/ft²)

LOCAL FRICTION

F_s (Ton/ft²)

FRICTION RATIO

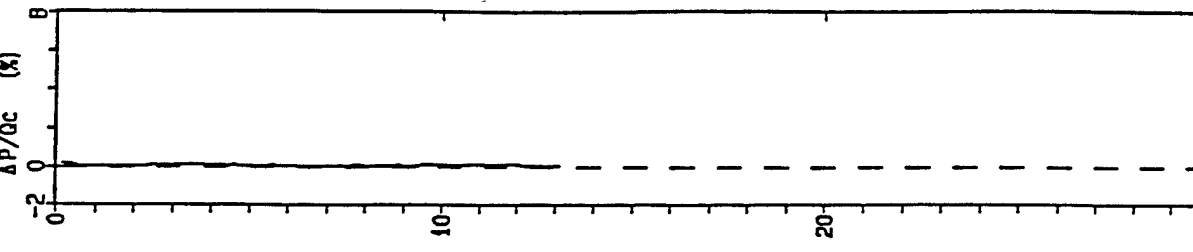
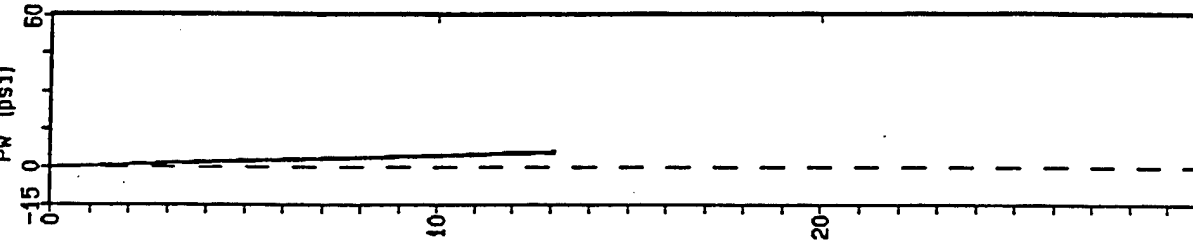
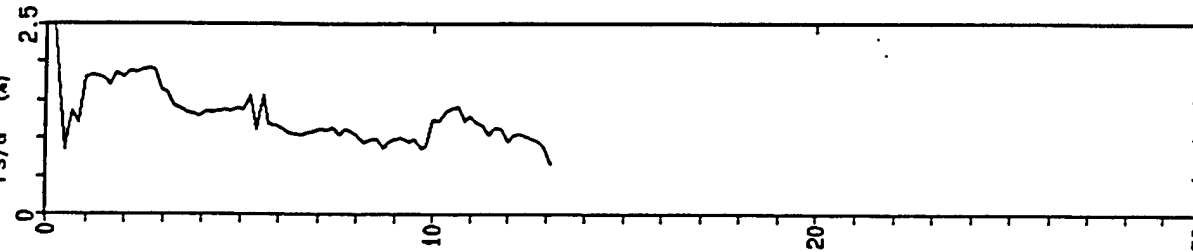
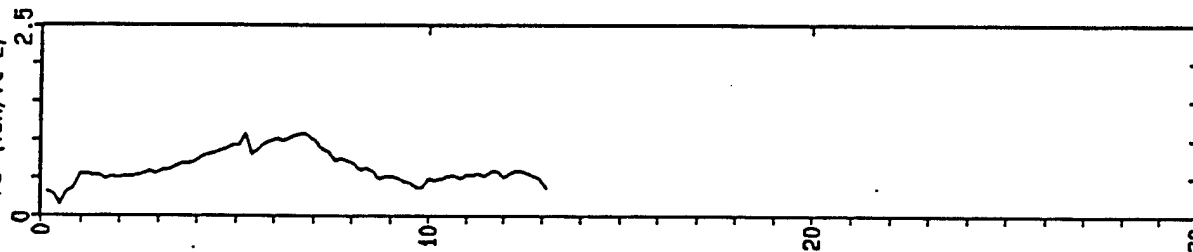
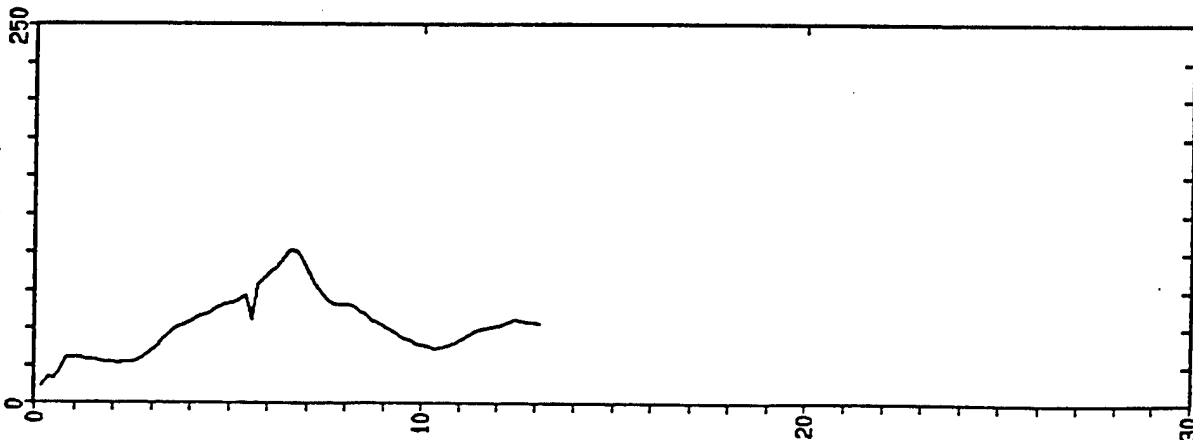
F_s/Q_c (%)

PORE PRESSURE

P_w (psi)

DIFF PP RATIO

$\Delta P/Q_c$ (%)



DEPTH (feet)

Depth Increment : .05 m

Max Depth : 13.12 ft

Contractor : TERRA TECH.
 Location : 350-200
 Job No. : 93-1003
 Unit Wt. (avg) : 100 pcf

Test Date : 03-22-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-18

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	TSF
0.25	0.82	19.66	0.28	1.43	0.02	sandy silt to clayey silt	UNDFND	UNDFD	8	1.63
0.50	1.64	29.78	0.53	1.79	0.06	sandy silt to clayey silt	UNDFND	UNDFD	11	2.47
0.75	2.46	27.64	0.52	1.87	0.10	sandy silt to clayey silt	UNDFND	UNDFD	11	2.29
1.00	3.28	34.62	0.58	1.68	0.14	sandy silt to clayey silt	UNDFND	UNDFD	13	2.87
1.25	4.10	52.02	0.70	1.35	0.17	silty sand to sandy silt	70-80	44-46	17	UNDEFINED
1.50	4.92	62.30	0.85	1.37	0.19	silty sand to sandy silt	70-80	46-48	20	UNDEFINED
1.75	5.74	68.72	0.93	1.35	0.20	silty sand to sandy silt	70-80	46-48	22	UNDEFINED
2.00	6.56	92.22	1.01	1.10	0.22	sand to silty sand	80-90	46-48	22	UNDEFINED
2.25	7.38	87.18	0.96	1.11	0.23	sand to silty sand	80-90	46-48	21	UNDEFINED
2.50	8.20	66.46	0.70	1.05	0.25	sand to silty sand	70-80	44-46	16	UNDEFINED
2.75	9.02	57.06	0.55	0.96	0.26	silty sand to sandy silt	60-70	44-46	18	UNDEFINED
3.00	9.84	44.54	0.42	0.95	0.28	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
3.25	10.66	37.94	0.50	1.32	0.29	silty sand to sandy silt	50-60	42-44	12	UNDEFINED
3.50	11.48	44.56	0.53	1.18	0.31	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
3.75	12.30	52.38	0.56	1.07	0.33	silty sand to sandy silt	60-70	42-44	17	UNDEFINED
4.00	13.12	55.14	0.50	0.91	0.34	sand to silty sand	60-70	42-44	13	UNDEFINED

Dr - All sands (Jamolkowski et al. 1985)

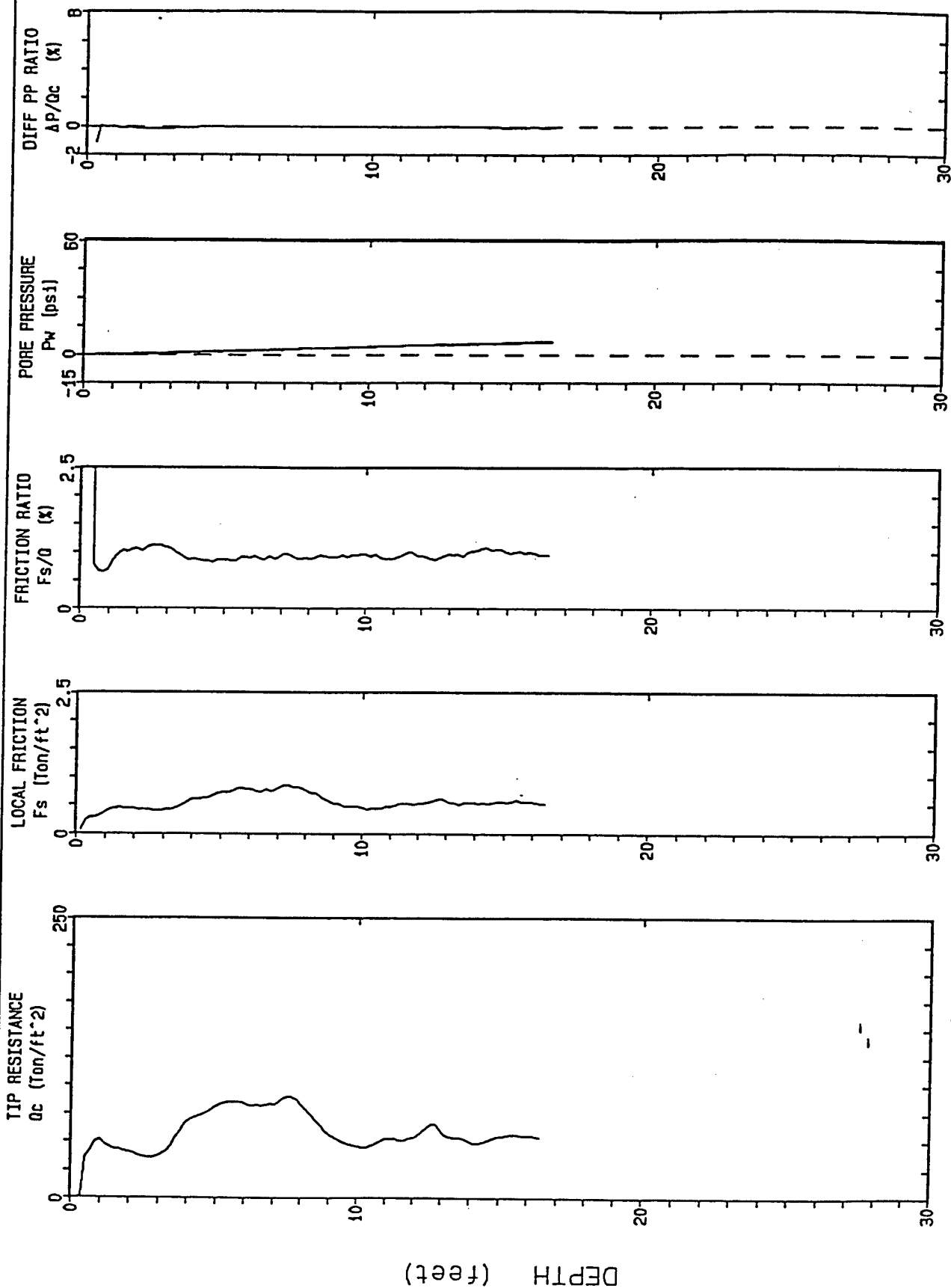
PHI - Robertson and Campanella 1983

Su: Nk= 12

Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.0)

EGLE AFB

CONTRACTOR : TERRA TECH. ? DATE : 2 03-26-93 SOUNDING NO. : 2 Pg 1 / 1
 LOCATION : ~~250-350~~ 350-250 ELEVATION : UNKNOWN TERRA JOB NO. : 93-1003



Depth Increment : .05 m

Max Depth : 16.40 ft

Contractor : TERRA TECH.

Test Date : 03-26-93

Location : 250-350

Elevation : UNKNOWN

Job No. : 93-1003

Water table (meters) : 1

Tot. Unit Wt. (avg) : 100 pcf

CPT-19

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	25.60	0.23	0.91	0.02	silty sand to sandy silt	80-90	>48	8	UNDEFINED
0.50	1.64	46.44	0.42	0.91	0.06	silty sand to sandy silt	80-90	>48	15	UNDEFINED
0.75	2.46	39.32	0.42	1.07	0.10	silty sand to sandy silt	70-80	46-48	13	UNDEFINED
1.00	3.28	37.78	0.41	1.08	0.14	silty sand to sandy silt	60-70	44-46	12	UNDEFINED
1.25	4.10	59.32	0.53	0.90	0.17	sand to silty sand	70-80	46-48	14	UNDEFINED
1.50	4.92	75.16	0.64	0.86	0.19	sand to silty sand	80-90	46-48	18	UNDEFINED
1.75	5.74	84.60	0.75	0.89	0.20	sand to silty sand	80-90	46-48	20	UNDEFINED
2.00	6.56	82.86	0.75	0.91	0.22	sand to silty sand	80-90	46-48	20	UNDEFINED
2.25	7.38	84.92	0.79	0.93	0.23	sand to silty sand	80-90	46-48	20	UNDEFINED
2.50	8.20	85.26	0.77	0.90	0.25	sand to silty sand	80-90	46-48	20	UNDEFINED
2.75	9.02	64.20	0.60	0.93	0.26	sand to silty sand	70-80	44-46	15	UNDEFINED
3.00	9.84	49.92	0.48	0.95	0.28	silty sand to sandy silt	60-70	42-44	16	UNDEFINED
3.25	10.66	46.44	0.43	0.93	0.29	silty sand to sandy silt	60-70	42-44	15	UNDEFINED
3.50	11.48	52.38	0.49	0.94	0.31	silty sand to sandy silt	60-70	42-44	17	UNDEFINED
3.75	12.30	54.64	0.51	0.94	0.33	silty sand to sandy silt	60-70	42-44	17	UNDEFINED
4.00	13.12	62.12	0.58	0.93	0.34	sand to silty sand	60-70	42-44	15	UNDEFINED
4.25	13.94	53.24	0.53	0.99	0.36	silty sand to sandy silt	60-70	42-44	17	UNDEFINED
4.50	14.76	50.28	0.53	1.06	0.37	silty sand to sandy silt	60-70	42-44	16	UNDEFINED
4.75	15.58	55.66	0.56	1.00	0.39	silty sand to sandy silt	60-70	42-44	18	UNDEFINED
5.00	16.40	55.16	0.54	0.97	0.40	silty sand to sandy silt	60-70	42-44	18	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI -

Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.

LOCATION : 350-300

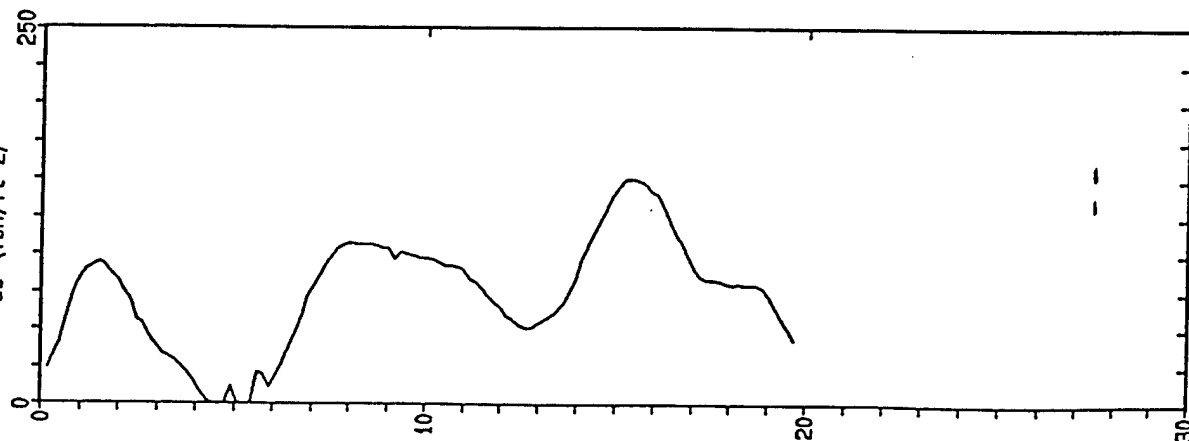
DATE : 5 03-24-93

ELEVATION : UNKNOWN

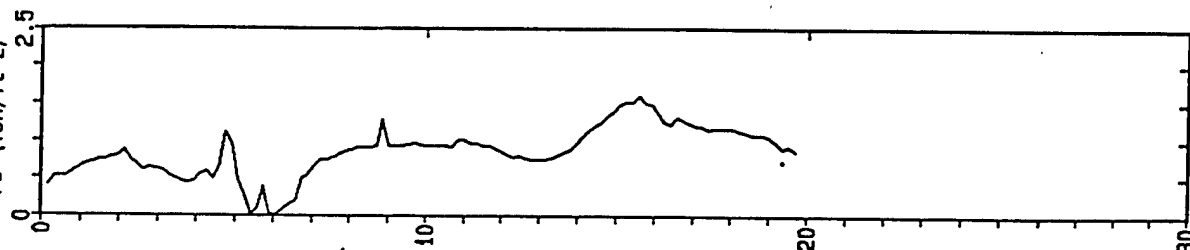
SOUNDING NO. : 1 Pg 1 / 1

TERRA JOB NO. : 93-1003

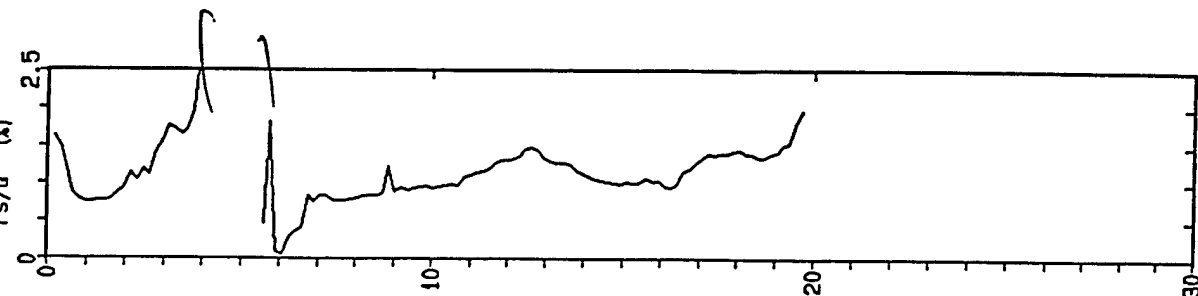
TIP RESISTANCE
Qc (Ton/ft²)



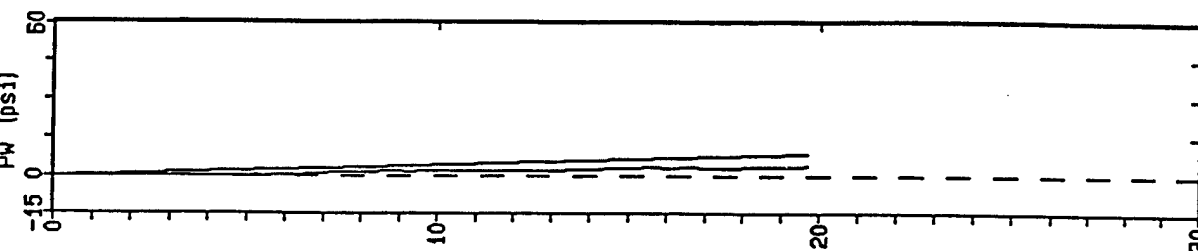
LOCAL FRICTION
Fs (Ton/ft²)



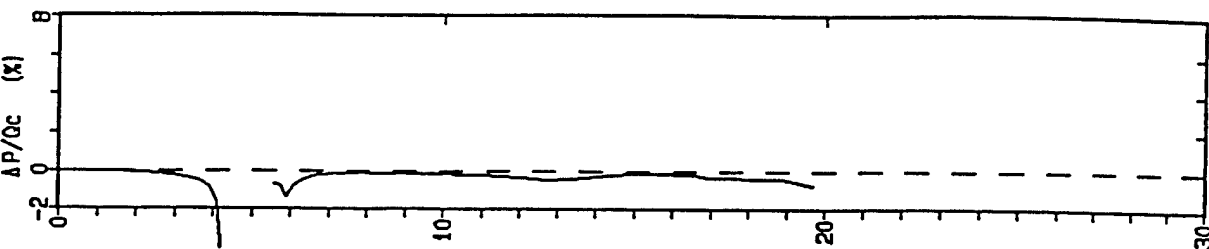
FRICTION RATIO
Fs/Qc (%)



PORE PRESSURE
Pw (psi)



DIFF PP RATIO
ΔP/Qc (%)



DEPTH (feet)

Depth Increment : .05 m

Max Depth : 19.69 ft

0

Contractor : TERRA TECH.
 Location : 350-300
 Job No. : 93-1003
 Tot. Unit Wt. (avg) : 100 pcf

Test Date : 03-24-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-20

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	46.64	0.51	1.08	0.02	silty sand to sandy silt	>90	>48	15	UNDEFINED
0.50	1.64	91.18	0.70	0.76	0.06	sand to silty sand	>90	>48	22	UNDEFINED
0.75	2.46	74.64	0.77	1.03	0.10	sand to silty sand	>90	>48	18	UNDEFINED
1.00	3.28	41.04	0.60	1.47	0.14	silty sand to sandy silt	60-70	44-46	13	UNDEFINED
1.25	4.10	20.38	0.48	2.34	0.17	clayey silt to silty clay	UNDFND	UNDFD	10	1.68
1.50	4.92	2.96	0.75	25.41	0.19	undefined	UNDFND	UNDFD	UDF	UNDEFINED
1.75	5.74	8.54	0.24	2.86	0.20	silty clay to clay	UNDFND	UNDFD	5	.68
2.00	6.56	29.22	0.09	0.30	0.22	silty sand to sandy silt	50-60	42-44	9	UNDEFINED
2.25	7.38	78.48	0.63	0.81	0.23	sand to silty sand	80-90	46-48	19	UNDEFINED
2.50	8.20	105.28	0.84	0.80	0.25	sand to silty sand	80-90	46-48	25	UNDEFINED
2.75	9.02	105.78	0.99	0.93	0.26	sand to silty sand	80-90	46-48	25	UNDEFINED
3.00	9.84	99.02	0.94	0.95	0.28	sand to silty sand	80-90	46-48	24	UNDEFINED
3.25	10.66	95.00	0.92	0.97	0.29	sand to silty sand	80-90	44-46	23	UNDEFINED
3.50	11.48	85.26	0.97	1.14	0.31	sand to silty sand	70-80	44-46	20	UNDEFINED
3.75	12.30	64.38	0.85	1.31	0.33	silty sand to sandy silt	70-80	44-46	21	UNDEFINED
4.00	13.12	53.38	0.75	1.40	0.34	silty sand to sandy silt	60-70	42-44	17	UNDEFINED
4.25	13.94	69.44	0.84	1.22	0.36	silty sand to sandy silt	70-80	42-44	22	UNDEFINED
4.50	14.76	113.82	1.19	1.04	0.37	sand to silty sand	80-90	44-46	27	UNDEFINED
4.75	15.58	147.20	1.50	1.02	0.39	sand	>90	46-48	28	UNDEFINED
5.00	16.40	136.58	1.36	0.99	0.40	sand to silty sand	80-90	46-48	33	UNDEFINED
5.25	17.22	98.32	1.24	1.26	0.42	sand to silty sand	70-80	44-46	24	UNDEFINED
5.50	18.04	82.12	1.16	1.41	0.43	silty sand to sandy silt	70-80	42-44	26	UNDEFINED
5.75	18.86	79.66	1.09	1.37	0.45	silty sand to sandy silt	70-80	42-44	25	UNDEFINED
6.00	19.69	57.76	0.93	1.61	0.46	silty sand to sandy silt	60-70	40-42	18	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH. ? DATE : 8 03-25-93 SOUNDING NO. : 1 Pg 1 / 1
 LOCATION : ~~400-350~~ 350-400 ELEVATION : UNKNOWN TERRA JOB NO. : 93-1003

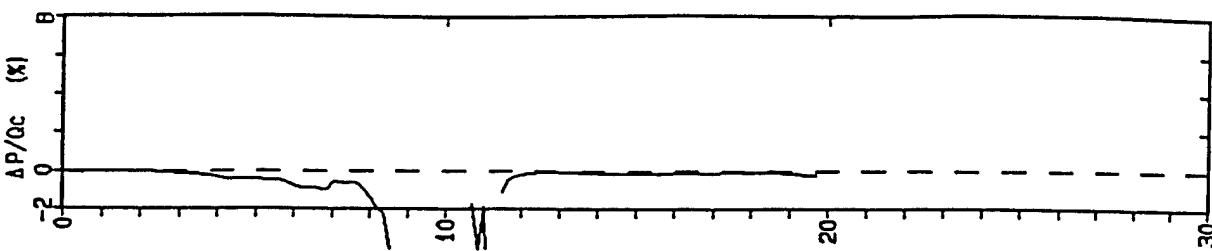
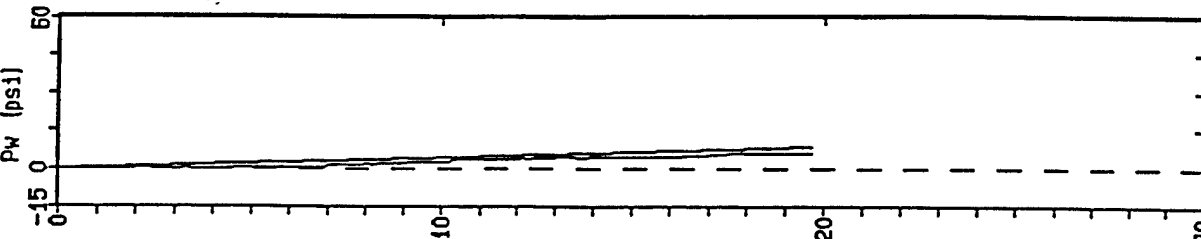
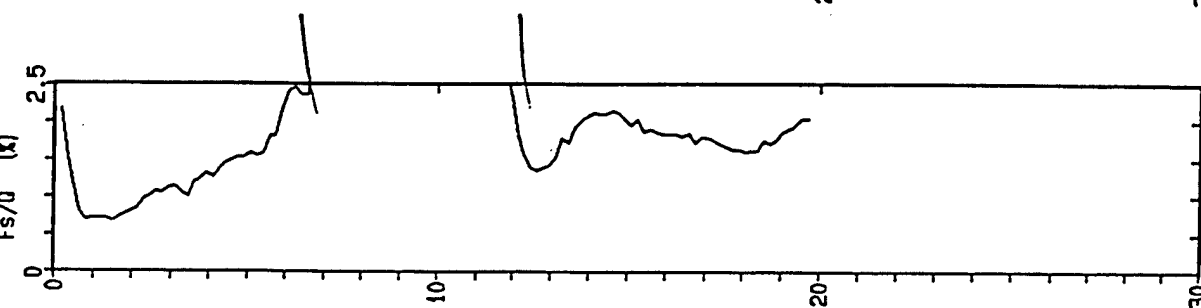
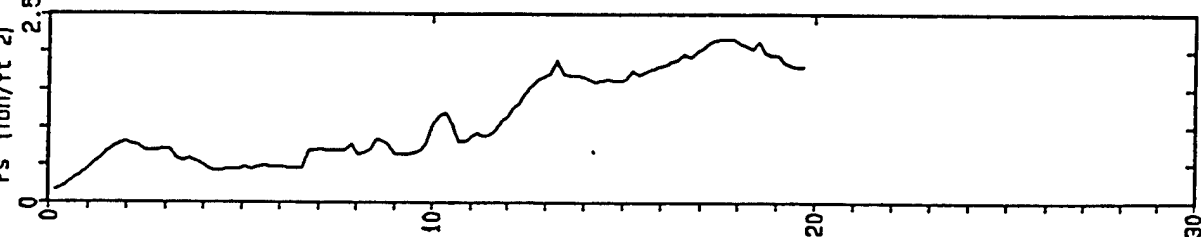
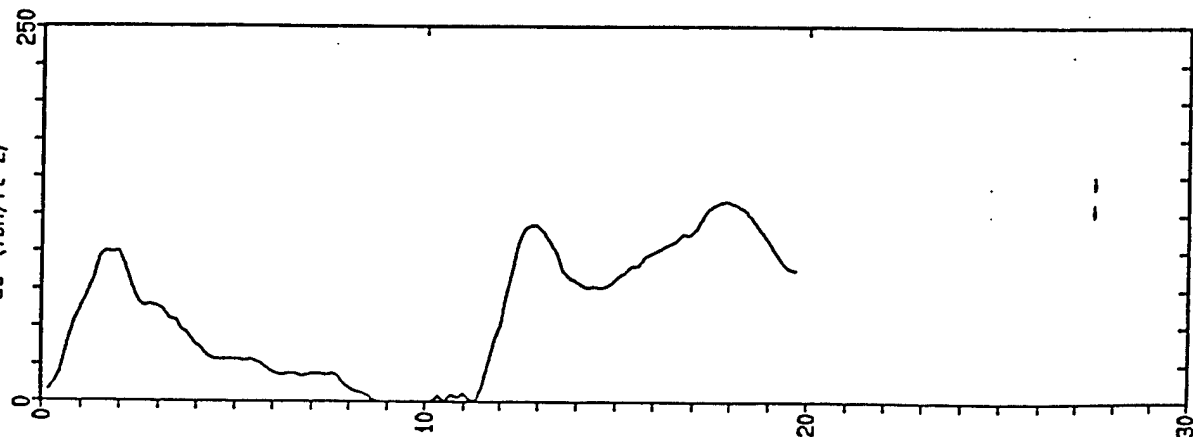
TIP RESISTANCE
 Q_c (Ton/ft²)

LOCAL FRICTION
 F_s (Ton/ft²)

FRICTION RATIO
 F_s/q (%)

PORE PRESSURE
 P_w (psi)

DIFF PP RATIO
 $\Delta P/q_c$ (%)



DEPTH (feet)

Depth Increment : .05 m

Max Depth : 19.69 ft

0

Contractor : TERRA TECH.
 Location : 400-350 350-400
 Job No. : 93-1003
 Test Unit Wt. (avg) : 100 pcf

Test Date : 03-25-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-21

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	26.64	0.26	0.98	0.02	silty sand to sandy silt	80-90	>48	9	UNDEFINED
0.50	1.64	82.32	0.59	0.71	0.06	sand to silty sand	>90	>48	20	UNDEFINED
0.75	2.46	86.84	0.76	0.87	0.10	sand to silty sand	>90	>48	21	UNDEFINED
1.00	3.28	61.60	0.67	1.09	0.14	silty sand to sandy silt	80-90	46-48	20	UNDEFINED
1.25	4.10	44.72	0.53	1.19	0.17	silty sand to sandy silt	60-70	44-46	14	UNDEFINED
1.50	4.92	29.06	0.43	1.48	0.19	sandy silt to clayey silt	UNDFND	UNDFD	11	2.40
1.75	5.74	27.48	0.46	1.67	0.20	sandy silt to clayey silt	UNDFND	UNDFD	11	2.26
2.00	6.56	19.48	0.46	2.34	0.22	clayey silt to silty clay	UNDFND	UNDFD	9	1.59
2.25	7.38	18.44	0.69	3.76	0.23	silty clay to clay	UNDFND	UNDFD	12	1.50
2.50	8.20	12.88	0.69	5.36	0.25	~~clay~~	UNDFND	UNDFD	12	1.04
2.75	9.02	1.92	0.75	38.96	0.26	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.00	9.84	0.00	0.67	0.00	0.28	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.25	10.66	1.90	1.05	55.05	0.29	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.50	11.48	4.16	0.87	20.87	0.31	~~undefined~~	UNDFND	UNDFD	UDF	UNDEFINED
3.75	12.30	54.46	1.15	2.11	0.33	sandy silt to clayey silt	UNDFND	UNDFD	21	4.48
4.00	13.12	113.42	1.60	1.41	0.34	sand to silty sand	80-90	46-48	27	UNDEFINED
4.25	13.94	91.00	1.73	1.90	0.36	silty sand to sandy silt	70-80	44-46	29	UNDEFINED
4.50	14.76	76.40	1.62	2.12	0.37	silty sand to sandy silt	70-80	44-46	24	UNDEFINED
4.75	15.58	86.12	1.68	1.96	0.39	silty sand to sandy silt	70-80	44-46	27	UNDEFINED
5.00	16.40	100.24	1.83	1.83	0.40	silty sand to sandy silt	70-80	44-46	32	UNDEFINED
5.25	17.22	112.92	2.02	1.79	0.42	silty sand to sandy silt	80-90	44-46	36	UNDEFINED
5.50	18.04	130.84	2.16	1.65	0.43	sand to silty sand	80-90	44-46	31	UNDEFINED
5.75	18.86	121.28	2.05	1.69	0.45	sand to silty sand	80-90	44-46	29	UNDEFINED
6.00	19.69	94.30	1.85	1.96	0.46	silty sand to sandy silt	70-80	44-46	30	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLI AFB

CONTRACTOR : TERRA TECH.

DATE : 4 03-26-93

SOUNDING NO. : 2 Pg 1 / 1

LOCATION : ~~0-100~~ 400-0

ELEVATION : UNKNOWN

TERRA JOB NO. : 93-1003

TIP RESISTANCE

Q_c (Ton/ft²)

LOCAL FRICTION

F_s (Ton/ft²)

FRICTION RATIO

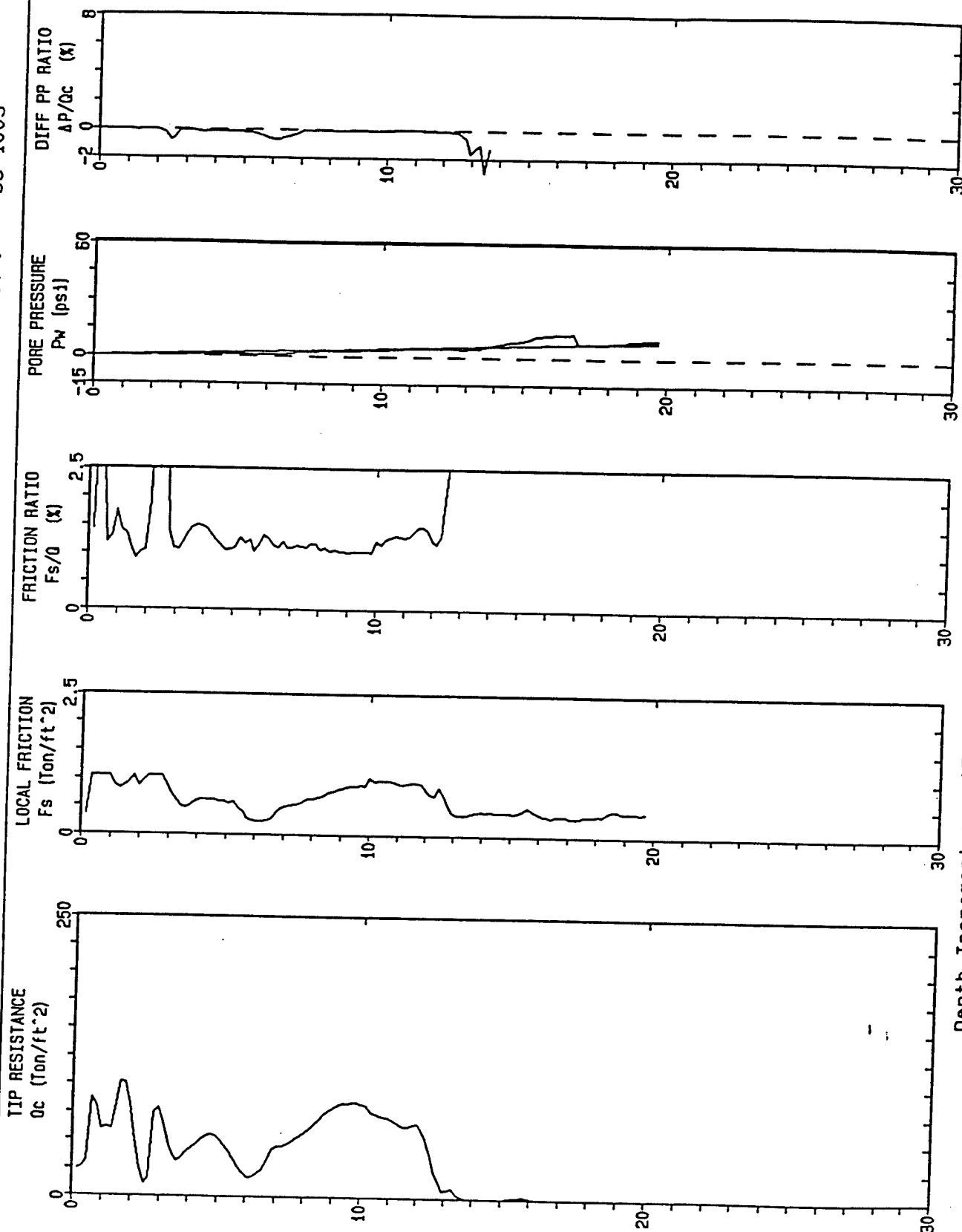
F_s/Q_c (%)

PORE PRESSURE

P_w (psf)

DIFF PP RATIO

$\Delta P/Q_c$ (%)



Depth Increment : .05 m

Max Depth : 19.69 ft

Contractor : TERRA TECH.
 Location : 0-400
 Job No. : 93-1003
 Tot. Unit Wt. (avg) : 100 pcf

Test Date : 03-26-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-22

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	tsf
0.25	0.82	50.30	0.91	1.81	0.02	silty sand to sandy silt	>90	>48	16	UNDEFINED
0.50	1.64	73.08	0.91	1.24	0.06	silty sand to sandy silt	>90	>48	23	UNDEFINED
0.75	2.46	53.76	0.99	1.84	0.10	silty sand to sandy silt	80-90	46-48	17	UNDEFINED
1.00	3.28	56.72	0.85	1.50	0.14	silty sand to sandy silt	70-80	46-48	18	UNDEFINED
1.25	4.10	37.06	0.54	1.45	0.17	silty sand to sandy silt	60-70	44-46	12	UNDEFINED
1.50	4.92	52.54	0.61	1.16	0.19	silty sand to sandy silt	70-80	44-46	17	UNDEFINED
1.75	5.74	38.82	0.46	1.17	0.20	silty sand to sandy silt	60-70	42-44	12	UNDEFINED
2.00	6.56	20.90	0.25	1.19	0.22	sandy silt to clayey silt	UNDFND	UNDFD	8	1.71
2.25	7.38	42.46	0.48	1.14	0.23	silty sand to sandy silt	60-70	42-44	14	UNDEFINED
2.50	8.20	55.16	0.62	1.12	0.25	silty sand to sandy silt	60-70	44-46	18	UNDEFINED
2.75	9.02	73.42	0.77	1.04	0.26	sand to silty sand	70-80	44-46	18	UNDEFINED
3.00	9.84	84.42	0.88	1.04	0.28	sand to silty sand	80-90	44-46	20	UNDEFINED
3.25	10.66	78.14	0.98	1.25	0.29	sand to silty sand	70-80	44-46	19	UNDEFINED
3.50	11.48	68.36	0.93	1.35	0.31	silty sand to sandy silt	70-80	44-46	22	UNDEFINED
3.75	12.30	61.96	0.82	1.32	0.33	silty sand to sandy silt	60-70	42-44	20	UNDEFINED
4.00	13.12	18.98	0.58	3.03	0.34	clayey silt to silty clay	UNDFND	UNDFD	9	1.52
4.25	13.94	2.96	0.39	13.31	0.36	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.50	14.76	0.00	0.42	0.00	0.37	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.75	15.58	0.86	0.44	51.40	0.39	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.00	16.40	1.04	0.39	37.31	0.40	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.25	17.22	0.00	0.35	0.00	0.42	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.50	18.04	0.00	0.36	0.00	0.43	undefined	UNDFND	UNDFD	UDF	UNDEFINED
5.75	18.86	0.00	0.43	0.00	0.45	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.00	19.69	0.00	0.43	0.00	0.46	undefined	UNDFND	UNDFD	UDF	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

*** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ***

EGLEIN AFB

CONTRACTOR : ERRA TECH.

LOCATION : 400-200

DATE : -22-93

ELEVATION : UNKNOWN

T SOUNDING NO. : 4 03 Pg 1 / 1

TERRA JOB NO. : 93-1003

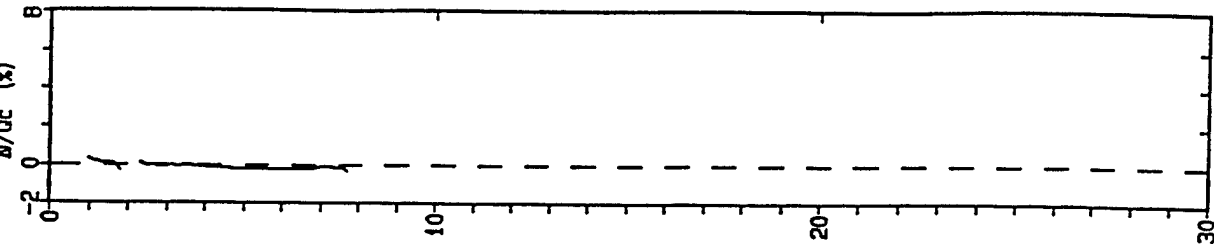
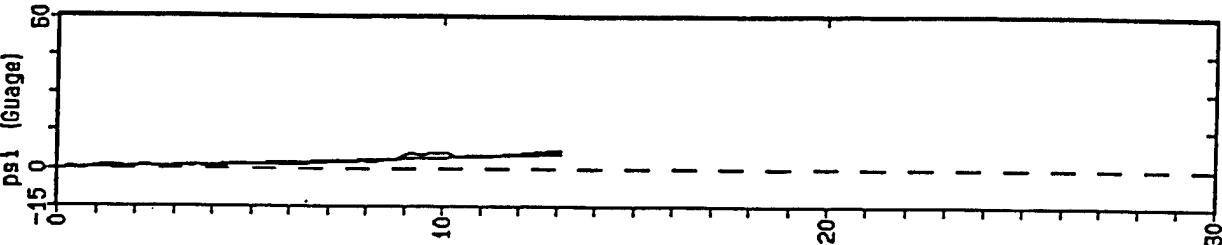
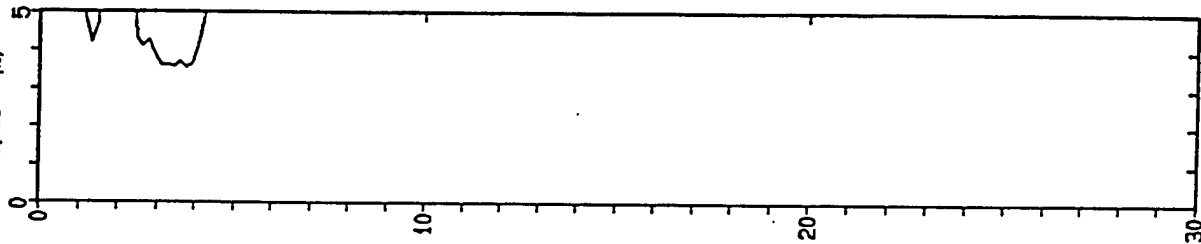
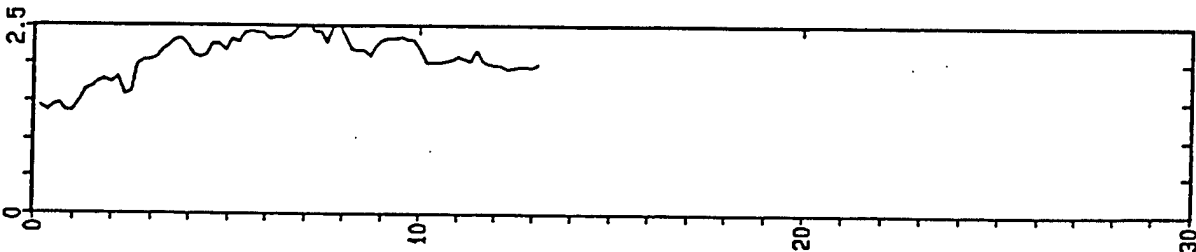
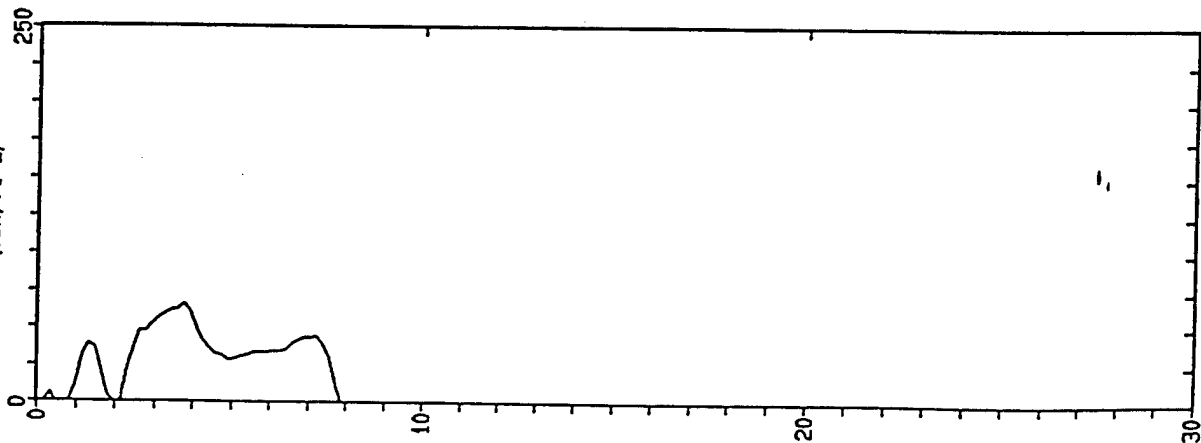
TIP RESISTANCE
 Q_c (Ton/ft²)

LOCAL FRICTION
 F_s (Ton/ft²)

FRICTION RATIO
 F_s/Q_c (%)

U
psi (Guage)

DIFF PP RATIO
 W/Q_c (%)



DEPTH (Feet)

Depth Increment : .05 m

Max Depth : 13.12 ft

Contractor :TERRA TECH.

Location : 400-200

Job No. : 93-1003

Tot. Unit Wt. (avg) : 100 pcf

Test Date : 04-22-93

Elevation : UNKNOWN

Water table (meters) : 1

CPT-23

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	1.22	1.42	116.23	0.02	undefined	UNDFND	UNDFD	UDF	UNDEFINED
0.50	1.64	27.86	1.59	5.71	0.06	clay	UNDFND	UNDFD	27	2.31
0.75	2.46	13.04	1.71	13.13	0.10	undefined	UNDFND	UNDFD	UDF	UNDEFINED
1.00	3.28	53.22	2.06	3.87	0.14	clayey silt to silty clay	UNDFND	UNDFD	25	4.42
1.25	4.10	60.36	2.25	3.72	0.17	clayey silt to silty clay	UNDFND	UNDFD	29	5.01
1.50	4.92	33.76	2.18	6.46	0.19	clay	UNDFND	UNDFD	32	2.79
1.75	5.74	31.52	2.37	7.53	0.20	clay	UNDFND	UNDFD	30	2.60
2.00	6.56	34.98	2.36	6.75	0.22	clay	UNDFND	UNDFD	34	2.88
2.25	7.38	42.30	2.48	5.87	0.23	clay	UNDFND	UNDFD	41	3.49
2.50	8.20	8.88	2.37	26.71	0.25	undefined	UNDFND	UNDFD	UDF	UNDEFINED
2.75	9.02	0.00	2.19	0.00	0.26	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.00	9.84	0.00	2.32	0.00	0.28	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.25	10.66	0.00	2.04	0.00	0.29	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.50	11.48	0.00	2.08	0.00	0.31	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.75	12.30	0.00	1.98	0.00	0.33	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.00	13.12	0.00	1.95	0.00	0.34	undefined	UNDFND	UNDFD	UDF	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02)

EGLETON AFB

CONTRACTOR : TERRA TECH.
 LOCATION : 300-500-400,350

DATE : 7 03-24-93
 ELEVATION : UNKNOWN

SOUNDING NO. : 1 Pg 1 / 1
 TERRA JOB NO. : 93-1003

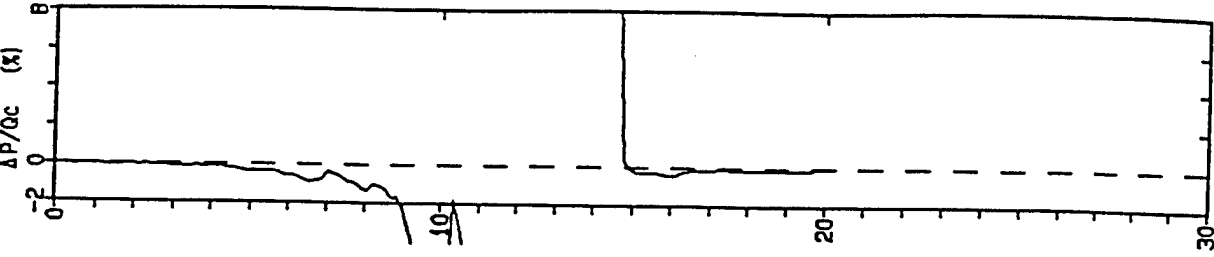
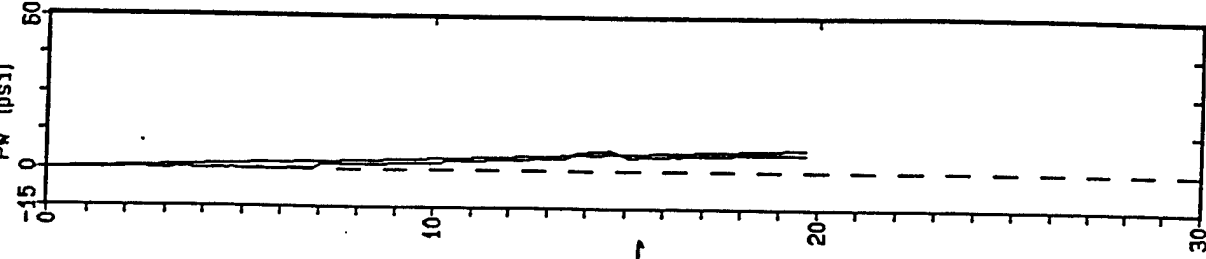
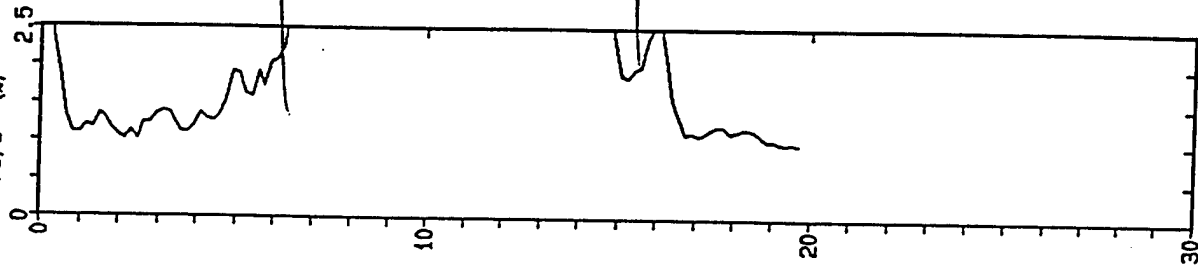
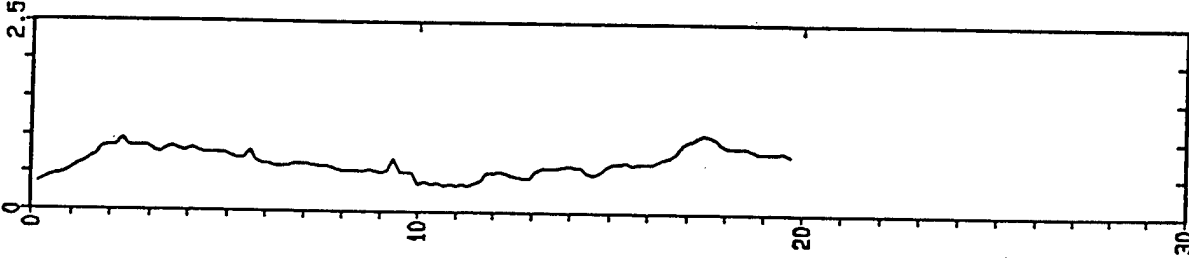
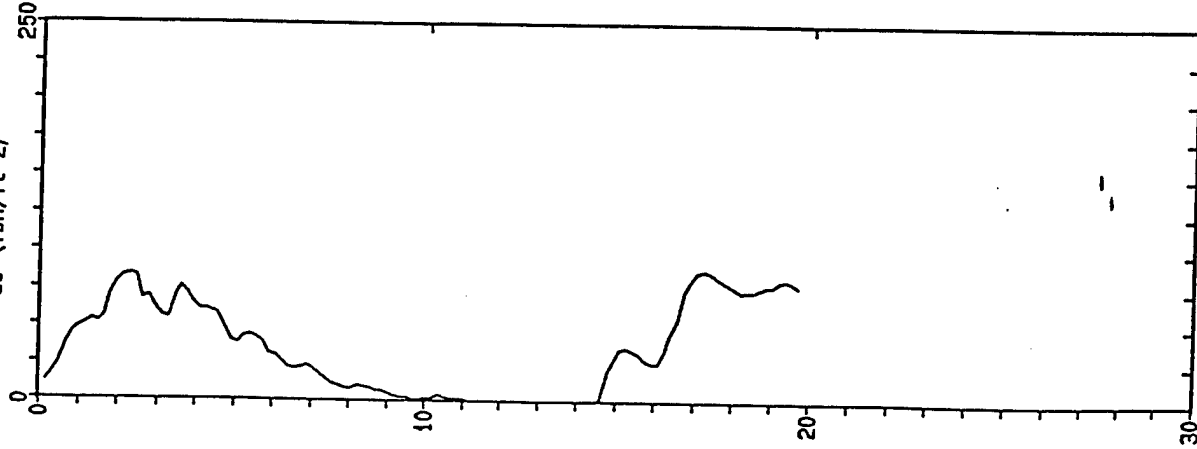
TIP RESISTANCE
 Q_c (Ton/ft²)

LOCAL FRICTION
 F_s (Ton/ft²)

FRICTION RATIO
 F_s/Q_c (%)

PORE PRESSURE
 P_w (psf)

DIFF PP RATIO
 $\Delta P/Q_c$ (%)



DEPTH (feet)

Depth Increment : .05 m

Max Depth : 19.69 ft

Contractor : TERRA TECH.
 Location : 300-500
 Job No. : 93-1003
 Tot. Unit Wt. (avg) : 100 pcf

Test Date : 03-24-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-1-4 57?

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV/ (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	26.64	0.44	1.64	0.02	sandy silt to clayey silt	UNDFND	UNDFD	10	2.21
0.50	1.64	52.20	0.64	1.23	0.06	silty sand to sandy silt	80-90	>48	17	UNDEFINED
0.75	2.46	80.38	0.87	1.09	0.10	sand to silty sand	>90	>48	19	UNDEFINED
1.00	3.28	62.46	0.82	1.32	0.14	silty sand to sandy silt	80-90	46-48	20	UNDEFINED
1.25	4.10	68.74	0.83	1.20	0.17	silty sand to sandy silt	80-90	46-48	22	UNDEFINED
1.50	4.92	53.76	0.78	1.44	0.19	silty sand to sandy silt	70-80	44-46	17	UNDEFINED
1.75	5.74	41.44	0.73	1.75	0.20	silty sand to sandy silt	60-70	44-46	13	UNDEFINED
2.00	6.56	26.64	0.62	2.33	0.22	sandy silt to clayey silt	UNDFND	UNDFD	10	2.19
2.25	7.38	20.38	0.62	3.06	0.23	clayey silt to silty clay	UNDFND	UNDFD	10	1.66
2.50	8.20	9.72	0.56	5.76	0.25	clay	UNDFND	UNDFD	9	.77
2.75	9.02	7.50	0.54	7.15	0.26	clay	UNDFND	UNDFD	7	.58
3.00	9.84	2.10	0.56	26.57	0.28	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.25	10.66	2.40	0.37	15.58	0.29	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.50	11.48	0.68	0.36	53.24	0.31	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.75	12.30	0.00	0.50	0.00	0.33	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.00	13.12	0.00	0.48	0.00	0.34	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.25	13.94	0.00	0.59	0.00	0.36	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.50	14.76	4.00	0.55	13.75	0.37	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.75	15.58	32.70	0.65	1.98	0.39	sandy silt to clayey silt	UNDFND	UNDFD	13	2.66
5.00	16.40	31.66	0.68	2.14	0.40	sandy silt to clayey silt	UNDFND	UNDFD	12	2.57
5.25	17.22	76.38	0.88	1.15	0.42	sand to silty sand	70-80	42-44	18	UNDEFINED
5.50	18.04	81.08	0.97	1.19	0.43	sand to silty sand	70-80	42-44	19	UNDE
5.75	18.86	74.80	0.85	1.14	0.45	sand to silty sand	60-70	42-44	18	UNDE
6.00	19.69	79.68	0.80	1.01	0.46	sand to silty sand	70-80	42-44	19	UNDE

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

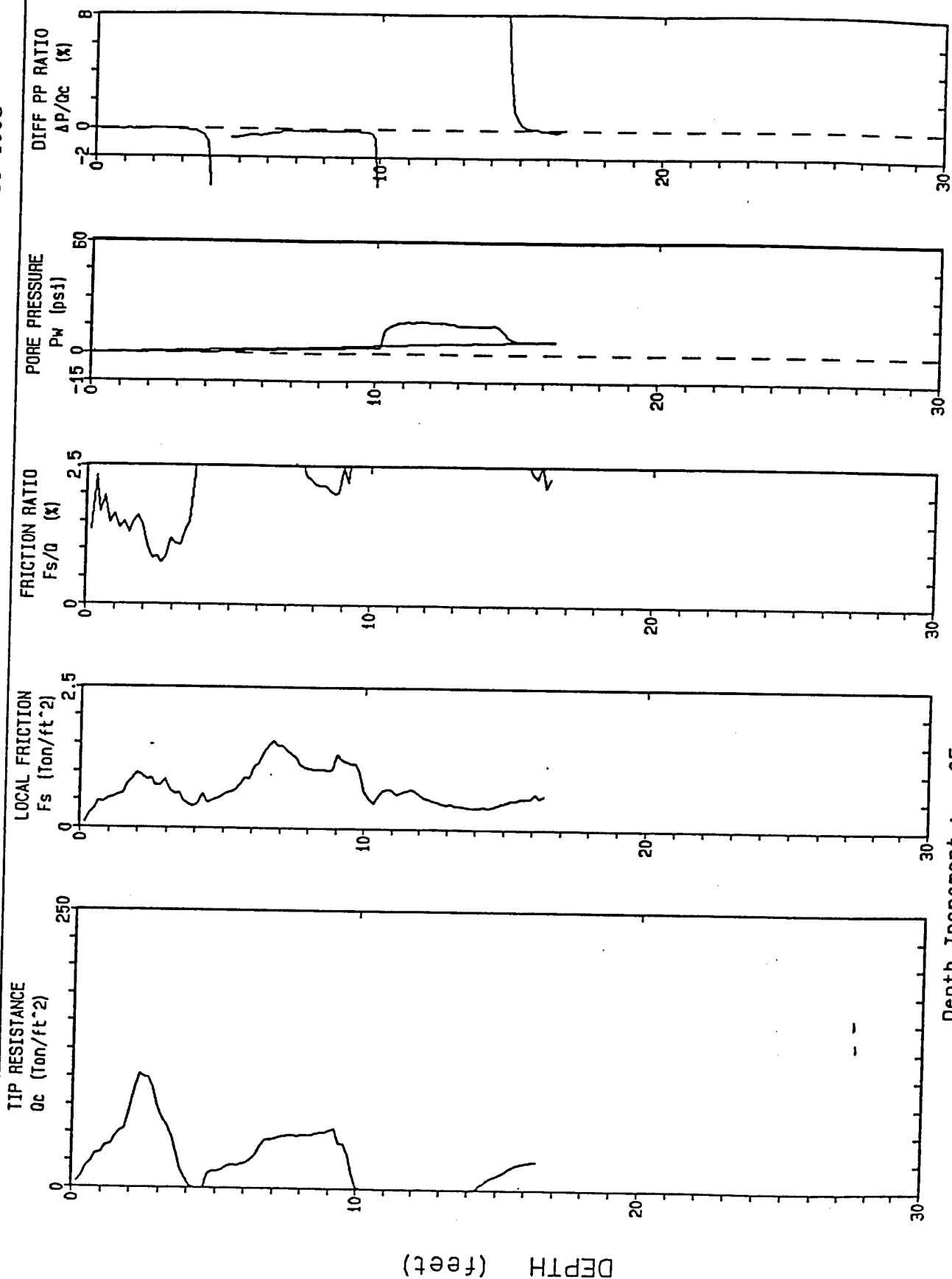
**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

EGLIN AFB

CONTRACTOR : TERRA TECH.
 LOCATION : 450-300

DATE : 6 03-24-93
 ELEVATION : UNKNOWN

SOUNDING NO. : 1 Pg 1 / 1
 TERRA JOB NO. : 93-1003



Depth Increment : .05 m

Max Depth : 16.40 ft

Contractor : TERRA TECH.
 Location : 450-300
 Job No. : 93-1003
 Tot. Unit Wt. (avg) : 100 pcf

Test Date : 03-24-93
 Elevation : UNKNOWN
 Water table (meters) : 1

C 87-25

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	17.74	0.31	1.74	0.02	sandy silt to clayey silt	UNDFND	UNDFD	7	1.47
0.50	1.64	41.42	0.60	1.45	0.06	silty sand to sandy silt	80-90	>48	13	UNDEFINED
0.75	2.46	82.82	0.90	1.08	0.10	sand to silty sand	>90	>48	20	UNDEFINED
1.00	3.28	75.86	0.73	0.96	0.14	sand to silty sand	80-90	46-48	18	UNDEFINED
1.25	4.10	21.40	0.47	2.18	0.17	sandy silt to clayey silt	UNDFND	UNDFD	8	1.76
1.50	4.92	5.92	0.52	8.82	0.19	undefined	UNDFND	UNDFD	UDF	UNDEFINED
1.75	5.74	19.34	0.72	3.74	0.20	silty clay to clay	UNDFND	UNDFD	12	1.58
2.00	6.56	28.48	1.19	4.18	0.22	silty clay to clay	UNDFND	UNDFD	18	2.34
2.25	7.38	45.76	1.44	3.14	0.23	sandy silt to clayey silt	UNDFND	UNDFD	18	3.78
2.50	8.20	48.52	1.11	2.29	0.25	sandy silt to clayey silt	UNDFND	UNDFD	19	4.01
2.75	9.02	50.98	1.10	2.16	0.26	sandy silt to clayey silt	UNDFND	UNDFD	20	4.21
3.00	9.84	36.38	1.13	3.12	0.28	clayey silt to silty clay	UNDFND	UNDFD	17	2.99
3.25	10.66	0.34	0.58	171.18	0.29	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.50	11.48	0.00	0.66	0.00	0.31	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.75	12.30	0.00	0.61	0.00	0.33	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.00	13.12	0.00	0.46	0.00	0.34	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.25	13.94	0.00	0.40	0.00	0.36	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.50	14.76	4.34	0.40	9.17	0.37	undefined	UNDFND	UNDFD	UDF	UNDEFINED
4.75	15.58	16.54	0.51	3.08	0.39	clayey silt to silty clay	UNDFND	UNDFD	8	1.31
5.00	16.40	25.06	0.58	2.33	0.40	sandy silt to clayey silt	UNDFND	UNDFD	10	2.02

Dr - All sands (Jamiolkowski et al. 1985)

PHI - Robertson and Campanella 1983

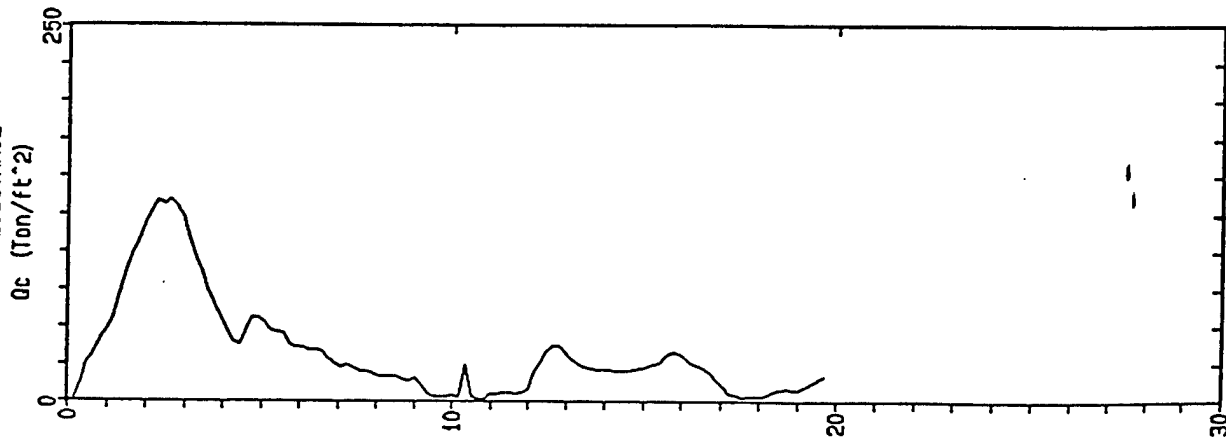
Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

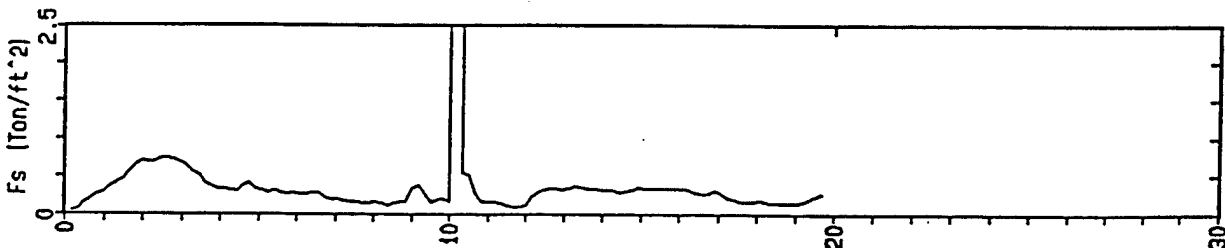
EGLIN AFB

CONTRACTOR : TERRA TECH.
 LOCATION : 450-500' 550-400' ELEVATION : UNKNOWN
 DATE : 9 03-25-93
 SOUNDING NO. : 1 Pg 1 / 1
 TERRA JOB NO. : 93-1003

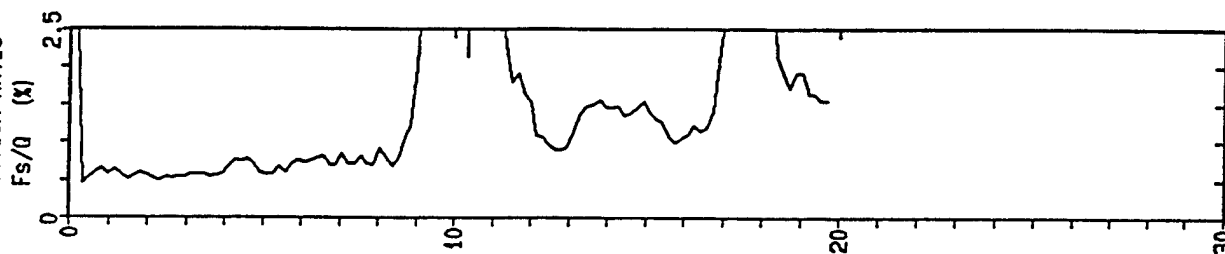
TIP RESISTANCE



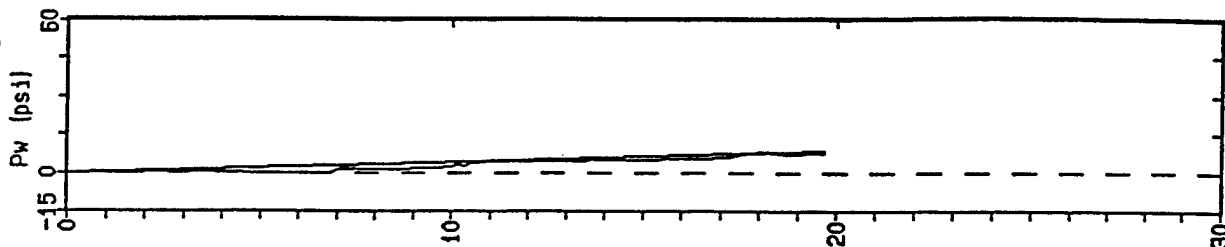
LOCAL FRICTION



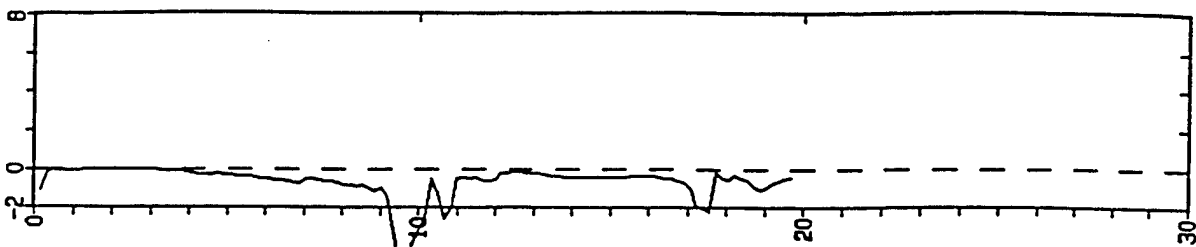
FRICTION RATIO



PORE PRESSURE



DIFF PP RATIO



Depth Increment : .05 m

Max Depth : 19.69 ft

Contractor : TERRA TECH.
 Location : 450-500
 Job No. : 93-1003
 Tot. Unit Wt. (avg) : 100 pcf

Test Date : 03-25-93
 Elevation : UNKNOWN
 Water table (meters) : 1

CPT-26

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	
0.25	0.82	22.62	0.14	0.63	0.02	silty sand to sandy silt	70-80	>48	7	UNDEFINED
0.50	1.64	72.20	0.42	0.58	0.06	sand to silty sand	>90	>48	17	UNDEFINED
0.75	2.46	123.54	0.69	0.56	0.10	sand	>90	>48	24	UNDEFINED
1.00	3.28	118.86	0.66	0.56	0.14	sand	>90	>48	23	UNDEFINED
1.25	4.10	66.28	0.39	0.59	0.17	sand to silty sand	80-90	46-48	16	UNDEFINED
1.50	4.92	47.66	0.34	0.72	0.19	sand to silty sand	60-70	44-46	11	UNDEFINED
1.75	5.74	46.46	0.29	0.63	0.20	sand to silty sand	60-70	44-46	11	UNDEFINED
2.00	6.56	35.30	0.27	0.78	0.22	silty sand to sandy silt	50-60	42-44	11	UNDEFINED
2.25	7.38	25.76	0.19	0.74	0.23	silty sand to sandy silt	40-50	40-42	8	UNDEFINED
2.50	8.20	19.32	0.15	0.79	0.25	sandy silt to clayey silt	UNDFND	UNDFD	7	1.57
2.75	9.02	16.00	0.18	1.15	0.26	sandy silt to clayey silt	UNDFND	UNDFD	6	1.29
3.00	9.84	5.40	0.24	4.37	0.28	clay	UNDFND	UNDFD	5	.41
3.25	10.66	7.50	7.76	103.41	0.29	undefined	UNDFND	UNDFD	UDF	UNDEFINED
3.50	11.48	4.86	0.15	3.13	0.31	clay	UNDFND	UNDFD	5	.35
3.75	12.30	12.86	0.16	1.26	0.33	sandy silt to clayey silt	UNDFND	UNDFD	5	1.02
4.00	13.12	34.28	0.33	0.97	0.34	silty sand to sandy silt	50-60	40-42	11	UNDEFINED
4.25	13.94	23.16	0.34	1.48	0.36	sandy silt to clayey silt	UNDFND	UNDFD	9	1.87
4.50	14.76	21.26	0.30	1.43	0.37	sandy silt to clayey silt	UNDFND	UNDFD	8	1.71
4.75	15.58	25.58	0.33	1.31	0.39	sandy silt to clayey silt	UNDFND	UNDFD	10	2.06
5.00	16.40	29.08	0.32	1.10	0.40	silty sand to sandy silt	40-50	38-40	9	UNDEFINED
5.25	17.22	14.08	0.27	1.89	0.42	clayey silt to silty clay	UNDFND	UNDFD	7	1.10
5.50	18.04	3.56	0.18	5.00	0.43	clay	UNDFND	UNDFD	3	?
5.75	18.86	7.12	0.15	2.16	0.45	silty clay to clay	UNDFND	UNDFD	5	
6.00	19.69	12.52	0.20	1.63	0.46	clayey silt to silty clay	UNDFND	UNDFD	6	

Dr - All sands (Jamiołkowski et al. 1985)

PHI - Robertson and Campanella 1983

Su: Nk= 12

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

LOCKABLE

STEEL PROTECTIVE CASING

DATUM: ELEVATION = 12.84' msl
NORTHING = 10028.15
EASTING = 10146.70

PVC CAP

WEEP HOLE

GROUND SURFACE ELEV. = 10.35' msl

CONCRETE

PORTLAND CEMENT-
SODIUM BENTONITE GROUT

2" I.D. SCH. 40
PVC CASING

17.0'

19.0'

20.2'

25.2'

26.0'

BENTONITE PELLETS

20-30 SILICA
SAND

2" I.D. SCH. 40 PVC SCREEN
W/THREADED JOINTS
SLOT SIZE = 0.010"

8" DIA. BOREHOLE

8" END CAP

WELL COMPLETION DIAGRAM EPA-83-1

Well: EPA-83-1

Installation Date: 09/21/93

Drilling Subcontractor: Layne Environmental

Geologist: R. Surrency, ES

T. Wiedemeier, ES

EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

LOCKABLE
STEEL PROTECTIVE CASING

DATUM: ELEVATION = 12.77' msl
NORTHING = 10030.72
EASTING = 10144.57

PVC CAP

WEEP HOLE

GROUND SURFACE ELEV. = 10.46'

CONCRETE

PORTLAND CEMENT-
SODIUM BENTONITE GROUT

2" I.D. SCH. 40
PVC CASING

1.0'

2.0'

2.3'

7.3'

8.0'

BENTONITE PELLETS

20-30 SILICA
SAND

2" I.D. SCH. 40 PVC SCREEN
W/THREADED JOINTS
SLOT SIZE = 0.010"

8" DIA. BOREHOLE

8" END CAP

WELL COMPLETION DIAGRAM EPA-83-2

Well: EPA-83-2

Installation Date: 09/21/93

Drilling Subcontractor: Layne Environmental

Geologist: R. Surrency, ES
T. Wiedemeier, ES

EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

LOCKABLE
STEEL PROTECTIVE CASING

DATUM: ELEVATION = 5.77' msl
NORTHING = 9922.04
EASTING = 10354.49

PVC CAP

WEEP HOLE

GROUND SURFACE ELEV. = 3.93' msl

CONCRETE

PORTLAND CEMENT-
SODIUM BENTONITE GROUT

2" I.D. SCH. 40
PVC CASING

11.0'

14.0'

14.4'

19.4'

20.2'

BENTONITE PELLETS

20-30 SILICA
SAND

2" I.D. SCH. 40 PVC SCREEN
W/THREADED JOINTS
SLOT SIZE = 0.010"

8" DIA. BOREHOLE

8" END CAP

WELL COMPLETION DIAGRAM EPA-83-3

Well: EPA-83-3

Installation Date: 09/21/93

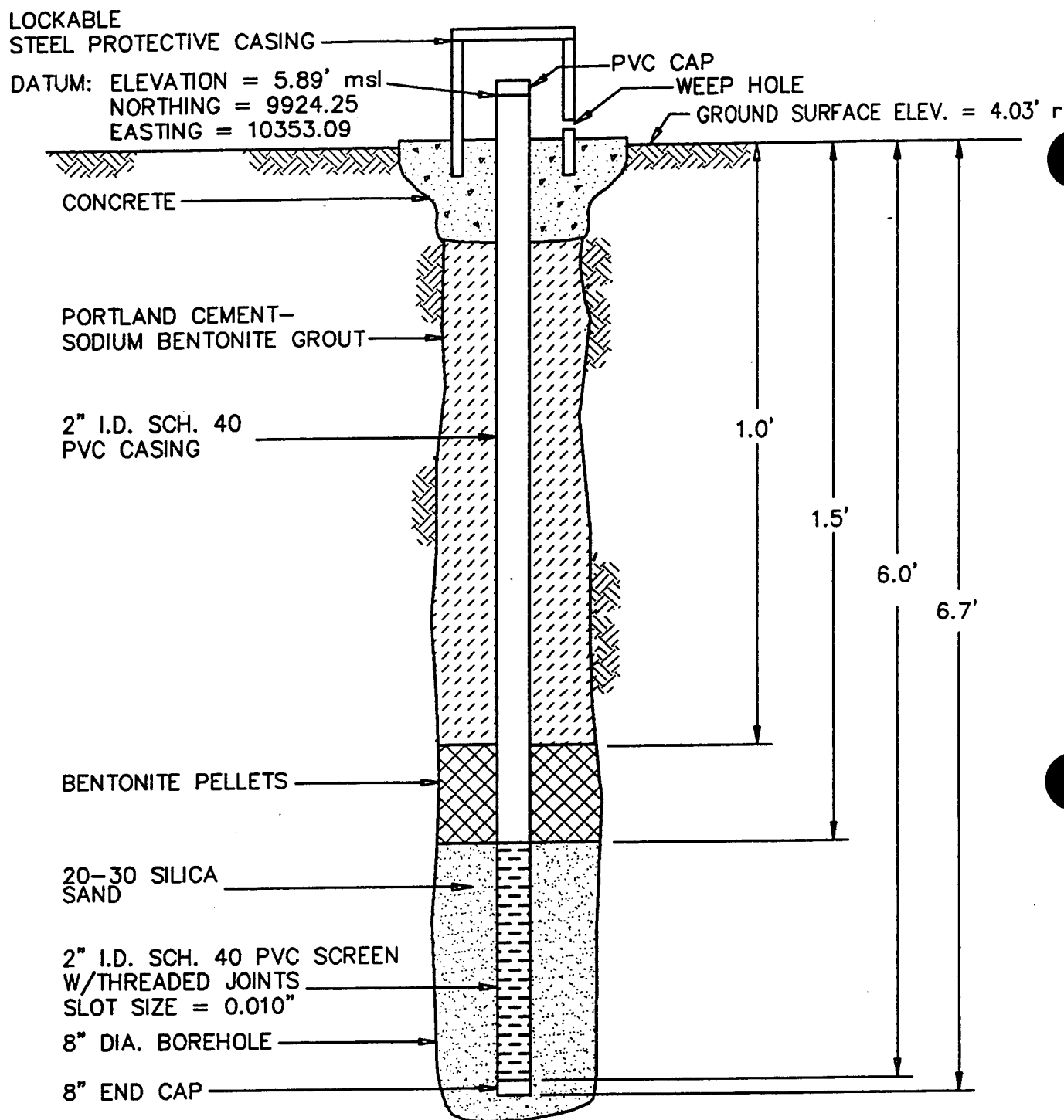
Drilling Subcontractor: Layne Environmental

Geologist: R. Surrency, ES
T. Wiedemeier, ES

EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado



**WELL COMPLETION DIAGRAM
EPA-83-4**

Well: EPA-83-4

Installation Date: 09/22/93

Drilling Subcontractor: Layne Environmental

Geologist: R. Surrency, ES
T. Wiedemeier, ES

EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

LOCKABLE
STEEL PROTECTIVE CASING

DATUM: ELEVATION = 6.98' msl
NORTHING = 10032.47
EASTING = 10363.49

PVC CAP

WEEP HOLE

GROUND SURFACE ELEV. = 5.11' msl

CONCRETE

PORTLAND CEMENT-
SODIUM BENTONITE GROUT

2" I.D. SCH. 40
PVC CASING

10.0'

12.0'

14.7'

19.7'

20.5'

BENTONITE PELLETS

20-30 SILICA
SAND

2" I.D. SCH. 40 PVC SCREEN
W/THREADED JOINTS
SLOT SIZE = 0.010"

8" DIA. BOREHOLE

8" END CAP

WELL COMPLETION DIAGRAM EPA-83-5

Well: EPA-83-5

Installation Date: 09/22/93

Drilling Subcontractor: Layne Environmental

Geologist: R. Surrency, ES
T. Wiedemeier, ES

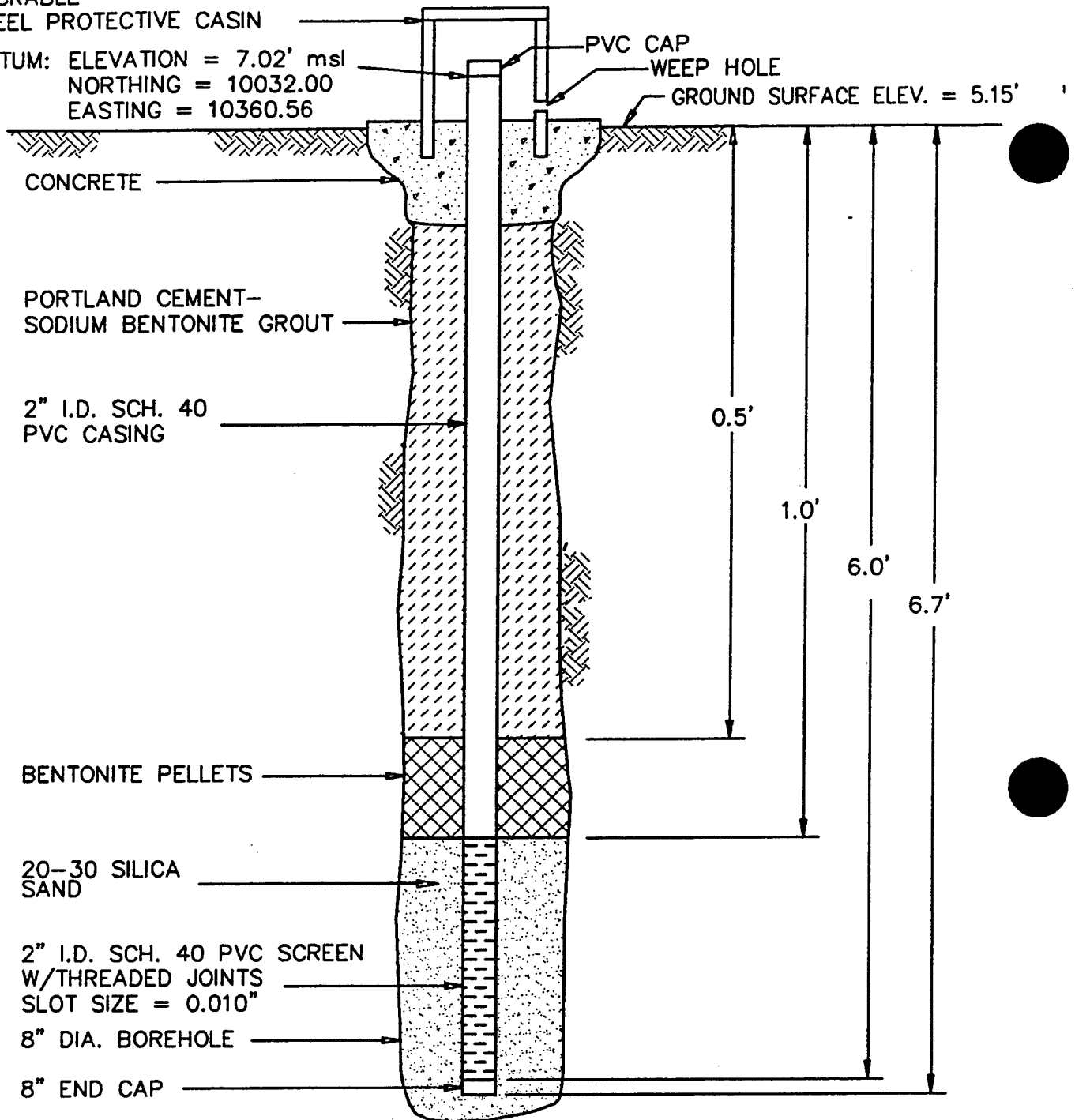
EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

LOCKABLE
STEEL PROTECTIVE CASIN

DATUM: ELEVATION = 7.02' msl
NORTHING = 10032.00
EASTING = 10360.56



**WELL COMPLETION DIAGRAM
EPA-83-6**

Well: EPA-83-6

Installation Date: 09/22/93

Drilling Subcontractor: Layne Environmental

Geologist: J. Hutton

EA, Engineering, Science and
Technology, Inc.

EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

LOCKABLE
STEEL PROTECTIVE CASING

DATUM: ELEVATION = 10.68' msl
NORTHING = 9967.36
EASTING = 10231.39

PVC CAP

WEEP HOLE

GROUND SURFACE ELEV. = 8.72' msl

CONCRETE

PORTLAND CEMENT-
SODIUM BENTONITE GROUT

2" I.D. SCH. 40
PVC CASING

1.5'

2.5'

3.4'

8.4'

9.1'

BENTONITE PELLETS

20-30 SILICA
SAND

2" I.D. SCH. 40 PVC SCREEN
W/THREADED JOINTS
SLOT SIZE = 0.010"

8" DIA. BOREHOLE

8" END CAP

WELL COMPLETION DIAGRAM EPA-83-7

Well: EPA-83-7

Installation Date: 09/23/93

Drilling Subcontractor: Layne Environmental

Geologist: T. Wiedemeier, ES

EGLIN AFB EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado



FIELD RECORD OF WELL DEVELOPMENT

Site: Eglin AFB - P02 Your Name: Guy Willis

Well No.: EPA-83-1 Date: 9/22/93 Time: 0800

Weather: clear, 72°

Well Condition: good Odor (describe): Strong

Well Diameter (inches): 2"

Sounding Method: IFD Measurement Reference: 700

Well Depth (ft): 28.45 Development Method: 2'-sub pump

(a) Initial Depth to Liquid (ft): _____ Time: 0815

(b) Initial Depth to Water (ft): 7.67

(c) Liquid Thickness (ft) [(1)-(2)]: _____

(a) Time Start Development: 0821 Calibrated Discharge Rate (gpm): 5 gpm

(b) Time Stop Development: 10:15 Calculated Discharge (gal): 250 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) at start H2O is very turbid,

dk brown in color w/ strong hydrocarbon odor - after 30 gal = no change - after

(e) Final Depth to Liquid (ft): _____ Time: 1015

(f) Final Depth to Water (ft): 11.82 while pumping

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: Thru carbon trailer

Remarks: 60 gal H2O is moderately turbid - brown in color - surged repeatedly + H2O became very turbid + dk brown after 90 gal = same as above - after 120 gal H2O = slightly turbid upon surging H2O became moderately/highly turbid - after 150 gal = same as above - Gripped pump to empty carbon trailer - instant 950 - H2O is mod turbid + brown in color - after 30 gal (1210 total) = slightly turbid - upon surging H2O =

FIELD RECORD OF WELL DEVELOPMENT

Site: Eglin AFB - Pol EPA wells Your Name: Guy Willis

Well No.: EPA 83-2 Date: 9/22/93 Time: 1310

Weather: clear hot 90°

Well Condition: good Odor (describe): mod hydrocarbon odor

Well Diameter (inches): 2"

Sounding Method: JFD Measurement Reference: TOC

Well Depth (ft): 10.34 Development Method: 2" sub pump

(a) Initial Depth to Liquid (ft): _____ Time: 1312

(b) Initial Depth to Water (ft): 4.90

(c) Liquid Thickness (ft) [(1)-(2)]: _____

(a) Time Start Development: 1315 Calibrated Discharge Rate (gpm): 3 gpm

(b) Time Stop Development: 1350 Calculated Discharge (gal): 130 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) At start H2O was very turbid + dk brown - w/mod hydrocarbon odor - after 30 gal H2O is only slightly turbid

(e) Final Depth to Liquid (ft): _____ Time: 1351

(f) Final Depth to Water (ft): 8.73

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: thru carbon trailer

Remarks: surged repeatedly & water became very turbid + dk brown in color - reduced flow rate to 1 gpm - after 60 gal H2O = purging almost clear after surging H2O became mod. turbid. after 90 gal H2O is purging clear after repeated surging H2O became mod. turbid & cleared w/in 5 gal. after 120 gal - water is purging clear - after surging turbidity increased to mod levels - no card is set more - H2O is clear - changed due

FIELD RECORD OF WELL DEVELOPMENT

Site: Eglin AFB - POL Your Name: Guy Willis

Well No.: EPA 83-3 Date: 9/23/93 Time: 14:10

Weather: clear - hot

Well Condition: good Odor (describe): mod. hydrocarbon odor

Well Diameter (inches): 2"

Sounding Method: IFP Measurement Reference: TOL

Well Depth (ft): 2200 Development Method: 2" sub pump

(a) Initial Depth to Liquid (ft): _____ Time: 14:10

(b) Initial Depth to Water (ft): 3.16

(c) Liquid Thickness (ft) [(1)-(2)]: 18.9 $\times .17 = 3.2 = \text{well vol}$

(a) Time Start Development: 14:15 Calibrated Discharge Rate (gpm): 5 gpm

(b) Time Stop Development: 15:05 Calculated Discharge (gal): 200 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) At start H₂O is moderately turbid - med. brown in color w/ slight / mod hydrocarbon odor - after 10

(e) Final Depth to Liquid (ft): _____ Time: 15:08

(f) Final Depth to Water (ft): 3.24

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: Thru carbon trailer -

Remarks: gallons H₂O slightly turbid - surged repeatedly + H₂O became highly turbid + lt tan in color - after 40 gal H₂O is moderately turbid - surged repeatedly + H₂O became very turbid (lt tan in color) - after 70 gal H₂O is slightly turbid - lowered pump in well + surged H₂O became highly turbid + med brown in color - after 100 gal H₂O is slightly turbid - upon surging H₂O became mod. turbid - after 120 gal -

FIELD RECORD OF WELL DEVELOPMENT

Site: Eglin AFB. POL Your Name: Guy Williams

Well No.: EPA83-4 Date: 9/23/93 Time: 1515

Weather: clear hot 92°

Well Condition: good Odor (describe): mod/strong h/c odor

Well Diameter (inches): 2"

Sounding Method: IFD Measurement Reference: TOC

Well Depth (ft): 8.60 Development Method: 2" sub pump

(a) Initial Depth to Liquid (ft): _____ Time: 16

(b) Initial Depth to Water (ft): 419

(c) Liquid Thickness (ft) [(1)-(2)]: 4.41 $\times .17 = .75 \text{ gal per well vol}$

(a) Time Start Development: 1547 Calibrated Discharge Rate (gpm): start at 5 gpm
cut back to 2

(b) Time Stop Development: 1630 Calculated Discharge (gal): 80 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) At start H₂O = very DK

brown + turbid - w/in 30 seconds ok start at 5 gpm pump began to surge

(e) Final Depth to Liquid (ft): _____ Time: 1630 cut flow back to 2

(f) Final Depth to Water (ft): 5.20

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: Thru utility trailer

Remarks: After 15 gal H₂O - purging clear upon surging turbidity increased to high levels (DK brown color) after 30 gal - same as above
after 40 gal H₂O purging clear - upon surging H₂O became mod turbid
after 50 gal H₂O purging clear - upon surging became slight/mod turbid -
after 60 gal - same as above - after 70 gal H₂O: clear after surging H₂O became
slight/mod turbid - turbidity cleared w/in 3 min - purged 10 more & started dis.

FIELD RECORD OF WELL DEVELOPMENT

Site: Eglin AFB - Pol Your Name: Guy Willis

Well No.: EPA 83-5 Date: 9/24/93 Time: 0815

Weather: clear - warm

Well Condition: good Odor (describe): mod/strong h/c odor

Well Diameter (inches): 2'

Sounding Method: IFP Measurement Reference: TOC

Well Depth (ft): 22.35 Development Method: 2" sub pump

(a) Initial Depth to Liquid (ft): _____ Time: 0825

(b) Initial Depth to Water (ft): 4.62

(c) Liquid Thickness (ft) [(1)-(2)]: _____

(a) Time Start Development: 0830 Calibrated Discharge Rate (gpm): 45 gpm

(b) Time Stop Development: 0925 Calculated Discharge (gal): 250 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) At start H₂O = very dk brown + turbid - after 15 gal H₂O began to clear - after 30 gal H₂O purging clear

(e) Final Depth to Liquid (ft): _____ Time: 0 surged ↓

(f) Final Depth to Water (ft): _____

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: Thru carbon trailer

Remarks: repeatedly + H₂O ~~became~~ became dk brown + highly turbid -

after 60 gal same as above - After 90 gal H₂O = clear - upon surging dk brown + mod/highly turbid - after 120 gal H₂O is clear upon surging H₂O became mod turbid - after 150 gal = same as above - after 180 gal = H₂O purging clear - after surging H₂O became slight mod turbid + dissipated very quickly - after 200 gal = same as above - after 210 gal =

FIELD RECORD OF WELL DEVELOPMENT

Site: Eglin AFB - POL Your Name: Guy Willes

Well No.: EPA 83-6 Date: 9/24/93 Time: 1045

Weather: clear-hot - nice

Well Condition: good Odor (describe): strong h/c odor

Well Diameter (inches): 2"

Sounding Method: EFM Measurement Reference: TOL

Well Depth (ft): 8.60 Development Method: 2" sub pump

(a) Initial Depth to Liquid (ft): _____ Time: 1048

(b) Initial Depth to Water (ft): 3.70

(c) Liquid Thickness (ft) [(1)-(2)]: _____

(a) Time Start Development: 1050 Calibrated Discharge Rate (gpm): 3.5 p.m.

(b) Time Stop Development: 1122 Calculated Discharge (gal): 90 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) AT start H2O is dk brown + turbid - after 20 gal H2O is clear - upon surging H2O became very turbid

(e) Final Depth to Liquid (ft): _____ Time: 1122 ↓

(f) Final Depth to Water (ft): 6.20

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: Thru carbon trailer

Remarks: and dark brown - after 40 gal H2O surging clear upon surging H2O became mod turbid - after 60 gal H2O - purge clear after surging turbidity increased slightly - after 80 gal - same as above - purged 10 gal more + stopped

Attention -- Todd Wiedemeier

FIELD RECORD OF WELL DEVELOPMENT

Site: EGLIN AFB - POL Your Name: Guy Willis

Well No.: EDA 83-7 Date: 9/23/93 Time: 1500

Weather: clear - hot - humid 92°

Well Condition: good Odor (describe): Strong hydrocarbon odor

Well Diameter (inches): 2"

Sounding Method: IFD Measurement Reference: 76C

Well Depth (ft): 11.10 Development Method: 2" s-b pump

(a) Initial Depth to Liquid (ft): _____ Time: 1500

(b) Initial Depth to Water (ft): 6.47

(c) Liquid Thickness (ft) [(1)-(2)]: _____

(a) Time Start Development: 1502 Calibrated Discharge Rate (gpm): Start at 2.5 gpm

(b) Time Stop Development: 16:30 Calculated Discharge (gal): 45 gal

(c) Remember to clean the entire screen length to remove silts and clays!

(d) Description of discharge (i.e., silty; clear after 30 min, etc.) A t Start H₂O mod turbid -

dk brown in color - w/ strong hydrocarbon odor - after 10 gal = Almost clear

(e) Final Depth to Liquid (ft): _____ Time: 16:31

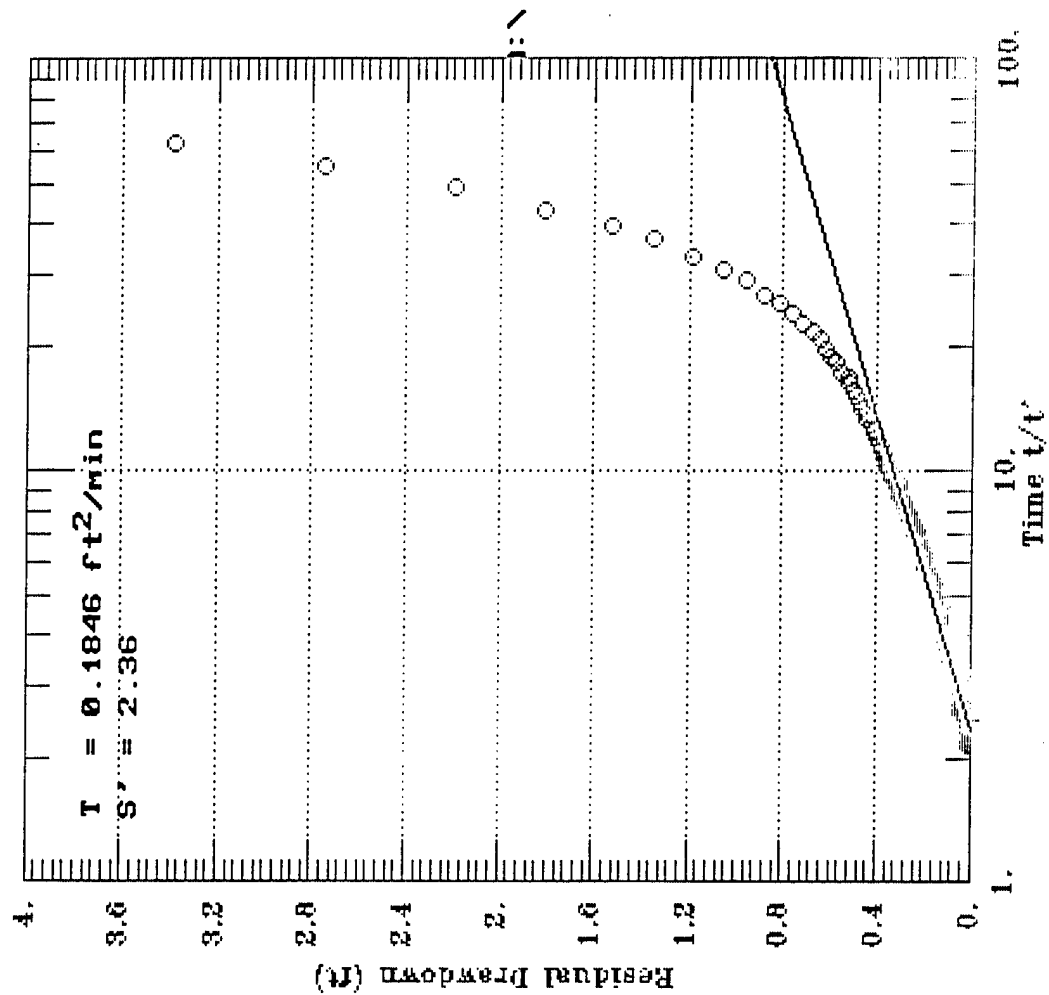
(f) Final Depth to Water (ft): 8.95

(c) Liquid Thickness (ft) [(1)-(2)]: _____

Disposal Method for Discharge: Three carbon Trainers

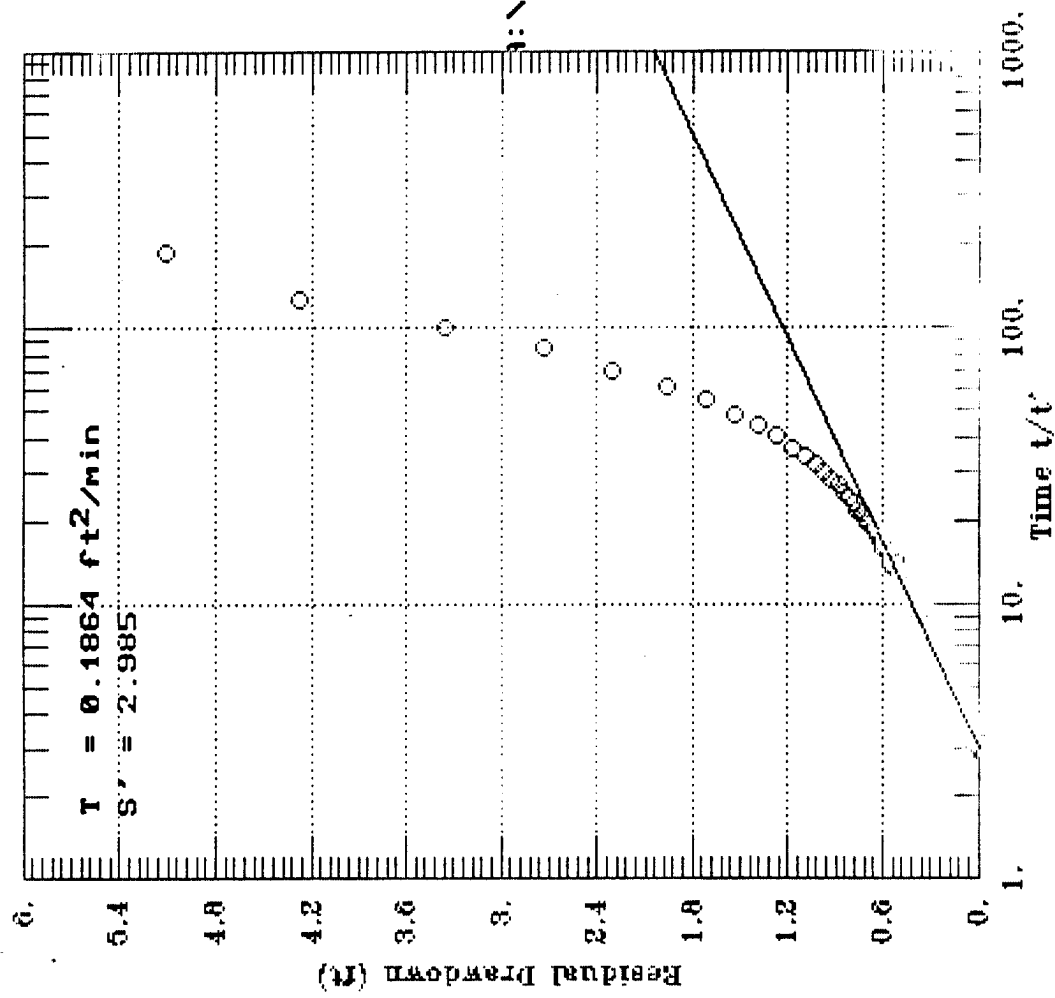
Remarks: pump surging pumping at 4.5 of 1.5 gpm - After surging
H₂O became dk brown & mod. turbid - after 25 gal H₂O is purging
clear - after surging turbidity increased to slight/mod levels -
after 35 gal H₂O is purging clear - upon surging turbidity increased
only slightly - purge rate = 4.5 gpm - after 45 gal H₂O is clear - and pu

EGLIN EPA-83-1 THEIRS RECOVERY TEST1



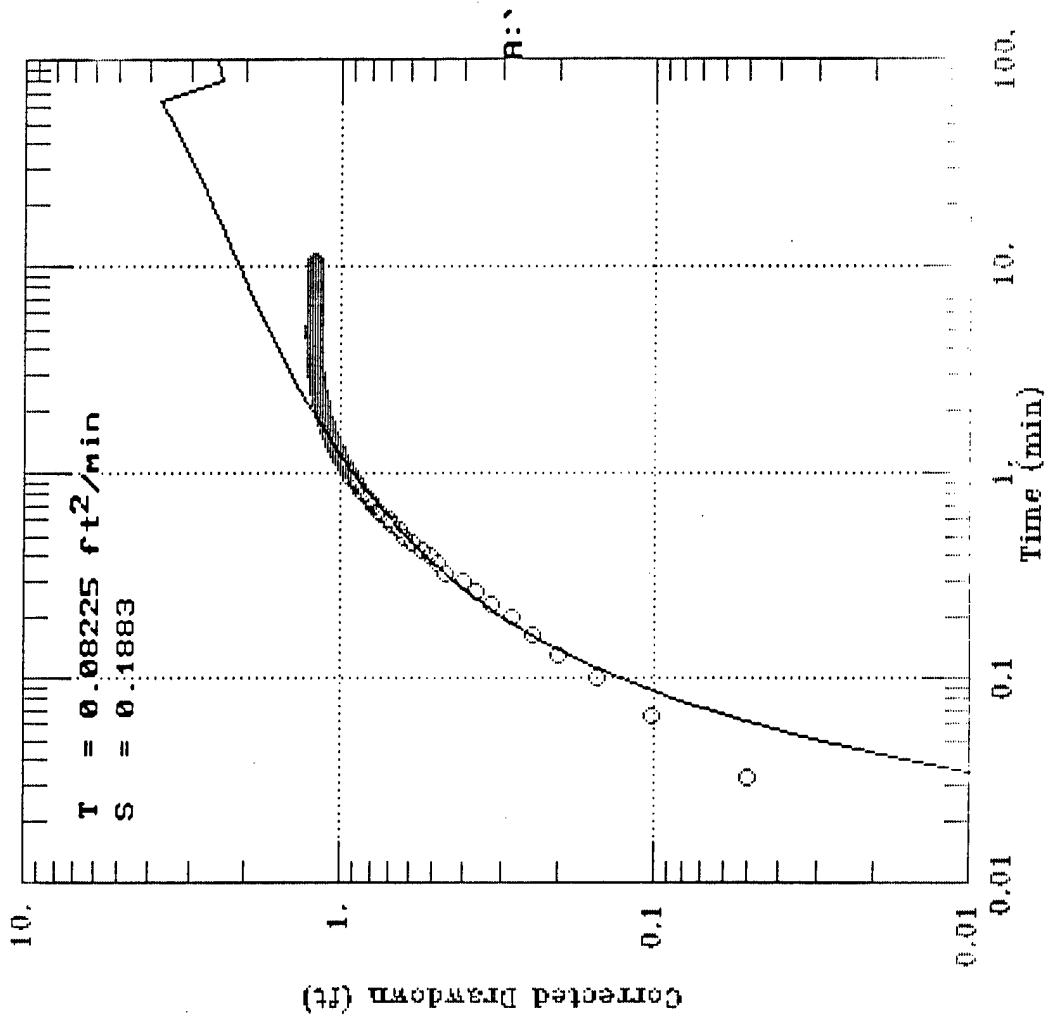
DAT

EGLIN EPA-83-1 THEIR RECOVERY TEST 2

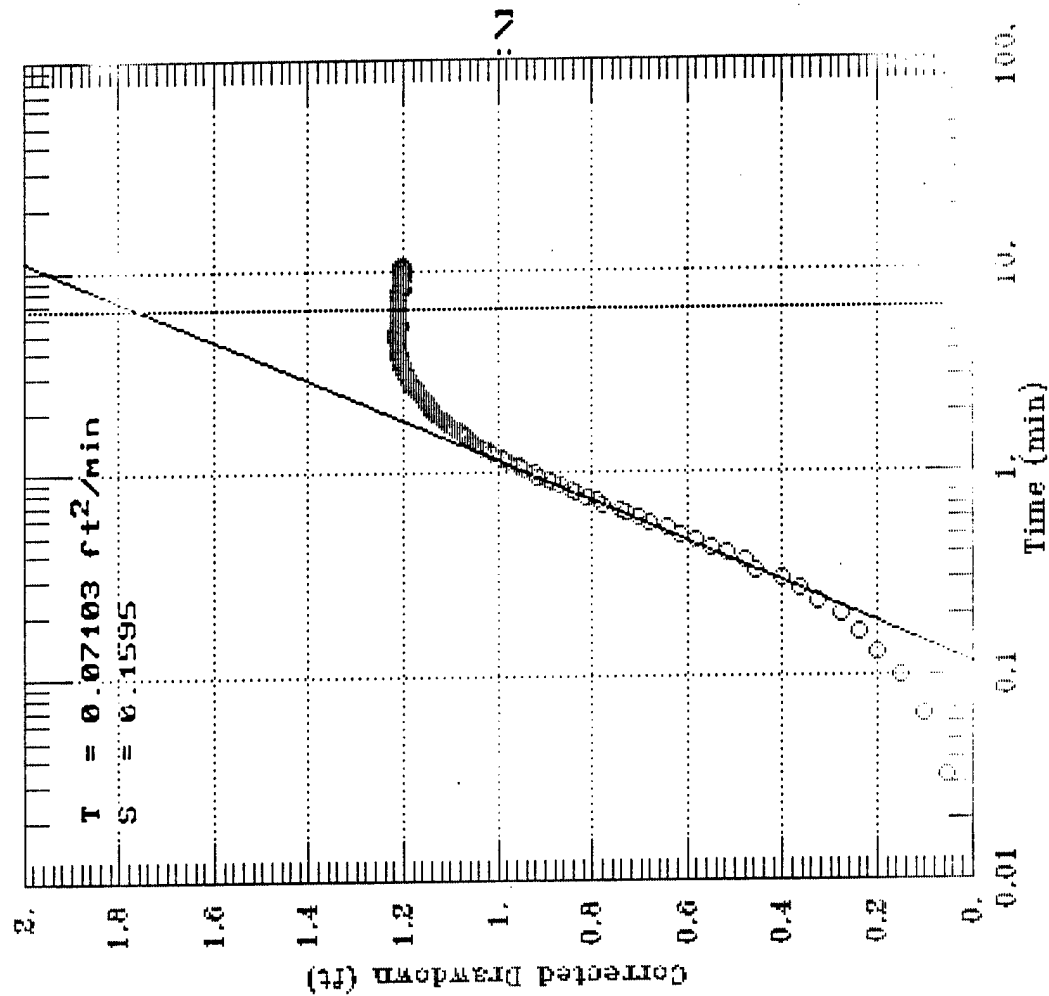


DAT

EGLIN EPA-83-2 THEIS DD UNCONFINED TEST1

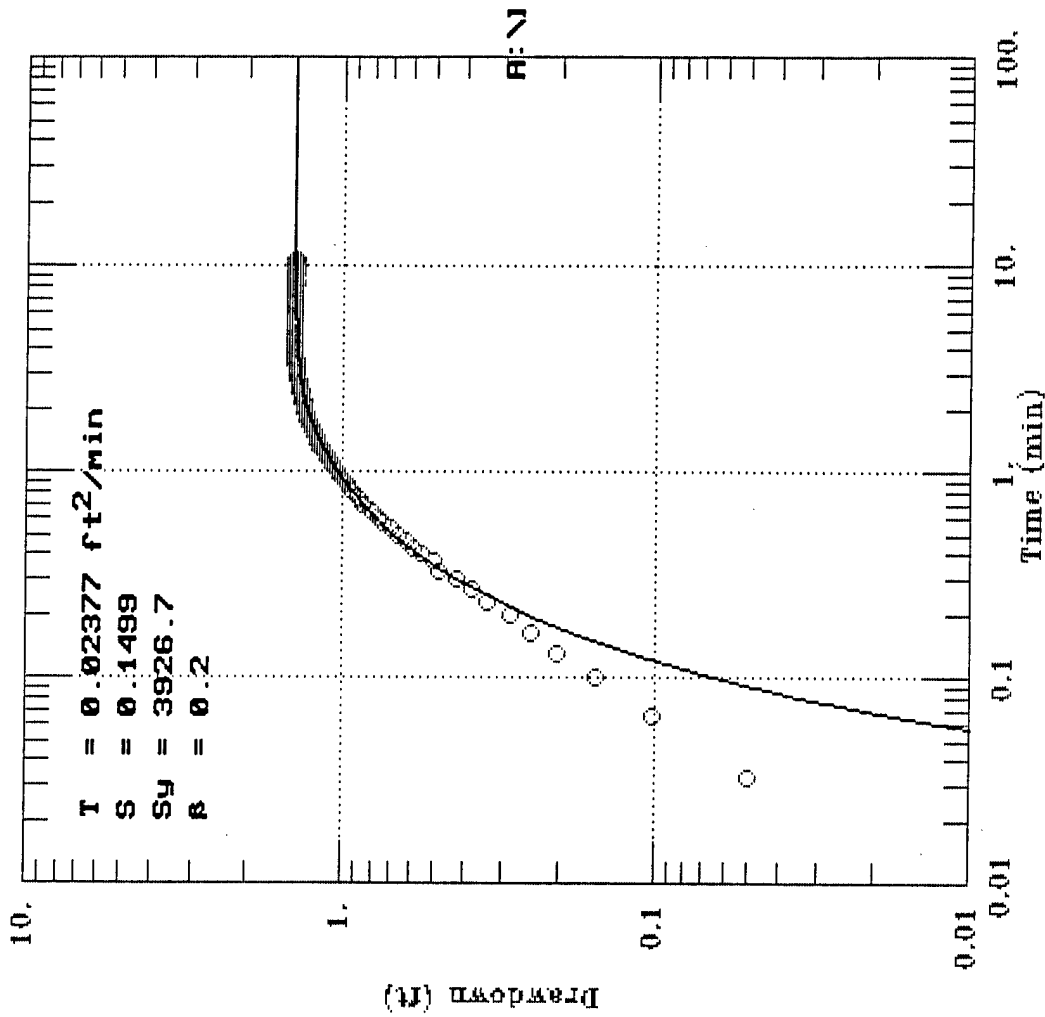


EGLIN EPA-83-2 COOPER-JACOB DD UNCONF. 1

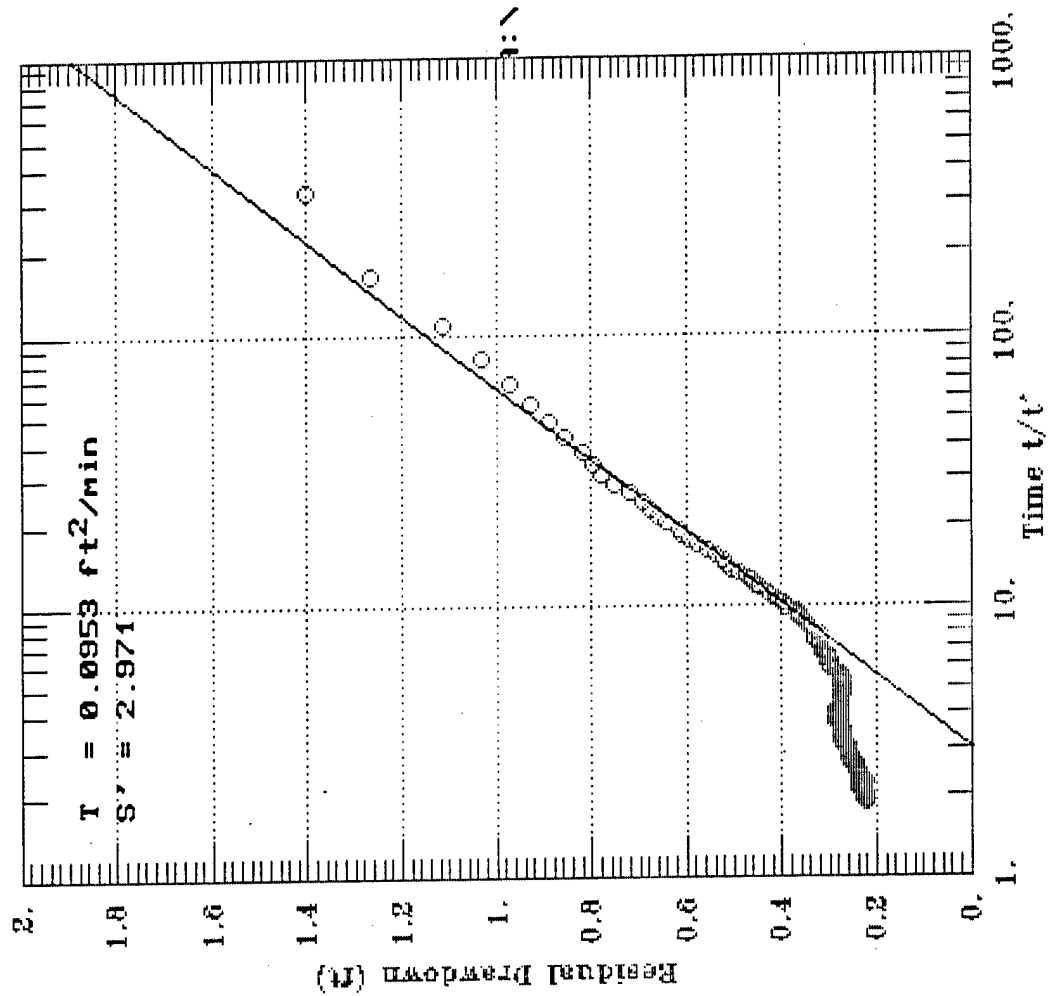


DAJ

Neuman
 EGLIN EPA-83-2 COOPER-JACOB DD UNCONF. 1



EGLIN EPA-83-2 THEIR RECOVERY TEST 1

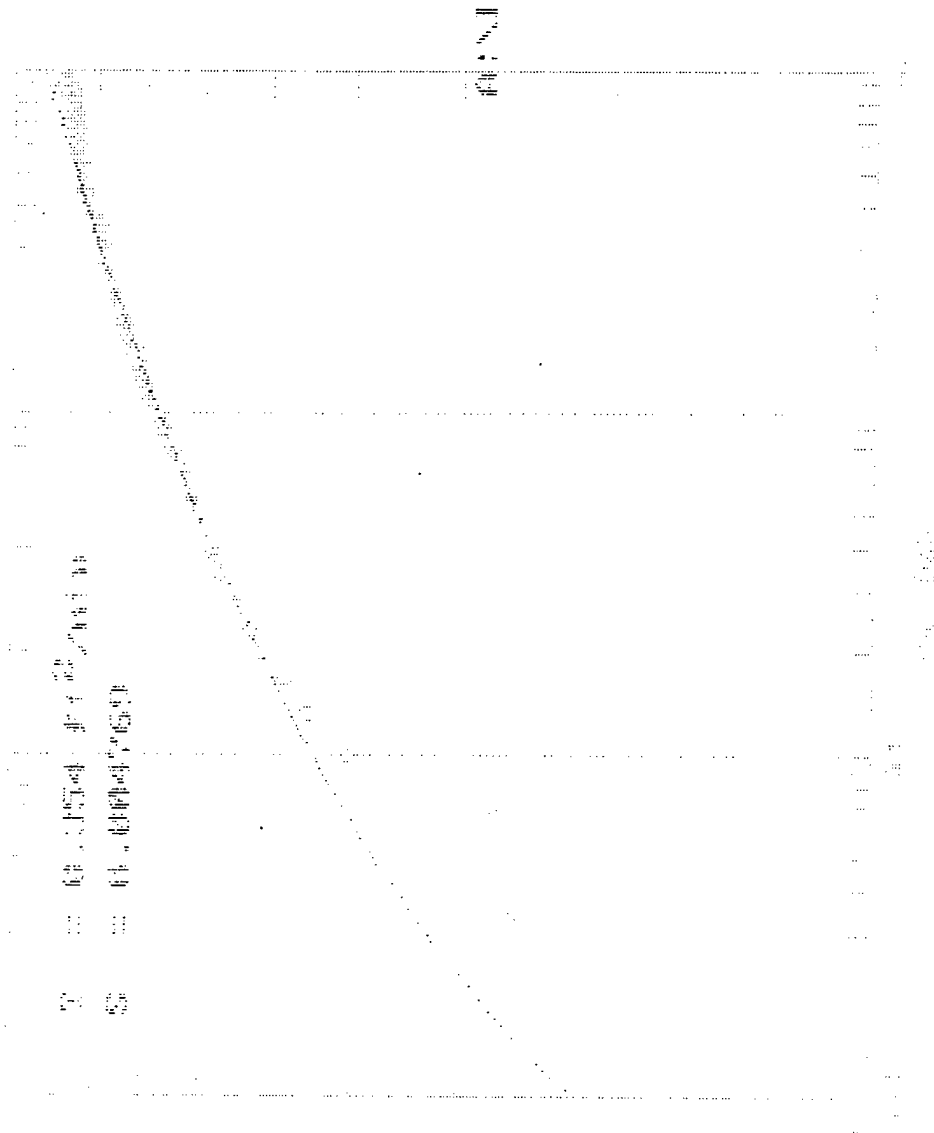


DAT

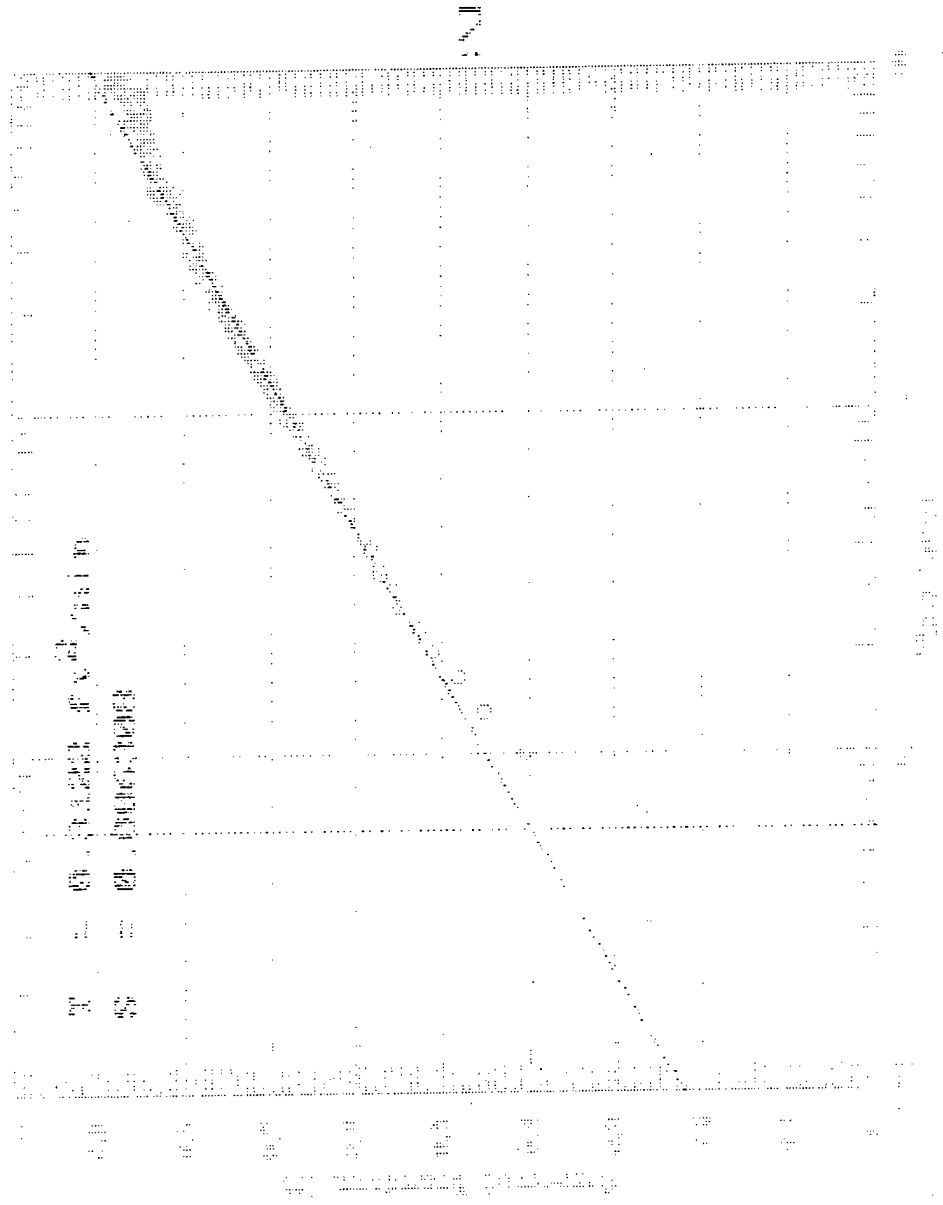
RELIN 3P8-03-2 THIS RELIN 3P8-03-2

3 = 0.0004 1/2 1/2 1/2

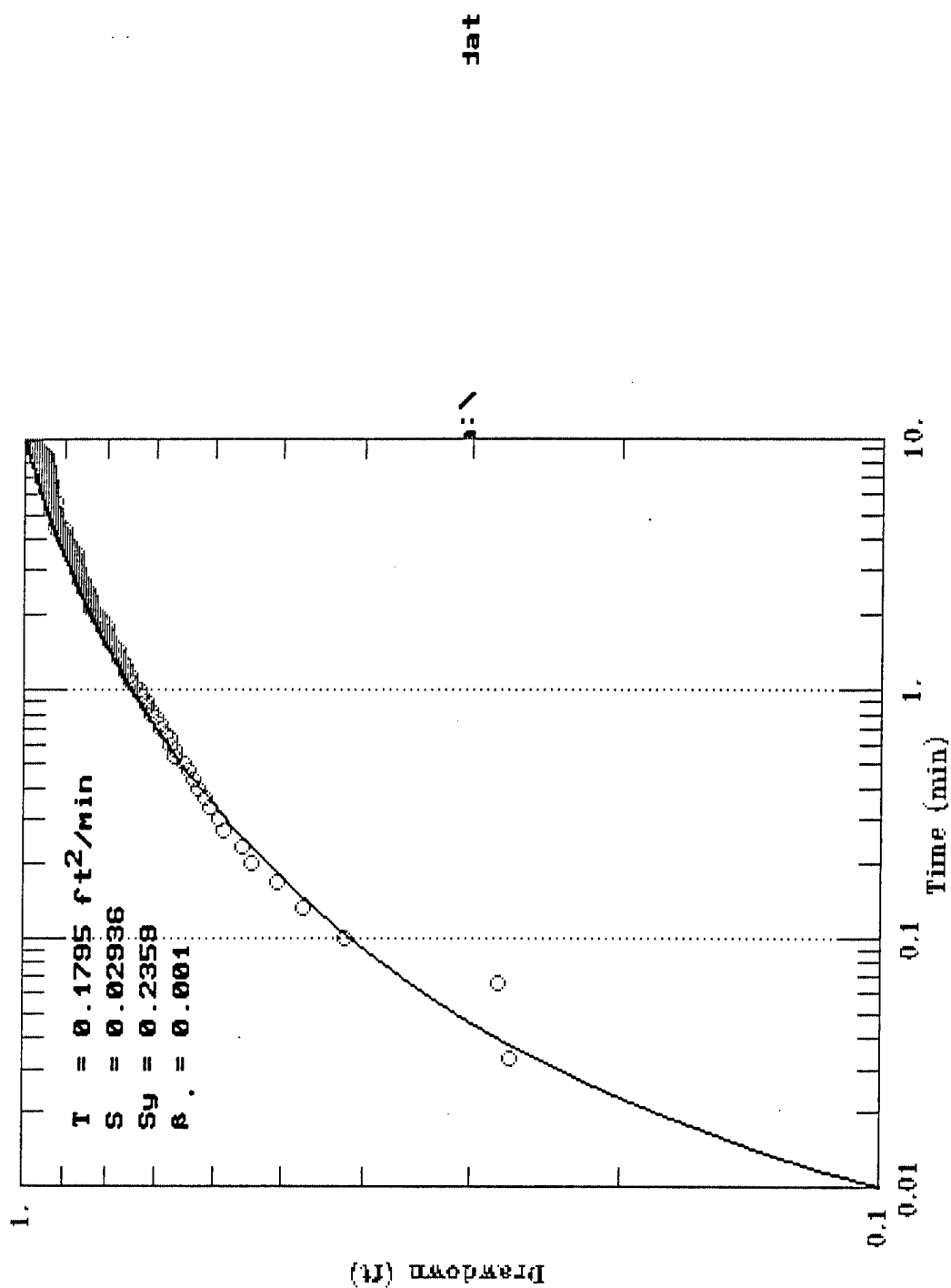
8 = 0.0004 1/2 1/2 1/2



ESLIN EPA-88-2 COOPER-JACOB DP TEST 2

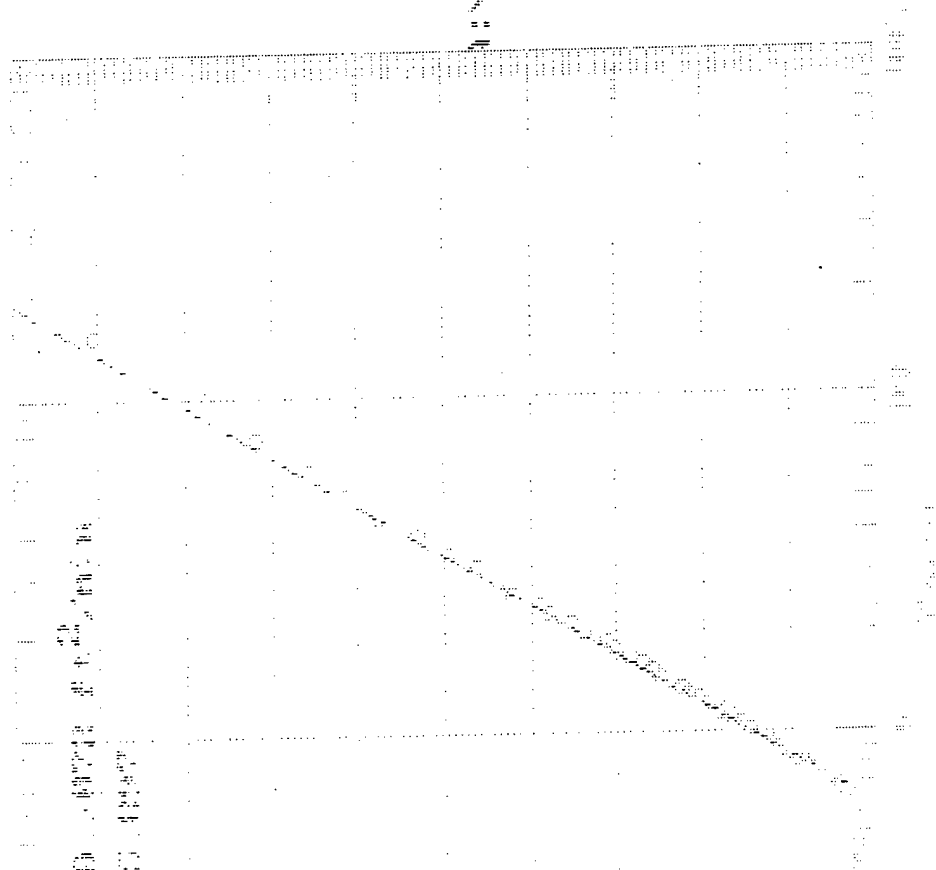


EGLIN EPA-83-2 NEUMAN DRAWDOWN TEST 2



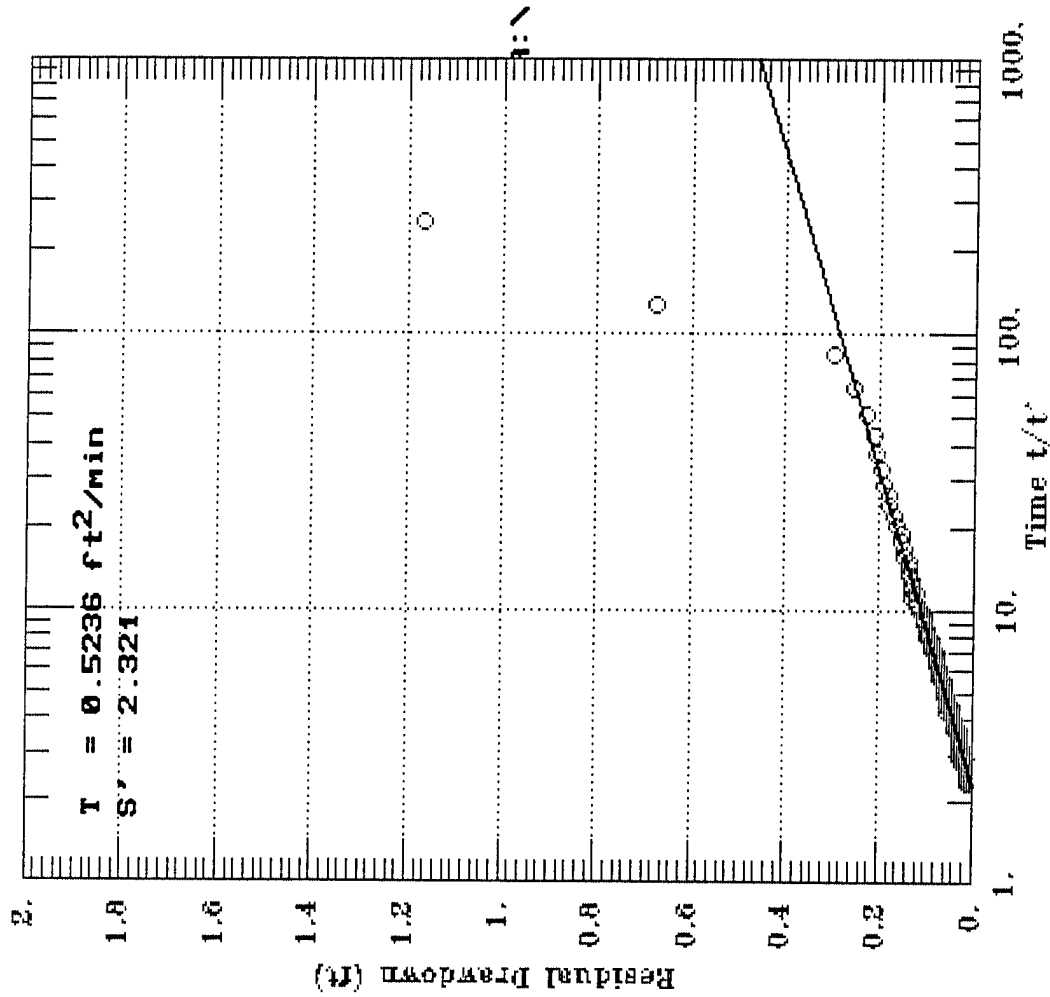
LOW K_A-M-2 THERM RECOVERY TEST 2

Q = 0.00128 BHP/IN
 Q = 0.0007



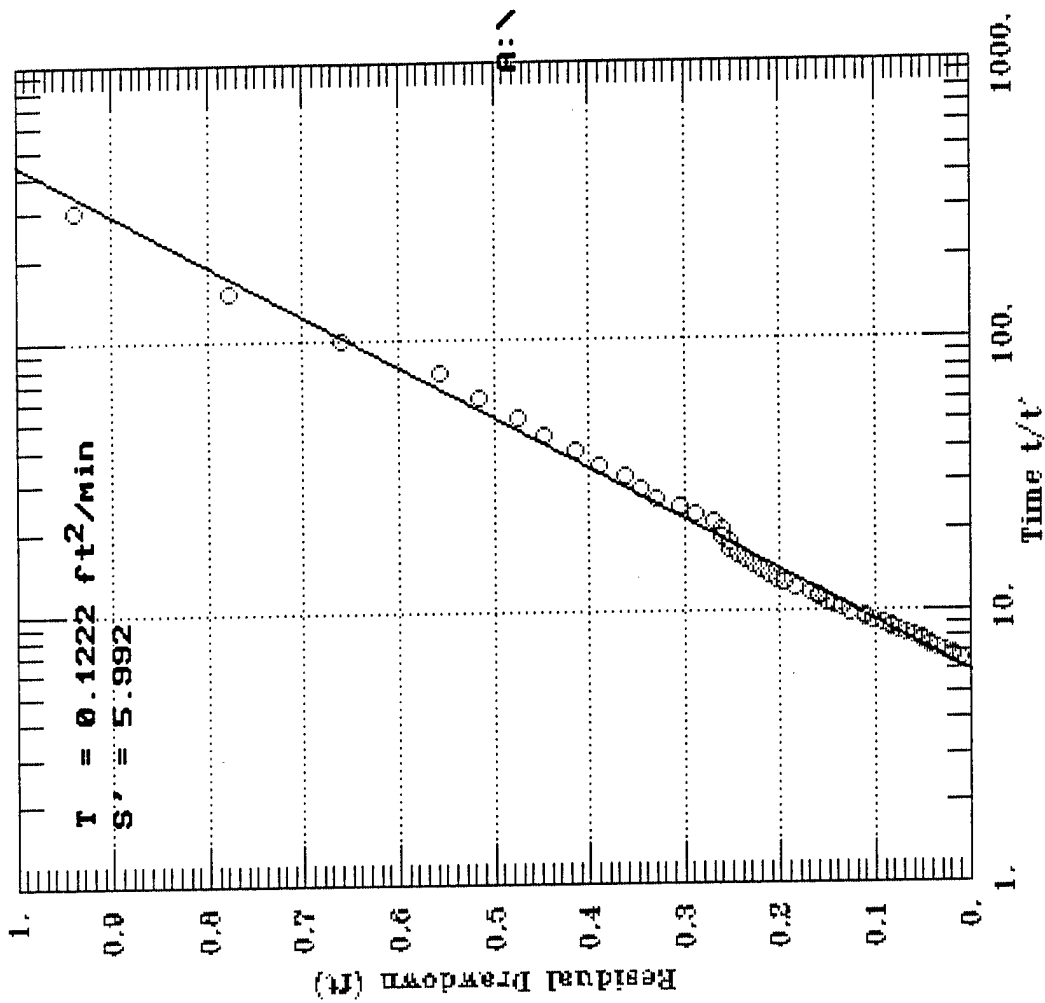
[illegible]

EGLIN EPA-83-3 THEIS RECOVERY TEST 1

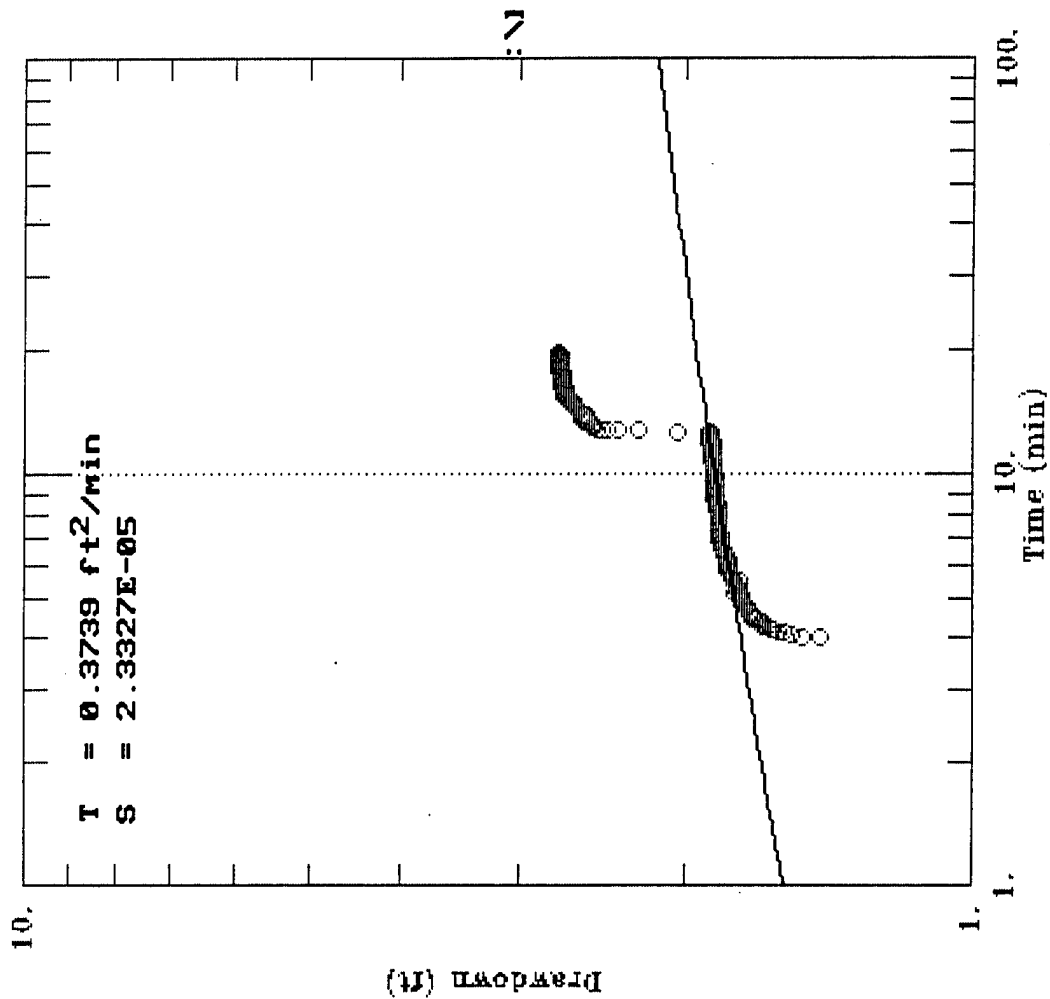


DAT

EGLIN EPA-83-4 THEIRS RECOVERY TEST 2

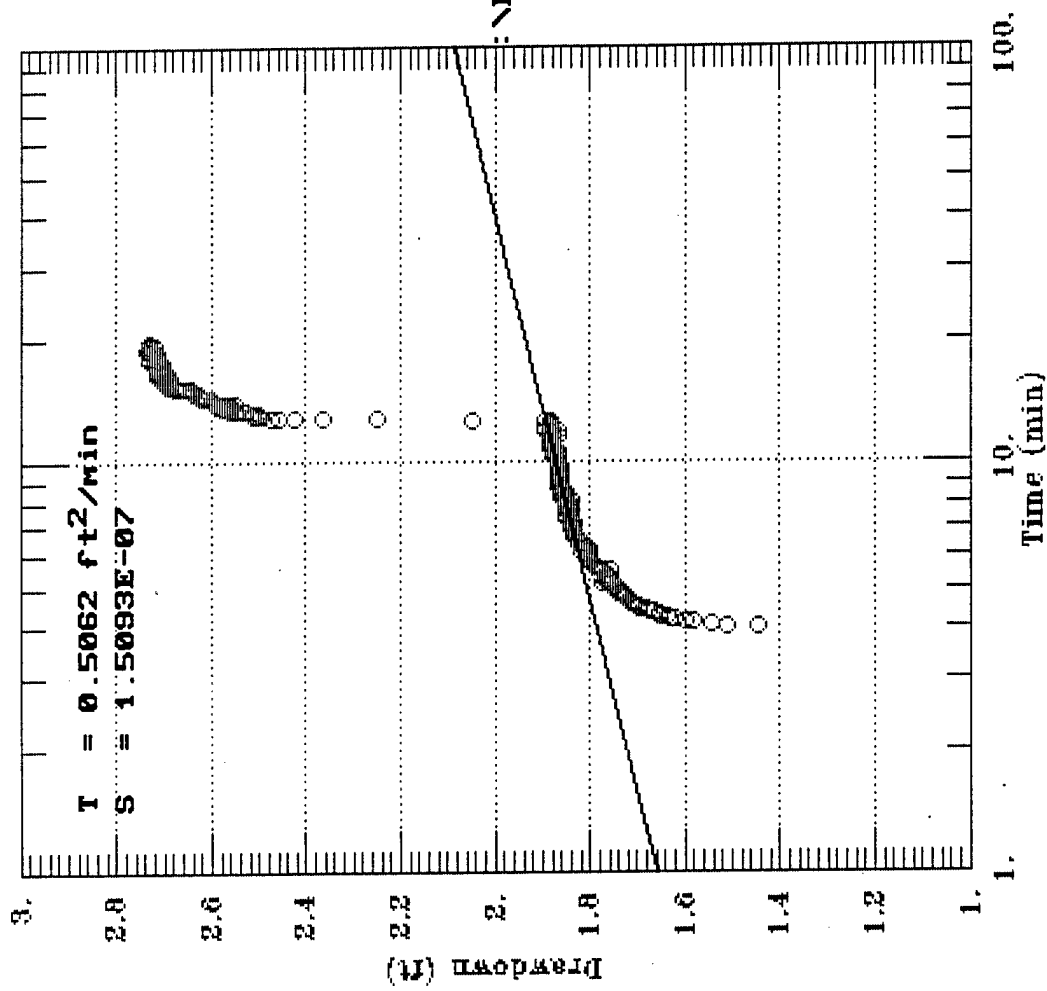


EGLIN EPA-83-5 THEIRS DRAWDOWN TEST 1



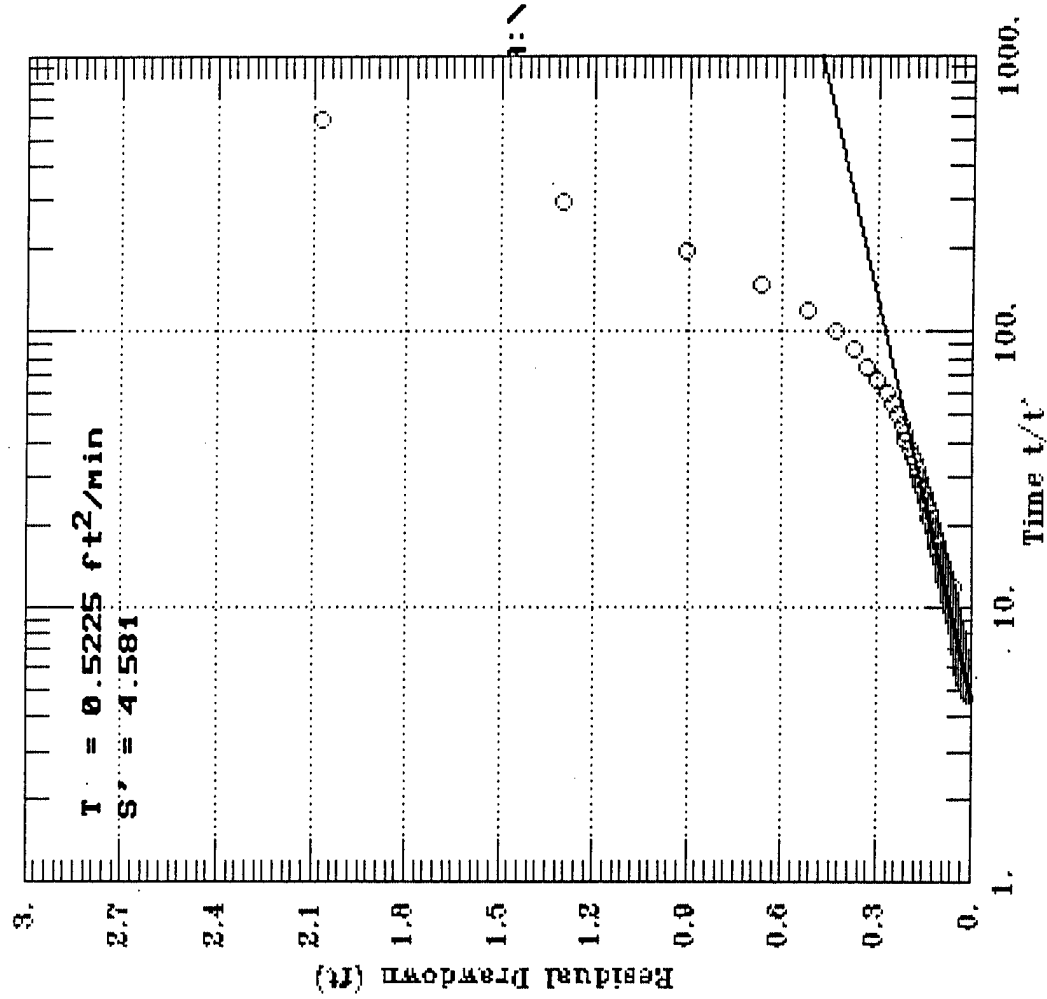
DR1

EGLIN EPA-83-5 COOPER-JACOB DD TEST 1



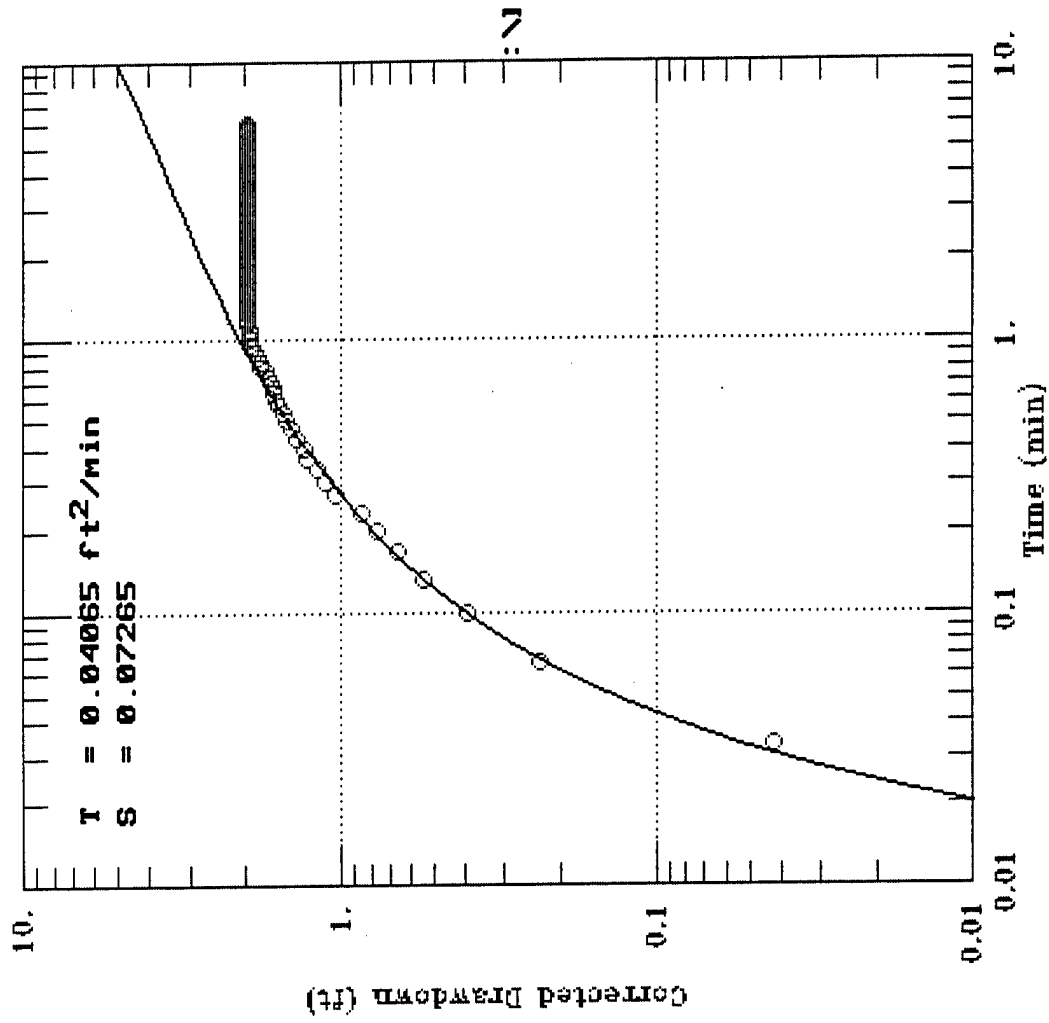
DAJ

EGLIN EPA-83-5 THEIR RECOVERY TEST 1



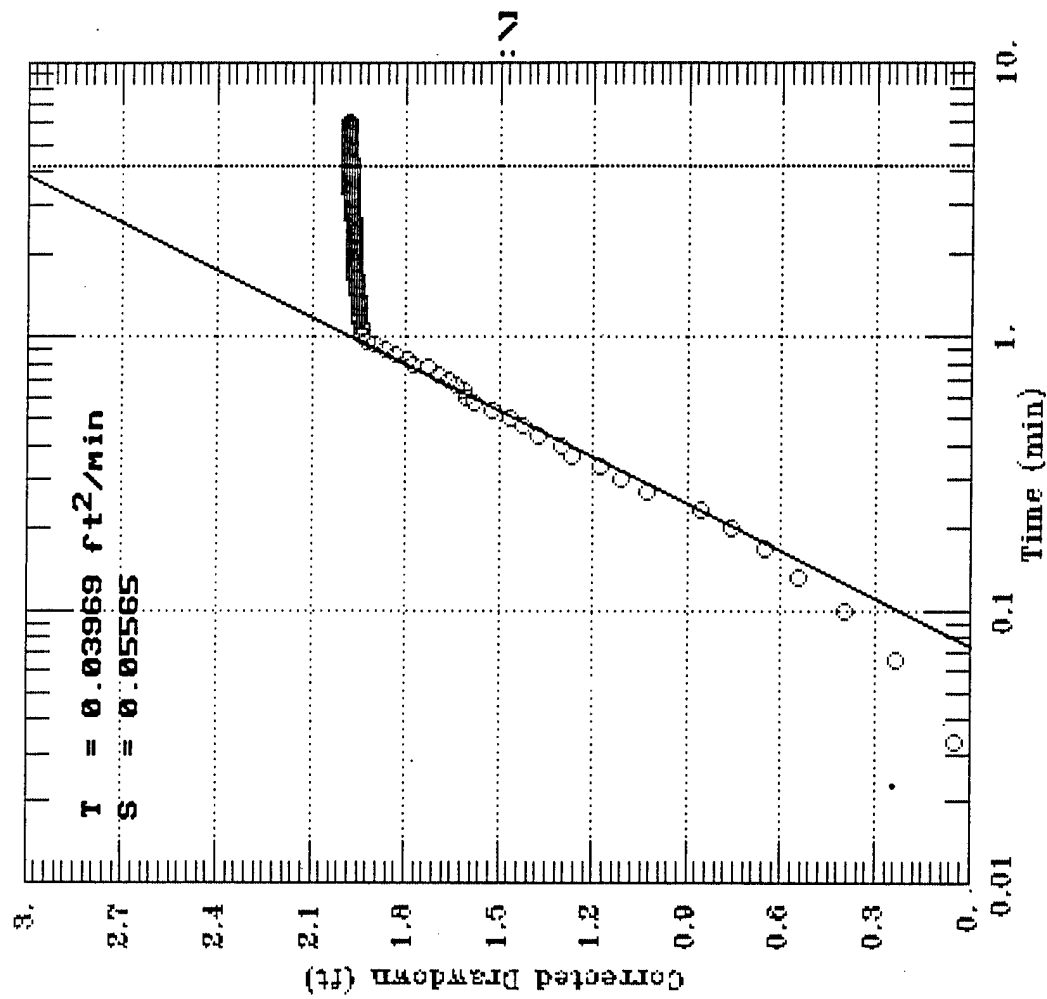
DAT

EGLIN EPA-83-6 THEIS DRAWDOWN TEST 1

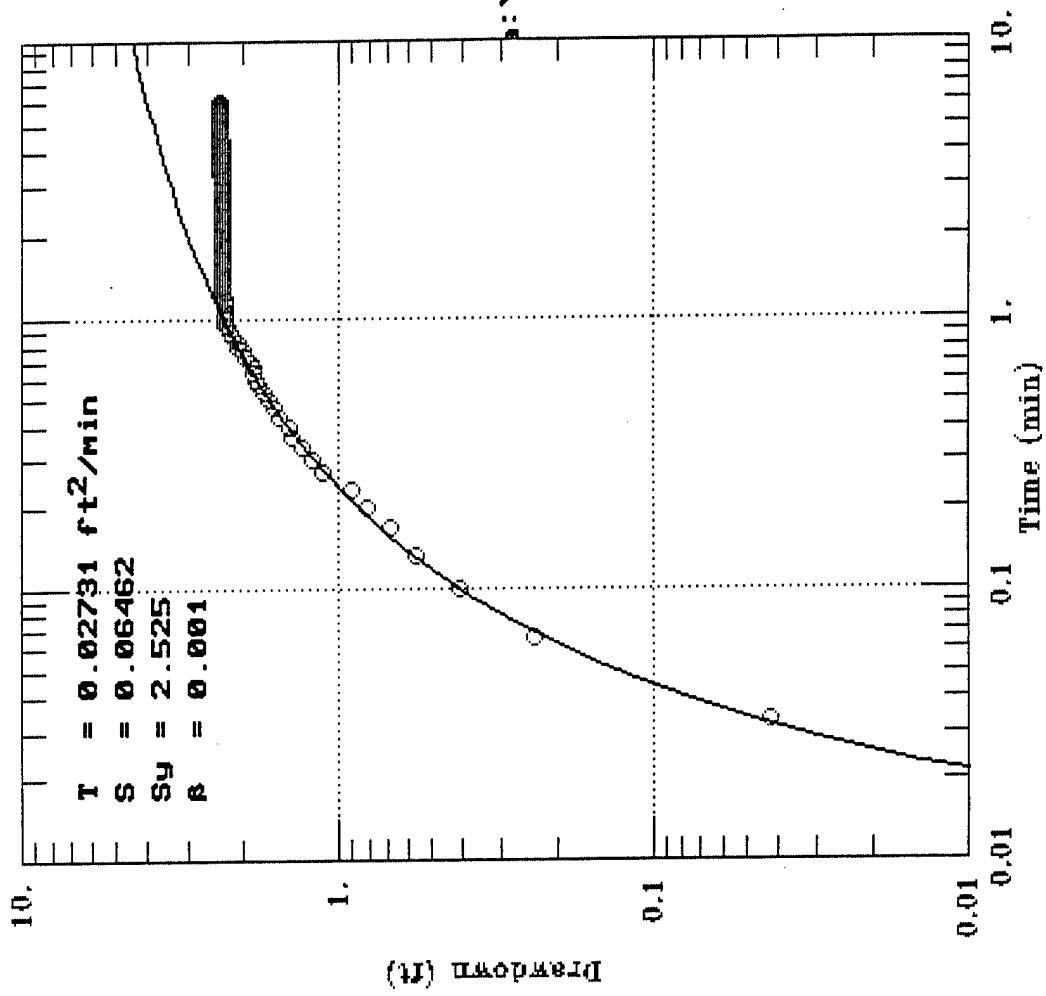


DR1

EGLIN EPA-83-6 COOPER-JACOB DD TEST 1

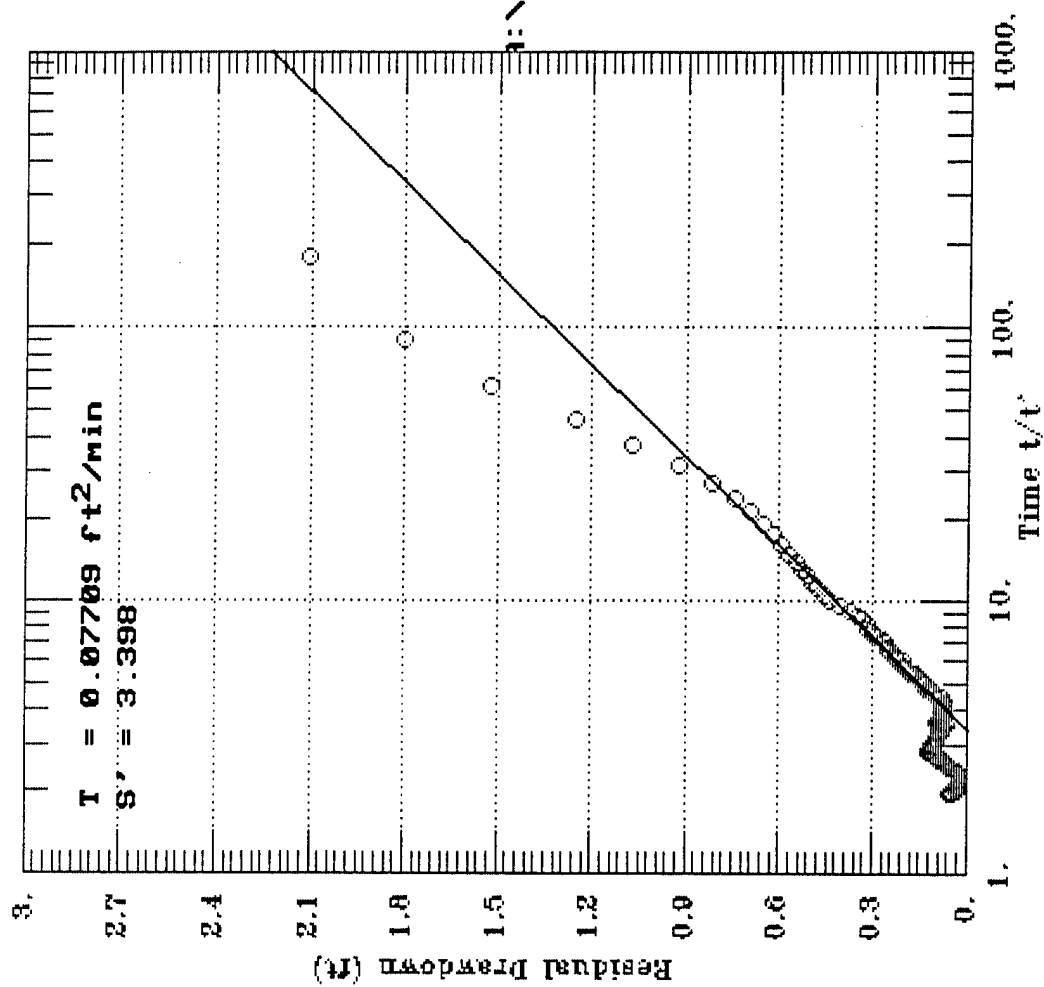


EGLIN EPA-83-6 NEUMAN DRAWDOWN TEST 1



fat

EGLIN EPA-83-6 THEIS RECOVERY TEST 1



DAT

APPENDIX B

SOIL AND GROUNDWATER ANALYTICAL DATA

MANITTECH TECHNOLOGY

Ref: 93-RC19/vg

October 29, 1993

Dr. Don Campbell

R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
Post Office Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached is a report of the data generated from the analyses of 33 sample core extracts from Eglin AFB, FL. The extracts, which were submitted under Service Request #SF-0-17, were analyzed for total fuel content as JP-4 jet fuel only. The reported values for fuel carbon were computed from the JP-4 determinations. I have also attached a report of the quality control analyses that were performed concurrently with the sample analyses.

Data quantification, peak identification, component concentration calculations, and dilution factor corrections were performed by MAXIMA chromatography software. JP-4 data was quantified with a 7-point external standard calibration curve ranging from 50 - 50,000 ng/ μ l.

The Minimum Detectable Limit (MDL) for JP-4 is determined by the concentration of the lowest calibration standard, which is 50 ng/ μ l. Since the MDL is determined by a calibration standard, it may also be defined as the Minimum Quantifiable Limit (MQL). It is important to note that values less than the MQL are reported in this data set, but cannot be considered quantified since they lie outside the range of the standard curve. All such unquantified data are approximations extrapolated from the JP-4 standard curve.

The samples from Service Request #SF-0-17 had an average mass of 25.31 g, and were extracted with 7.0 ml of methylene chloride. For simplicity's sake, I have assumed complete extraction of the sample's contents into the 7.0 ml of solvent.

In order to compute the MQL of JP-4 in the average sample core, assume the following:

Sample mass = 25.31 g
Extract volume = 7.0 ml
Extraction efficiency = 100%
Determined mass of JP-4 = 50 ng
(in 1.0 μ l of extract)

ManTech Environmental Technology, Inc.

Computation of the total mass of JP-4 in 7.0 ml of extract is as follows:

$$1. \left(\frac{50 \text{ ng}}{1.0 \text{ ml}} \right) \left(\frac{1000 \text{ ml}}{\text{ml}} \right) \left(\frac{1 \text{ ug}}{1000 \text{ ng}} \right) \frac{7.0 \text{ ml}}{\text{ml}} = 350 \text{ ug}$$

Consider that 25.31 g of sample was extracted with the 7.0 ml aliquot of methylene chloride and the original concentration is computed by division of the extracted mass of JP-4 by the sample mass:

$$2. \frac{350 \text{ ug}}{25.31 \text{ g}} = 13.83 \text{ ug/g}$$

Therefore, 13.83 ug/g (or mg/kg, or ppm if you prefer either of these units) is the Minimum Quantifiable Limit (MQL) of JP-4 determined in these samples.

It should be realized that JP-4 determinations are based on the summation of multiple peak areas detected over a defined period of time rather than the area of a specific peak, which is typical of individual fuel component determinations. When using this method of determination, it is entirely possible for a single peak or a group of peaks not attributable to JP-4 to register enough area to be mistakenly represented as JP-4.

Sample extracts were received September 29 and October 20, 1993. Analyses were started on September 29, 1993, and concluded on October 21, 1993. Sample extracts and quality control samples were analyzed according to RSKSOP-72, Rev. No. 1, excepting the modifications listed in the attached outline.

If you have any questions concerning this report, please contact me at your convenience.

Sincerely,

Randy Callaway
Randy Callaway

xc: R.L. Cosby
J.L. Seeley *jls*

SR#SF-0-17 / Kampbell / Eglin AF.

all conc. are ug/g

Sample I.D.	Dilution Factor	JP-4	Fuel Carbon (JP-4 x 0.85)
EPA 83-1 2-2.4'	1	33.00 ✓	28.10
EPA 83-1 2.5'	1	407.00 ✓	346.00
EPA 83-1 3-3.4'	1	2140.00 ✓	1820.00
EPA 83-1 4-5'	1	209.00 ✓	178.00
EPA 83-1 5-6'	1	491.00 ✓	417.00
EPA 83-1 6-7'	1	53.60 ✓	45.60
EPA 83-1 15-16'	1	21.30 ✓	18.10
EPA 83-1 16-17'	1	5.84 ✓	4.96
EPA 83-1 17-18'	1	12.00 ✓	10.20
EPA 83-1 18-19'	1	8.40 ✓	7.14
EPA 83-1 19-20'	1	5.90 ✓	5.02
EPA 83-1 20-21'	1	16.60 ✓	14.10
EPA 83-1 21-22'	1	1.18 ✓	1.00
EPA 83-1 22-24'	1	0.37 ✓	0.32
EPA 83-2 3-3.5'	1	1550.00 ✓	1320.00
EPA 83-2 3.5-4'	1	190.00 ✓	162.00
EPA 83-3 1.5-2'	1	1210.00 ✓	1030.00
EPA 83-3 2-2.5'	1	1970.00 ✓	1670.00
EPA 83-3 2-3'	1	7090.00 ✓	6030.00
EPA 83-3 4-5'	1	4.91 ✓	4.17
EPA 83-3 8-9'	1	6.02 ✓	5.12
EPA 83-3 9-10'	1	4.96 ✓	4.22
EPA 83-3 12-13'	1	3.61 ✓	3.07
EPA 83-5 10-11'	1	9.73 ✓	8.27
EPA 83-5 12-13'	1	1.02 ✓	0.87
EPA 83-5 13-14'	1	1.16 ✓	0.99
EPA 83-5 14-15'	1	2.37 ✓	2.01
EPA 83-5 15-16'	1	3.27 ✓	2.78
EPA 83-7 3-4'	1	0.46 ✓	0.39
EPA 83-7 4-5'	1	1170.00 ✓	995.00
EPA 83-7 6-7'	1	5310.00 ✓	4510.00
EPA 83-7 8-9'	1	40.30 ✓	34.30
EPA 83-7 10-11'	1	16.20 ✓	13.80

NOTE: all reported values are corrected for dilution factors where applicable

SR4SF-0-17 / Kampbell / QC Table

all conc. are ng/ul

Sample I.D. Date JP-4

blk MeCl2	29SEP93	1.54
Method blank		5.28
Truck water		5.29
100 jp4		119.00
500 jp4		521.00
5000 jp4		4840.00
50000 jp4		47800.00

blk MeCl2	20OCT93	1.49
Method blank		2.24
500 jp4		532.00
5000 jp4		4500.00
50000 jp4		46900.00

blk MeCl2 - methylene chloride solvent blank
jp4 - JP-4 fuel standard (ng/ul)

I. HP5890 GC - OPERATING CONDITIONS

- A. Instrument Control
 - 1. Analyses: "SH-2-JP4"
 - 2. Program: "RWC-AS10"
 - 3. Calibration: "DK-5-BTEX"
- B. Temperature Program
 - 1. Initial Temp & Time: 10°C for 3.00 min
 - 2. Level 1: Rate = 4°C/min to 70°C, Final Time = 0.00
 - 3. Level 2: Rate = 10°C/min to 270°C, Final Time = 2.00
 - 4. Run Time: 40.00 min
 - 5. Oven Equilibration Time: 1.00 min
- C. Miscellaneous
 - 1. Peak Width: 0.02
 - 2. Attenuation: 2⁵
 - 3. Chart Speed: 0.50
 - 4. Threshold = 0
 - 5. Offset = 10%

II. MAXIMA PEAK INTEGRATION

- A. Peak Detection Parameters
 - 1. Baseline Points: 18
 - 2. Filter Window (in points): 9
 - 3. Intg. Sensitivity (coarse): 10.50 $\mu\text{V}/\text{sec}$
 - 4. Intg. Sensitivity (fine): 5.00 $\mu\text{V}/\text{sec}$
 - 5. Skim Ratio: 100.00
- B. Peak Rejection Criteria
 - 1. Minimum Area: 2000 $\mu\text{V}\text{-sec}$
 - 2. Minimum Height: 300.0 μV
 - 3. Minimum Width: 3.00 sec
- C. Integration Events
 - 1. 0.00: Disable Peak Skimming
 - 2. 0.00: Disable Peak Detection
 - 3. 5.00: Enable Peak Detection
 - 4. 5.12: Set Baseline
 - 5. 5.50: Set Baseline
 - 6. 5.77: Set Baseline
 - 7. 7.60: Set Baseline
 - 8. 18.25: Set Baseline
 - 9. 21.78: Set Baseline
 - 10. 24.84: Set Baseline
 - 11. 27.61: Set Baseline
 - 12. 30.16: Set Baseline
 - 13. 32.85: Set Baseline
 - 14. 34.65: Set Baseline
 - 15. 35.93: Set Baseline
 - 16. 39.54: Set Baseline

IV. MAXIMA DATA ACQUISITION

- A. Preacquisition Delay: 5.00 min
- B. Duration: 35.00 min
- C. Rate: 3.00 points/sec
- D. Run Time: 40.00 min

V. MAXIMA CALIBRATION CURVES

- A. JP-4
 - 1. Calibration Range = 50 - 50,000 ng/ μl
 - 2. Summation of all peaks detected from 5.00 - 40.00 minutes

SAMPLE	BENZENE	TOLUENE	EB	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
100 µg/ml QC	1.04E+02	9.53E+01	9.94E+01	9.51E+01	9.36E+01	9.55E+01	9.18E+01	9.40E+01	9.57E+01
1.0 µg/ml	9.80E-01	9.50E-01	9.52E-01	9.51E-01	9.58E-01	9.54E-01	9.58E-01	9.57E-01	9.65E-01
METHOD BLANK	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-12-2.4'	ND	BLQ	BLQ	BLQ	3.01E-03	3.47E-02	6.44E-02	3.10E-03	1.70E-02
EPA 83-12.5'	ND	2.92E-01	4.54E-01	5.87E-01	1.29E+00	4.00E+00	6.33E+00	3.01E+00	3.44E+00
EPA 83-13-3.4'	2.66E+00	5.68E+00	4.01E+00	1.06E+01	2.12E+01	1.72E+01	1.93E+00	3.07E+00	1.26E+00
EPA 83-14-5'	1.94E-01	7.12E-01	2.42E-01	1.48E+00	2.46E+00	3.23E+00	1.17E+00	1.51E+00	6.61E-01
EPA 83-15-8'	3.60E-01	4.45E-01	2.38E-01	7.33E-01	1.30E+00	1.39E+00	7.53E-01	7.01E-01	3.37E-01
EPA 83-16-7'	2.55E-02	9.95E-02	3.27E-02	3.02E-01	5.01E-01	6.44E-01	3.22E-01	4.31E-01	1.70E-01
EPA 83-115-16'	1.38E-02	4.45E-02	3.03E-02	1.27E-01	2.80E-01	2.39E-01	1.06E-01	1.59E-01	6.39E-02
EPA 83-116-17'	3.82E-03	1.34E-02	1.10E-02	3.32E-02	6.49E-02	4.31E-02	1.61E-02	3.64E-02	1.50E-02
EPA 83-117-18'	1.32E+00	1.57E-02	8.52E-02	1.11E-01	8.19E-01	4.76E-03	4.38E-02	2.69E-01	1.13E-01
10 µg/ml	1.06E+01	1.04E+01	1.04E+01	1.04E+01	1.04E+01	1.04E+01	1.05E+01	1.05E+01	1.05E+01
EPA 83-118-19'	6.45E-01	2.68E-02	3.00E-02	4.83E-02	1.22E-01	1.79E-02	8.17E-03	1.40E-02	1.11E-02
EPA 83-119-20'	BLQ	BLQ	2.62E-03	2.85E-03	3.99E-03	3.89E-03	2.80E-03	5.72E-03	3.27E-03
EPA 83-120-21'	7.81E-01	1.59E-02	6.98E-03	7.72E-03	3.28E-02	4.83E-03	BLQ	BLQ	BLQ
1.0 µg/ml	1.02E+00	1.08E+00	1.09E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.09E+00	1.08E+00
EPA 83-121-22'	BLQ	ND	BLQ	BLQ	2.14E-03	BLQ	BLQ	2.78E-03	BLQ
EPA 83-23-3.5'	1.65E-01	1.82E+01	2.05E+00	4.17E+01	6.91E+01	5.92E+01	2.19E+01	4.78E+01	1.31E+01
EPA 83-23.5-4'	1.47E-01	1.21E+00	4.00E-02	6.33E-02	1.41E-01	1.10E-01	2.45E-01	1.18E-01	8.25E-02
EPA 83-31.5-2'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-32-2.5'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-34.5'	ND	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-38.9'	ND	BLQ	BLQ	BLQ	3.18E-03	BLQ	1.06E-02	1.65E-02	9.88E-03
0.1 µg/ml <i>spoil</i>	1.00E-01	1.03E-01	1.04E-01	1.04E-01	1.04E-01	1.04E-01	1.04E-01	1.04E-01	1.03E-01
EPA 83-39-10'	2.56E-02	BLQ	BLQ	3.29E-03	3.91E-03	BLQ	7.26E-03	1.57E-02	3.26E-02
100 µg/ml	9.81E+01	1.04E+02	1.04E+02	1.06E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02
EPA 83-312-13'	1.31E-02	2.86E-03	8.31E-03	6.75E-03	1.06E-02	1.11E-02	1.70E-02	1.91E-02	2.56E-02
EPA 83-510-11'	BLQ	BLQ	BLQ	5.05E-03	5.54E-03	4.92E-03	5.37E-03	6.04E-03	5.94E-03
EPA 83-512-13'	ND	ND	BLQ	BLQ	BLQ	BLQ	ND	BLQ	ND
EPA 83-513-14'	BLQ	2.84E+00	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-514-15'	BLQ	ND	BLQ	4.23E-03	4.95E-03	BLQ	ND	BLQ	ND
"Truck Water" Blank	ND	ND	ND	BLQ	BLQ	BLQ	ND	BLQ	ND
1.0 µg/ml	9.57E-01	9.89E-01	9.98E-01	9.90E-01	9.92E-01	9.71E-01	9.52E-01	9.87E-01	9.85E-01

Request SF-0-17 Mod.1 Dr. Campbell Eglin AFB Core Products GC/MSD Analyses

Units = mg/kg

<u>SAMPLE</u>	<u>BENZENE</u>	<u>TOLUENE</u>	<u>EB</u>	<u>P-XYLENE</u>	<u>M-XYLENE</u>	<u>O-XYLENE</u>	<u>1,3,5-TMB</u>	<u>1,2,4-TMB</u>	<u>1,2,3-TMB</u>
100 µg/ml	1.08E+02	1.07E+02	1.07E+02	1.08E+02	1.07E+02	1.07E+02	1.07E+02	1.07E+02	1.07E+02
50 µg/ml QC	4.76E+01	4.76E+01	4.80E+01	4.83E+01	4.88E+01	4.84E+01	5.00E+01	4.90E+01	4.87E+01
1 µg/ml	1.03E+00	1.03E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00
EPA 83-1 22-24' Sieve	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-3 2-3' Sieve	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-5 15-18'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-7 3-4'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
EPA 83-7 4-5'	ND	ND	ND	ND	ND	ND	ND	ND	ND
EPA 83-7 6-7'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	3.23E+00	8.32E-01	8.08E-01
EPA 83-7 8-9'	6.37E-03	BLQ	1.43E-02	3.46E-02	1.24E-01	6.89E-02	4.08E-01	7.81E-01	4.18E-01
EPA 83-7 10-11'	BLQ	BLQ	BLQ	9.22E-02	2.37E-01	BLQ	6.68E-01	1.19E+00	8.92E-01
Method Blank	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ
10 µg/ml	1.07E+01	1.08E+01	1.08E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.08E+01
0.1 µg/ml	1.06E-01	1.06E-01	1.08E-01	1.07E-01	1.08E-01	1.07E-01	1.10E-01	1.08E-01	1.08E-01

Analyst: David A. Kovacs

BLQ < 0.01 µg/ml

Page 1 of 1 Printed: 10/25/93

MANAGEMENT TECHNOLOGY

Ref: 93-BB8

September 24, 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 ^{SNV}

Dear Don:

As requested in Service Request # SF-0-19, headspace GC/MS analysis of 6 water samples for BTEXXTMB compounds was completed. The samples were received on September 20 and analyzed on September 21-22, 1993. RSKSOP-158-Pending was used for this analysis.

This SOP is designed for the Varian Saturn II Mass Spectrometer (MS) (Software Revision C) in combination with a Varian 3400 Gas Chromatograph and a Tekmar 7000 Headspace Autoanalyzer. The MS was tuned to meet EPA method 524.2 MS tune criteria for bromofluorobenzene spectrum. The MS was operated at 2 scans/second over a mass range of 45 to 250 amu. Other important settings were: acquire time = 14 min; emission current = 35 μ A; electron multiplier = 2550 volts; filament and multiplier delay = 80 sec; peak threshold = 3; ion time = 100 μ s; mass defect = -50 mmu/100 amu; and background mass 45 amu. The tune parameters were: segment 1 = 130, segment 2 = 70, segment 3 = 100, and segment 4 = 90.

The GC injector temperature was 175°C, and the transfer line temperature was 200°C. A 30 meter, 0.25 mm Restek Stabilwax capillary column with 0.5 μ m film thickness was temperature programmed from initial temperature 35°C, hold time 2.0 min, then at an 8°C/min rate to mid temperature 131°C, hold time 0 min, then at a 30°C/min rate to final temperature 225°C. The column flow rate was 1 ml/min, and the split flow was 30 ml/min.

The headspace autoanalyzer settings were: platen 85°C; sample equilibrium 30 min; sample loop 1 ml; valve 150°C; transfer line 200°C.

An internal standard calibration method was established for the 9 aromatic compounds. The standard curves were prepared using concentrations of 1.0, 5.0, 10.0, 50.0, 100, 500, 1000, and 2000 ppb. The lower quantitation limits were 0.5 ppb. The internal standard was fluorobenzene at a concentration of 100 ppb in the

Maritech Environmental Technology, Inc.

P.O. Box 1198, Ada, Oklahoma 74820 405-332-8800 FAX 405-332-8800 ext. 235

headspace vial.

Samples 83H-1, 83S-2, and all lab duplicate samples were analyzed undiluted and were prepared by adding 10 ml of sample to a headspace vial containing 2 g of sodium chloride (NaCl). 8 μ l of 125 μ g/ml fluorobenzene was added to this 10 ml liquid volume before the vial was capped. Samples 83H-2, 83L-2, 83S-3, and 83Z-2 were originally analyzed at 1/10 dilutions. They were prepared by adding 1 ml of sample to a headspace vial containing 9 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, lab duplicates, lab blanks, and QC standards is presented in Table 1.

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 *jls*

Table 1. Dilution Corrected Quantitation Report for
Service Request# SF-0-19.

Concentration = ppb

Compound	83H-1		83H-2		83H-2		83L-2		83L-2		83S-2		83S-3		83Z-2	
	No DI	1/10 DI	Lab Dup	No DI	1/10 DI	Lab Dup	No DI	1/10 DI	No DI	1/10 DI	No DI	1/10 DI	Lab Dup	No DI	1/10 DI	1/10 DI
Benzene	32	---	2.3	---	36.7	32.2	---	---	322	---	---	---	---	---	153	---
Toluene	30	---	---	---	---	0.9	---	---	3.1	---	---	---	---	---	22.4	---
Ethylbenzene	796	---	0.5	---	8.4	6.5	---	---	3.3	---	---	---	---	---	231	---
p-Xylene	1280	---	0.9	---	57.6	53.0	---	---	29.1	---	---	---	1.8	---	669	---
m-Xylene	1450	14.6	13.1	---	240	237	---	---	54.0	---	---	---	---	---	1470	---
o-Xylene	0.6	---	---	---	---	---	---	---	0.9	---	---	---	---	---	---	---
1,3,5-Trimethylbenzene	177	12.3	10.9	---	52.5	49.1	---	---	9.9	---	---	---	---	---	134	---
1,2,4-Trimethylbenzene	892	95.4	90.4	---	243	240	---	---	36.9	21.3	---	---	17.8	---	423	---
1,2,3-Trimethylbenzene	281	14.8	12.8	---	127	118	---	---	16.2	---	---	---	0.5	---	213	---

Compound	83Z-2		QC0920E		QC0922A		QC0922B		BK0920E		BK0922B		BK0922C	
	Lab Dup	No DI	Lab Dup	No DI	Lab Dup	No DI	Lab Dup	No DI	Lab Dup	No DI	Lab Dup	No DI	Lab Dup	No DI
Benzene	157	---	49.1	---	46.8	---	480	---	---	---	---	---	---	---
Toluene	19.3	---	52.6	---	49.0	---	476	---	---	---	---	---	---	---
Ethylbenzene	230	---	51.3	---	50.8	---	536	---	---	---	---	---	---	---
p-Xylene	669	---	51.6	---	49.9	---	523	---	---	---	---	---	---	---
m-Xylene	1400	---	51.6	---	50.1	---	529	---	---	---	---	---	---	---
o-Xylene	1.0	---	52.0	---	50.6	---	547	---	---	---	---	---	---	---
1,3,5-Trimethylbenzene	130	---	52.1	---	50.6	---	503	---	---	---	---	---	---	---
1,2,4-Trimethylbenzene	412	---	52.2	---	50.4	---	533	---	---	---	---	---	---	---
1,2,3-Trimethylbenzene	209	---	52.1	---	50.8	---	516	---	---	---	---	---	---	---

----- = Below Quantitation Limit (0.5 ppb) Dup = Duplicate Dil = Dilution BK = Lab Blank QC = Quality Control Standard (50 or 500 ppb)

MANAGEMENT TECHNOLOGY

Ref: 93-LS14
September 24, 1993

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74821-1198

THRU: Steve Vandegrift, M

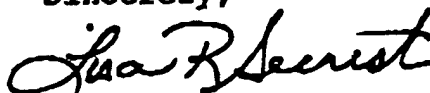
Dear Don:

Please find attached results of the aqueous samples from Eglin AFB, Florida, to be analyzed by purge-and-trap GC-PID for Benzene, Toluene, Ethylbenzene, the Xylene isomers, and the Trimethylbenzenes. We received your 34 samples, in duplicate, on September 20, 1993 in 40 mL VOA vials preserved with lead line septa and 0.4 g Na₂PO₄. Samples were stored at 4°C until analyzed. On September 21, 22, & 23, 1993, automated purge-and-trap sampling was performed using an OI autosampler and an OI 4460 sample concentrator in line with a HP 5890 gas chromatograph. A 6 place external standard curve (1-10-100-500-1000-2000 ppb) was used to quantitate the samples.

This work was performed under Service Request #SF-0-12. RSKSOI 122, "Analysis of Xylene Isomers in Ground Water Samples by Purge and Trap Gas Chromatography" was used for these analyses.

If you have any questions about these analyses, please contact me at your convenience.

Sincerely,



Lisa R. Secrest

xc: R.L. Cosby
J.L. Seeley *JS*

ManTech Environmental Technology, Inc.

P.O. Box 1198, Ada, Oklahoma 74820 405-332-8800 FAX 405-332-8800 ext. 235

P. 5 09/28/95 15:42

FROM RSKERL - ADA, OK

SAMPLE NAME	BENZENE	TOLUENE	ETHYLBENZENE	P-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
QC, OBSERVED, PPB	4.65E+01	4.75E+01	4.85E+01	4.58E+01	4.51E+01	4.68E+01	4.50E+01	4.78E+01	4.62E+01
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
20 PPB	2.02E+01	2.13E+01	2.12E+01	2.12E+01	2.13E+01	2.05E+01	2.18E+01	2.22E+01	2.16E+01
83 C-1	8.65E+01	1.24E+00	2.08E+00	5.88E+01	8.18E+01	ND	4.94E+00	2.97E+01	9.28E+00
83 C-2	ND	ND	2.93E+00	2.71E+00	1.82E+00	ND	4.00E+00	4.98E+01	8.82E+00
83 C-2 DUPLICATE	ND	ND	2.96E+00	2.70E+00	1.78E+00	ND	3.88E+00	4.34E+01	8.25E+00
83 H FIELD BLANK	ND	ND	ND	ND	ND	ND	ND	5.68E+00	ND
83 H-1	3.10E+01	3.04E+01	8.41E+02	1.39E+03	1.57E+03	ND	1.88E+02	8.86E+02	2.91E+02
83 H-2	ND	ND	8.39E+00	1.00E+01	1.86E+01	ND	2.18E+01	2.98E+02	ND
83 L-1	3.78E+00	6.51E+00	2.84E+01	9.28E+01	1.65E+02	1.25E+02	1.39E+01	8.27E+01	2.16E+01
83 L-1 DUPLICATE	3.88E+00	6.73E+00	2.89E+01	9.30E+01	1.67E+02	1.25E+02	1.37E+01	8.36E+01	2.14E+01
83 L-2	3.37E+01	ND	9.86E+00	5.15E+01	2.17E+02	ND	5.01E+01	2.87E+02	1.00E+02
83 N-1	ND	ND	ND	ND	ND	ND	2.28E+00	BLQ	ND
100 PPB	1.02E+02	1.01E+02	9.88E+01	9.91E+01	9.87E+01	1.02E+02	9.61E+01	1.01E+02	1.04E+02
83 N-2	8.78E+00	BLQ	1.39E+00	2.51E+01	3.97E+01	ND	1.18E+02	2.98E+02	1.82E+02
83 N-2 DUPLICATE	8.98E+00	BLQ	1.38E+00	2.51E+01	3.98E+01	ND	1.18E+02	2.99E+02	1.87E+02
83 N-3	1.98E+02	1.12E+00	1.41E+00	1.38E+01	1.35E+01	ND	7.09E+01	1.72E+02	1.15E+02
83 O-1	ND	ND	ND	2.14E+00	1.86E+00	ND	ND	BLQ	ND
83 O-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 P-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 P-2	8.12E+00	1.28E+00	4.18E+00	1.15E+01	5.63E+00	ND	3.22E+00	1.38E+02	3.65E+01
83 Q-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 Q-2	ND	BLQ	ND	3.98E+00	1.77E+00	ND	ND	1.14E+02	1.03E+01
83 R-1	ND	ND	ND	ND	1.15E+00	ND	1.92E+00	BLQ	ND
10 PPB	9.63E+00	9.46E+00	9.86E+00	9.52E+00	9.56E+00	8.60E+00	1.00E+01	9.10E+00	7.67E+00
83 R-2	BLQ	BLQ	3.61E+00	6.47E+00	1.63E+01	BLQ	3.03E+01	8.03E+01	4.15E+01
83 R-3	3.88E+01	1.55E+00	8.61E+00	2.39E+01	3.60E+01	ND	6.83E+00	1.14E+02	2.27E+01
83 R-3 DUPLICATE	3.75E+01	1.58E+00	8.51E+00	2.33E+01	3.53E+01	ND	6.82E+00	1.17E+02	2.30E+01
83 R-4	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 S-1	ND	ND	BLQ	1.10E+00	1.01E+00	ND	2.10E+00	BLQ	ND
83 S-2	3.27E+02	3.05E+00	3.29E+00	2.64E+01	5.14E+01	ND	9.75E+00	3.47E+01	1.72E+01
83 S-3	ND	ND	ND	ND	ND	ND	ND	1.18E+01	ND
83 W-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 W-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 Z-1	2.28E+01	2.12E+00	1.93E+01	3.98E+01	1.43E+02	ND	ND	8.71E+01	ND
QC, OBSERVED, PPB	4.77E+01	4.89E+01	4.90E+01	4.61E+01	4.59E+01	1.05E+02	1.71E+02	3.52E+02	2.47E+02
QC, TRUE VALUE, PPB	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	4.78E+01	4.59E+01	5.11E+01	4.77E+02
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	5.00E+01	5.00E+01	5.00E+01	5.00E+02
83 Z-2	1.53E+02	1.83E+01	2.27E+02	5.94E+02	1.27E+03	ND	ND	ND	ND
83 Z-3	3.39E+00	BLQ	1.88E+00	1.04E+01	4.17E+00	ND	1.14E+02	4.20E+02	1.82E+02
83 XF	ND	ND	ND	ND	ND	ND	3.55E+00	1.54E+02	1.92E+01
83 XS	ND	ND	ND	ND	ND	ND	ND	BLQ	ND
83 X s/w	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 YF	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 YS	ND	ND	ND	ND	ND	ND	ND	ND	ND
83 Y s/w	ND	ND	ND	ND	ND	ND	ND	ND	ND
20 PPB	1.97E+01	2.03E+01	1.89E+01	1.83E+01	1.90E+01	1.92E+01	1.83E+01	1.85E+01	1.90E+01

IC 257 64

09/28/95 15:43

FROM RSKERL - ADA, OK

* Lower Limit of Quantitation is 10 ppb due to 1/10 dilution of sample, see Brad Black's report, ref. no. 93-BB8, for undiluted results

Steve Williams
Eglin AFB, Florida

Dear Steve;

As promised, here are our results on alkylbenzenes in ground water along the North side of the POL. Enclosed are maps showing the sampling locations, a tables listing concentrations of monoaromatic hydrocarbons, nutrients, and methane. The following text and table summarizes the most important features of the study to date.

The ground water contamination in the north east border of POL probably does not come from the 1988 spill of MUR. The JP-4 spill that is the object of Steve Hutchins' bioremediation study is aerobically weathered. In particular, concentrations of benzene in the residual oily phase are lower than would be expected for fresh JP-4. The highest concentrations of alkylbenzenes occur in the water table aquifer just above the first confining layer. The concentrations at 80H are characteristic of concentrations that would be expected of ground water in contact with aerobially weathered JP-4. The JP-4 spill is the most likely source of the plume of ground water contamination.

Along the flow path from 80H, to 83Z, to 83U, benzene concentrations remain stable, while the other monoaromatic hydrocarbons are depleted. This is the usual pattern when the monoaromatics are degraded through a methanogenic pathway. Then compare 83U-3 and 83U-2 just above it. The concentration of benzene is greatly reduced, while the concentrations of other monoaromatic hydrocarbons are essentially identical. Selective removal of benzene is expected when oxygen is supporting metabolism of the monoaromatics. The concentration of oxygen in 83U-2 (0.6 mg/l), is higher than the concentration at 83U-3 (0.3 mg/l).

Sample	Elev- ation FAMSL	Ben -zene	Tol- uene	Ethyl- ben- zene	p- Xylene	m- Xylene	o- Xylene	1,3,5- TMB	1,2,4- TMB	1,2,3- TMB
--- (ug/l) ---										
80H-3	+3.31 to +1.74	100	5150	1700	3120	6750	5480	327	1090	406
83Z-2	-4.53 to -6.03	153	18.3	227	594	1270	<0.5	114	420	182
83U-3	-5.9	198	1.1	1.4	13.8	13.5	<1	70.9	172	115
The following is a sample 2.6 feet above 83U-3, and 1.5 feet below surface water.										
83U-2	-3.3	6.9	<1	1.4	25.1	39.8	<1	119	299	187

Sample	Date	Elevation of land surface FAMSL	Depth to water table FBLs	Depth to sample FBLs	Yield ml/sec	D.O. mg/l	Iron II mg/l
80H-1	3-20-93	12.65	4.25	4.17-5.67	OK	1.2	2.4
80H-2	3-20-93	12.65	not taken	7.17-8.67	OK	0.5	7.5
80H-3	3-20-93	12.65	not taken	10.15-11.67	OK	0.4	2.3
80I-0	3-23-93	10.4*	not taken	3.16-4.67	No Yield		
80I-1	3-23-93	10.4	not taken	3.66-5.16	OK	0.2	4.8
80I-3	3-23-93	10.4	not taken	5.67-7.17	OK	0.3	5.8
80I-4	3-23-93	10.4	not taken	9.67-11.2	No Yield		
At 80H the permeable sands must extend down to at least 1 foot above MSL, consistent with 83H. At 80I there is a shallow nonpermeable layer as deep as 5.7 feet above MSL that was not seen in the 83 geoprobe data. The permeable layer at 80I extends to a depth between 3.2 and 0.6 feet above mean sea level, with a nonpermeable zone underneath.							

Sample	date	Depth (feet below water surface)	Depth (feet below sediment surface)	Dissolved Oxygen (mg/l)	Temp. °C
Location 83U is below surface water, approximately 10 feet North from the location where the storm drain opens in the ditch. Samples were taken by driving a geoprobe tip into the sediment with a sledge hammer. At location 83U, there was 1.8 feet of water above the sediment in the ditch. The tide was in, and no fresh water was flowing from the drain into the ditch. The first 0.5 feet of sediment was a black mixture of leaf litter and silt. Below that was grey sand. The chemist that measured VOAs misread 83U as 83N. Because 83N was not used as a location name at another site, 83N will be considered a synonym of 83U.					
83U-1	9-14-93	1.8	0.0	3.8	not taken
83U-2	9-14-93	3.3	1.5	0.6	28.9
83U-3	9-14-93	5.9	4.1	0.3	30.1
The following samples were taken by opening a 40 ml VOA vial below the water in the draining ditch. Location 83X was in the water column above 83U. The tide was out, and there was a layer of fresh water 0.75 feet thick lying above a layer of salty water 1.2 feet thick. 83Y was taken where the ditch opened out to Weakly Bayou. The layer of fresh water was 0.25 feet thick, and the layer of salt water 0.75 feet thick.					
83Xf fresh	9-17-93	0.25		5.1	24.9
82Xs salt	9-17-93	1.25		2.9	28.2
83Xs/w sediment	9-17-93	1.83	0.0	2.8	28.7
83Yf fresh	9-17-93	0.15		5.6	25.9
83Ys salt	9-17-93	0.6		5.6	28.7
83Ys/w sediment	9-17-93	1.0	0.0	5.0	29.7
80H-3					

Sample	date	Elevation of surface FAMSL	Depth (feet)	Dis. Oxy. (mg/l)	Temp. °C
83C-1	9-16-93	10.03	7.25-8.25	0.0	27.0
83C-2	9-16-93	10.03	13.25-14.75	0.5	25.7
83H-1	9-15-93	10.40	4.25-5.75	0.7	27.7
83H-2	9-16-93	10.40	25.25-26.75	0.0	24.5
83L-1	9-16-93	10.92	4.25-5.75	0.0	28.6
83L-2	9-16-93	10.92	16.25-17.75	0.6	25.6
83O-1	9-15-93	10.19	10.25-11.75	0.1	26.8
83O-2	9-15-93	10.19	22.25-23.75	0.3	24.8
83P-1	9-14-93	6.64	13.25-14.75	0.3	28.7
83P-2	9-14-93	6.64	25.25-26.75	0.0	24.2
83Q-1	9-14-93	5.19	4.25-5.75	0.2	28.0
83Q-2	9-14-93	5.19	24.25-26.75	0.4	23.8
83R-1	9-13-93	4.10	3.55-5.05	0.8/0.9	30.0
83R-2	9-13-93	4.10	4.30-5.80	0.2/0.3	29.7
83R-3	9-13-93	4.10	19.30-20.80	0.2	26.1
83R-4	9-14-93	4.10	32.25-33.75	not taken	not taken
83S-1	9-15-93	4.91	4.25-5.75	0.5	28.4
83S-2	9-15-93	4.91	16.25-17.75	1.1	24.1
83S-3	9-15-93	4.91	25.25-26.75	0.45	25.2
83W-1	9-17-93	5.08	3.75-5.25	not taken	not taken
83W-2	9-17-93	5.08	21.75-23.25	1.2	22.9
83Z-1	9-17-93	8.72	5.25-6.75	0.1	29.1
83Z-2	9-17-93	8.72	13.25-14.75	0.2	24.8
83Z-3	9-17-93	8.72	22.25-23.75	0.1	24.2

sample	benzene	toluene	ethyl- benzene	p- xylene	m- xylene	o- xylene	1,3,5- TMB	1,2,4- TMB	1,2,3- TMB
----(ug/liter)----									
QC, obs	46.5	47.5	48.6	45.6	45.1	46.8	45.0	47.9	46.2
QC, true	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
20 µg/l	20.2	21.3	21.2	21.2	21.3	20.5	21.9	22.2	21.6
83 C-1	96.5	1.24	2.08	58.6	81.8	<1	4.94	29.7	9.29
83 C-2	<1	<1	2.93	2.71	1.82	<1	4.00	49.8	8.82
83 C-2 dup	<1	<1	2.95	2.70	1.76	<1	3.88	43.4	8.25
83 H field blank	<1	<1	<1	<1	<1	<1	<1	5.66	<1
83 H-1	31.0	30.4	841	1390	1570	<1	168	886	291
83 H-2	2.3	<0.5	6.39	10.0	18.6	<0.5	21.8	296	<1
83 L-1	3.76	6.51	26.4	92.8	165	123	13.9	62.7	21.6
83 L-1 dup	3.88	6.73	26.8	93.0	167	123	13.7	63.6	21.4
83 L-2	33.7	0.9	9.86	51.5	217	<0.5	50.1	267	100
83 U-1	<1	<1	<1	<1	<1	<1	2.28	<1	<1
100 µg/l	102	101	99.8	99.1	98.7	102	96.1	101	104
83 U-2	6.76	<1	1.38	25.1	39.7	<1	119	298	182
83 U-2 dup	6.98	<1	1.39	25.1	39.8	<1	119	299	187
83 U-3	198	1.12	1.41	13.8	13.5	<1	70.9	172	115

values in **bold** obtained by mass spectral analysis, others by GC/FID.

sample	benzene	toluene	ethyl- benzene	p- xylene	m- xylene	o- xylene	1,3,5- TMB	1,2,4- TMB	1,2,3- TMB
----- (ug/liter) -----									
83 O-1	<1	<1	<1	2.14	1.86	<1	<1	<1	<1
83 O-2	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 P-1	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 P-2	8.12	1.26	4.18	11.5	5.63	<1	3.22	138	36.9
83 Q-1	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 Q-2	<1	<1	<1	3.38	1.77	<1	<1	114	10.3
83 R-1	<1	<1	<1	<1	1.15	<1	1.92	<1	<1
10µg/l	9.63	9.46	9.66	9.52	9.56	8.60	10.0	9.10	7.67
83 R-2	<1	<1	3.61	6.47	16.3	<1	30.3	54.2	41.5
83 R-3	38.6	1.55	8.61	23.8	36.0	<1	6.83	114	22.7
83 R-3 dup	37.5	1.58	8.51	23.3	35.3	<1	6.82	117	23.0
83 R-4	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 S-1	<1	<1	<1	1.10	1.01	<1	2.10	<1	<1
83 S-2	327	3.05	3.29	26.4	51.4	<1	9.75	34.7	17.2
83 S-3	<0.5	<0.5	<0.5	1.8	<0.5	<0.5	<0.5	11.9	0.5
83 W-1	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 W-2	<1	<1	<1	<1	<1	<1	<1	67.1	<1
83 Z-1	22.6	2.12	19.3	39.8	143	105	171	352	247

Values in **bold** are obtained by mass spectral analysis, others by GC/FID.

sample	benzene	toluene	ethyl- benzene	p- xylene	m- xylene	o- xylene	1,3,5- TMB	1,2,4- TMB	1,2,3- TMB
---- (ug/liter) ----									
QC, obs	47.7	48.8	49.0	46.1	45.9	47.8	45.9	51.1	477
QC, true	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	500
GC lab blank	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 Z-2	153	18.3	227	594	1270	<0.5	114	420	182
83 Z-3	3.39	<1	1.88	10.4	4.17	<1	3.55	154	19.2
83 X F	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 X S	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 X S/w	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 Y F	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 Y S	<1	<1	<1	<1	<1	<1	<1	<1	<1
83 Y S/w	<1	<1	<1	<1	<1	<1	<1	<1	<1
20µg/l	19.7	20.3	18.9	18.3	19.0	19.2	18.3	18.5	19.0
Data from Steve Hutchin's JP-4 nitrate bioremediation project									
80 H-3	100	5150	1700	3120	6750	5480	327	1090	406

Field Data Eglin Air Force Base, Florida

Sample	Date	pH	Conductivity	Redox mVolts	Total Alkalinity	Chloride	Iron II
					-- (mg/l) --		
83 R-1	9/13/93	5.6	42	-117	28	8	.6
83 R-2	9/13/93	5.6	57	-152	13	10	1.1
83 R-3	9/13/93	6.1	126	-40	59	10	6.6
83 R-4	9/14/93	6.3	112	-110	54	10	10.0
83 U-1	9/14/93	7.1	23,300	99	75	7800	<.05
83 U-2	9/14/93	5.9	78	-159	37	10	2.8
83 U-3	9/14/93	5.9	137	-133	46	11	3.3
83 Q-1	9/14/93	5.9	51	-154	20	12	2.6
83 Q-2	9/14/93	6.2	108	-133	45	5	4.1
83 P-1	9/14/93	5.7	34	-141	13	8	.7
83 P-2	9/14/93	6.4	108	-160	41	9	4.4
83 O-1	9/15/93	6.2	48	-181	20	9	.8
83 O-2	9/15/93	6.6	132	-91	69	7	10.5
83 S-1	9/15/93	6.7	164	-86	76	10	.7
83 S-2	9/15/93	6.5	64	-142	22	6	3.8
83 S-3	9/15/93	6.7	119	-91	63	6	8.4
83 H-1	9/15/93	6.3	149	-182	55	9	4.3
83 H-2	9/16/93	6.4	84	-209	36	9	5.0
83 C-1	9/16/93	6.3	67	-253	25	8	1.2
83 C-2	9/16/93	6.4	24	-200	31	7	1.1
83 L-1	9/16/93	6.4	47	-201	20	8	2.6
83 L-2	9/16/93	6.4	92	-207	40	8	4.0

Field Data Eglin Air Force Base, Florida

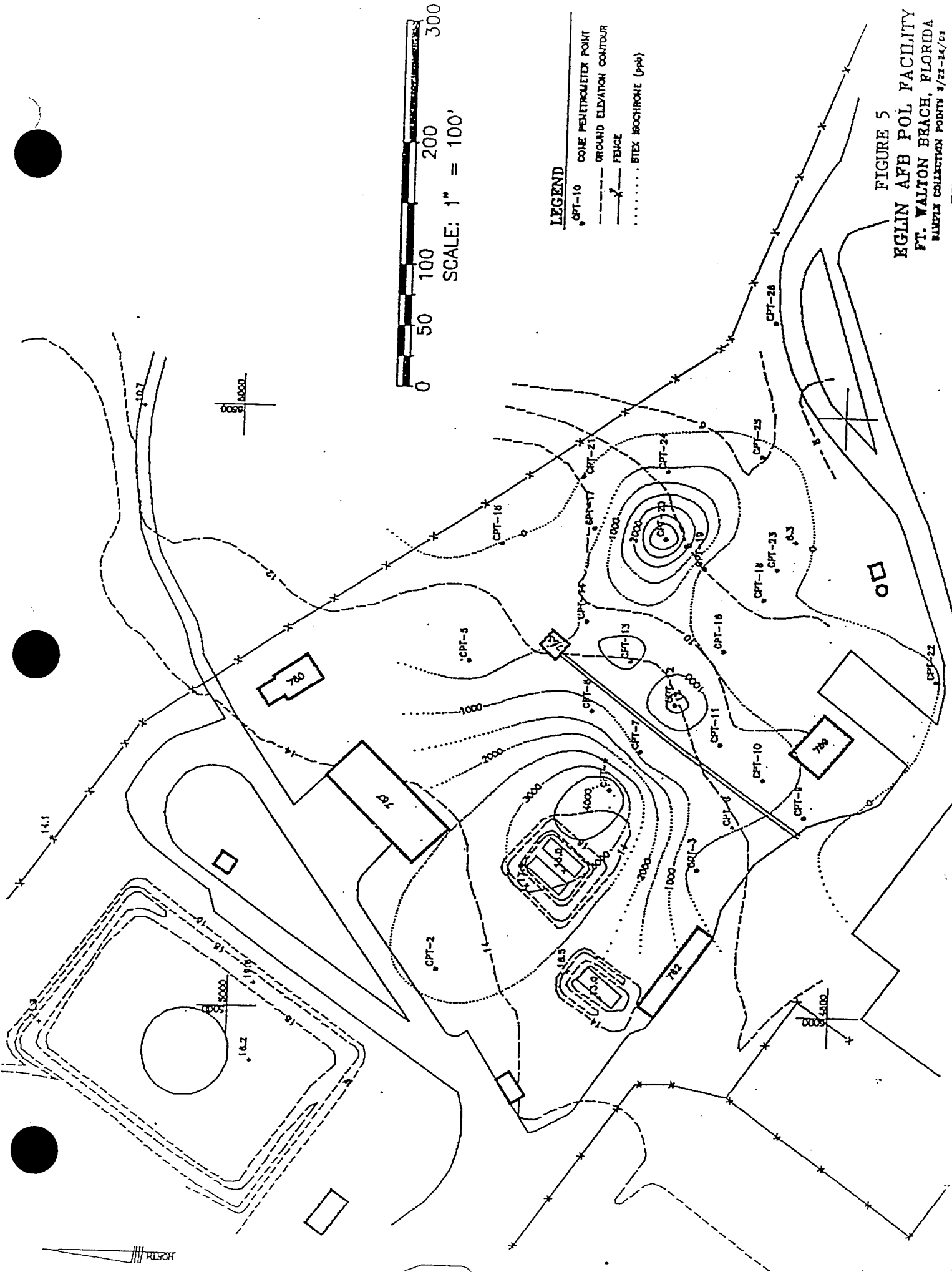
[illegible]

sample	total organic carbon	sample	total organic carbon
83 C-1	5.9		
83 C-2	3.5		
83 H-1	12.4		
83 H-2	11.3		
83 L-1	8.3		
83 L-2	6.7		
83 O-1	3.1		
83 O-2	4.9		
83 P-1	4.2		
83 P-2	4.4		
83 Q-1	10.1		
83 Q-2	6.5		
83 Q-2 dup	6.6		
83 R-1	20.0		
83 R-2	23.2		
83 R-3	10.0		
83 R-4	6.1		
83 S-1	6.1		
83 S-2	8.0		
83 S-3	7.2		
83 S-3 dup	7.4		
83 U-1	4.4		

[illegible]

Sample	Chloride	Sulfate	Total Phosphorus	Ammonia Nitrogen	Nitrate+ Nitrite Nitrogen	Alkalinity as Calcium Carbonate	Methane
--- (mg/l) ----							
83 C-1	1.31	2.28	.11	.49	<.05	27.2	3.80
83 C-2	1.64	.56	.07	.60	<.05	24.0	4.51
83 C-2 dup	1.44	.50					
83 H-1	4.98	.56	.28	2.41	<.05	58.5	10.98
83 H-1 dup	4.93	.51					
83 H-2	4.15	.12	.30	.68	<.05	27.5	4.21
83 L-1	1.79	3.92	.11	.37	.11	13.8	1.71
83 L-1 dup			.10				
83 L-2	2.20	<.05	.18	.59	.10	33.8	8.12
83 O-1	<.5	1.00	<.05	.29	<.05	19.8	8.34
83 O-2	<.5	.53	.26	.74	<.05	38.3	1.13
83 P-1	<.5	3.68	.05	.06	<.05	4.1	0.60
83 P-1 dup						3.8	
83 P-2	.68	3.26	.14	.77	<.05	38.8	5.99
83 P-2 dup				.77	<.05		
83 Q-1	1.06	<.5	.08	.34	<.05	12.3	5.18
83 Q-2	.52	<.5	.14	1.02	<.05	40.1	3.78
83 Q-2 dup			.14				
83 R-1	<.5	<.5	.06	.76	<.05	11.6	4.32
83 R-1 dup				.76	<.05		
83 R-2	<.5	<.5	.08	1.64	<.05	11.6	8.02
83 R-2 dup			.08				

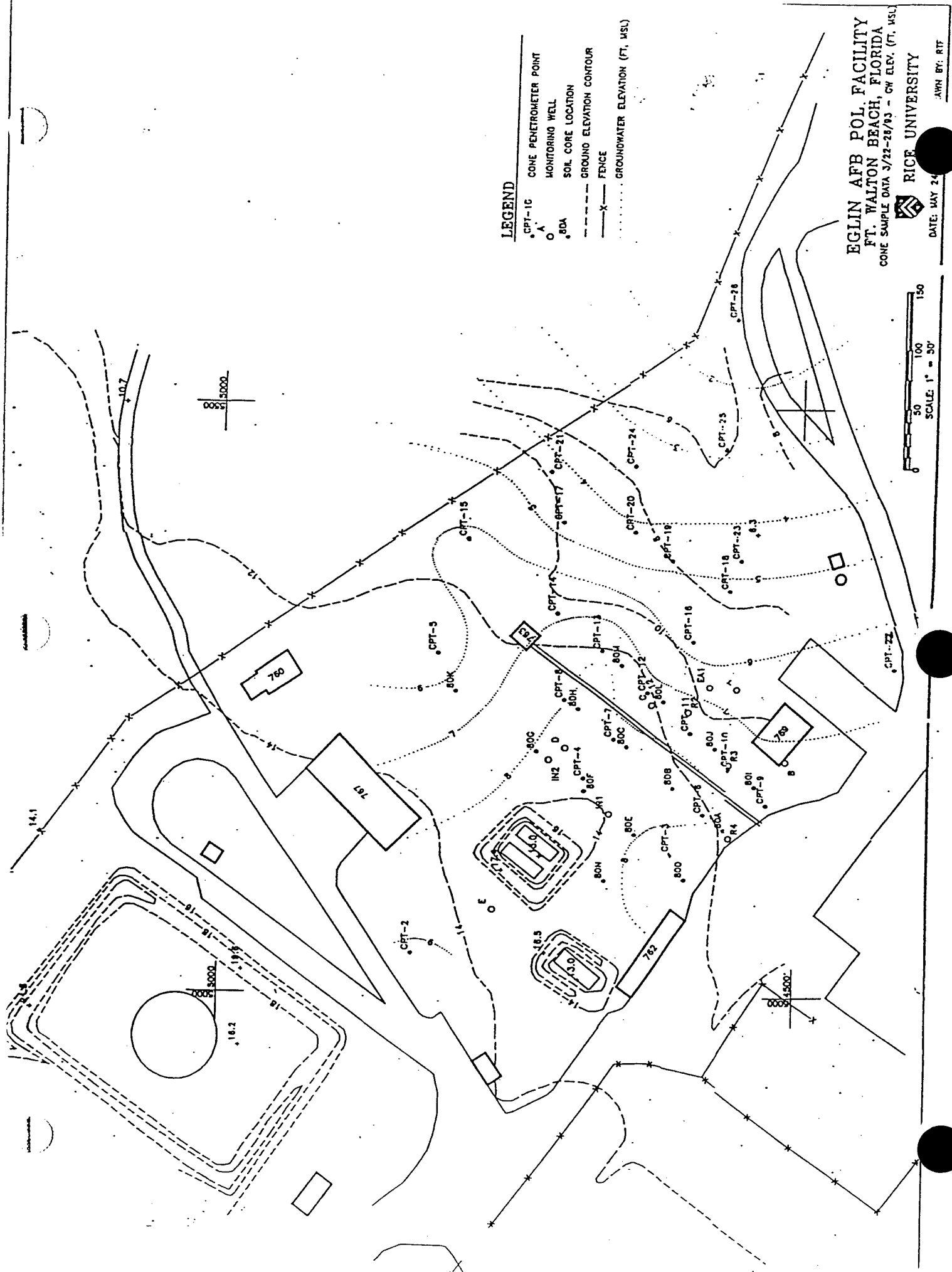
Sample	Chloride	Sulfate	Total Phosphorus	Ammonia Nitrogen	Nitrate + Nitrite Nitrogen	Alkalinity as Calcium Carbonate	Methane
-- (mg/l) --							
83 R-3	<.5	<.5	.62	1.56	<.05	40.7	5.69
83 R-3 dup				1.56	<.05		
83 R-4	1.79	<.5	.38	.68	<.05	27.3	1.89
83 S-1	2.99	4.94	<.05	.25	.13	70.0	2.49
83 S-1 dup			<.05	.25	.12		
83 S-2	1.59	.28	.12	.89	<.05	23.5	4.91
83 S-3	3.65	<.05	.30	1.17	<.05	31.8	0.69
83 U-1	<.5	<.5	.08	.16	<.05	70.0	0.69
83 U-2	<.5	1.76	.14	2.51	<.05	28.2	14.22
83 U-3	<.5	5.62	.15	2.86	<.05	36.2	12.48
83 W-1	7.18	<.05	<.05	.07	.09	22.5	3.24
83 W-1 dup						22.5	
83 W-2	2.48	<.05	.19	.96	.19	30.0	4.95
83 Z-1	5.58	.59	.08	.83	.10	13.8	16.97
83 Z-1 dup	5.58	.59					
83 Z-2	3.15	.62	1.59	1.31	.12	27.5	16.82
83 Z-2 dup				1.32	.17		
83 Z-3	2.69	<.05	1.12	1.81	.17	38.8	3.36



LEGEND

- CPT-10 COLE PENETRATOR POINT
- - - GROUND ELEVATION CONTOUR
- - - FENCE
- BITEX BOOTHONE (Dph)

FIGURE 5
EGLIN AFB POL FACILITY
FT. WALTON BEACH, FLORIDA
 SAMPLE COLLECTION POINTS 2/23-24/03
 RICE UNIVERSITY



ELEVATIONS OF BORES & WELLS

SOIL BORINGS			MONITORING WELLS		
BORE	GROUND ELEVATION	TOP OF PIPE ELEVATION	WELL	GROUND ELEVATION	TOP OF PIPE ELEVATION
A	11.07'	N/A	1-P1	11.25'	N/A
B	11.00'	N/A	2-P1	12.51'	N/A
C	12.03'	N/A	A	8.74'	10.60'
D	12.38'	N/A	B	10.53'	12.14'
E	12.31'	N/A	C	11.54'	13.74'
F	13.50'	N/A	D	13.16'	15.03'
G	13.08'	N/A	E	13.78'	16.10'
H	12.65'	N/A	EA-1	8.43'	8.59'
O	11.80'	N/A	EA-6	13.91'	16.42'
P	12.60'	N/A	EPA-1	11.87'	13.17'
			EPA-2	12.79'	14.80'
			1-1	13.00'	16.51'
			1-2	13.38'	16.91'
			PL-1	10.51'	12.51'
			PL-2	13.35'	15.43'
			PL-3	6.43'	8.94'
			R-1	12.43'	13.41'
			R-2	9.79'	10.60'
			R-3	10.23'	10.10'
			R-4	11.40'	11.16'
			XY	9.03'	10.78'
			YT	7.31'	8.17'
			ZZ	6.45'	8.91'

NOTES:

- (1) ELEVATIONS SHOWN HEREON ARE REFERENCED TO BENCHMARK "71-20". SEE BY THE
 CENTS. OF ELEVATION IN 1913 AND HAVING AN ELEVATION OF 8.63' M.S.L.
- (2) INTERNAL IMPROVEMENTS WERE NOT LOCATED, EXCEPT AS SHOWN.
- (3) UNDERGROUND UTILITIES, OR OTHER NON-VISIBLE STRUCTURES OR ENCROACHMENTS,
 IF ANY, WERE NOT LOCATED.
- (4) ABUTMENTS OR DEVIATIONS TO SUNNY DAVIDS OF OTHER THAN THE SIGNING PARTY
 OR PARTIES IS PROHIBITED WITHOUT WRITTEN CONSENT OF THE SIGNING PARTY OR
 PARTIES. (FLORIDA ADMINISTRATIVE CODE CHAPTER 31M-5, 1981)

GEORGE, NIELSEN & TOOE, P.A.
CONSULTING ENGINEERS & LAND SURVEYORS

648 NORTH WILSON STREET, CRESTVIEW, FLORIDA (904) 682-4269/7112

STATE OF FLORIDA

L. FREDERICK B. TOOME, JR. HEREBY CERTIFY THAT THIS PLAN AND THE INFORMATION SHOWN HEREON MEETS THE MINIMUM TECHNICAL STANDARDS AS SET FORTH BY THE FLORIDA BOARD OF PROFESSIONAL LAND SURVEYORS IN CHAPTER 21H44-8 FLORIDA ADMINISTRATIVE CODE PURSUANT TO SECTION 472.027, FLORIDA STATUTES.

NOT VALID
UNLESS BEARING
SURVEYOR'S
EMBOSSSED SEAL

08-06-93

END.

- ```

3" MONITORING WELL
4" MONITORING WELL
5" MONITORING WELL
SOIL BORING
POWER POLE
OVERHEAD POWER LINE
NEAR SEA LEVEL
TEMPERATURE BENCHMARK
ELEVATION
LAND SURVEYOR
LAND SURVEYOR BUSINESS

```



**GRAPHIC SCALE**  
(1 inch = 50 feet)

# Monitoring Well Data for Eglin AFB Site

| Well     | Date    | Sample Information | Depth to Ground<br>(ft from TOC) | Depth to water<br>(ft from TOC) | Depth to Bottom<br>(ft from TOC) | Temp<br>(deg C) | pH          | DO-Probe<br>(mg/L) | Conductivity<br>(umhos/cm) | Alkalinity<br>(mg/L) |
|----------|---------|--------------------|----------------------------------|---------------------------------|----------------------------------|-----------------|-------------|--------------------|----------------------------|----------------------|
| A        | 2/23/93 | Bailer (BioEnvir)  | -                                | 3.77                            | -                                | 16.0            | 6.70 (6.01) | 9.6                | 127 (122)                  | 53.1                 |
|          | 2/25/93 | PP-BH (RSKERL)     | 1.88                             | 3.78                            | 14.63                            | 16.2            | 6.15        | 0.6                | NA                         | NA                   |
| B        | 2/23/93 | Bailer (BioEnvir)  | -                                | 4.64                            | -                                | 19.4            | 6.80 (6.29) | 9.6                | 154 (150)                  | 73.3                 |
|          | 2/25/93 | PP-BH (RSKERL)     | 0.79                             | 4.58                            | 14.75                            | 19.5            | 6.54        | 0.6                | NA                         | NA                   |
| C        | 2/23/93 | Bailer (BioEnvir)  | -                                | 5.28                            | -                                | 18.5            | 6.70 (6.20) | NA                 | 97 (90.9)                  | 40.6                 |
|          | 2/25/93 | PP-BH (RSKERL)     | 2.25                             | 4.90                            | 16.87                            | 18.2            | 6.01        | 0.8                | NA                         | NA                   |
| D        | 2/23/93 | Bailer (BioEnvir)  | -                                | 6.77                            | -                                | 19.0            | NA (6.27)   | NA                 | 118 (116)                  | 49.8                 |
|          | 2/25/93 | PP-BH (RSKERL)     | 2.38                             | 6.44                            | 16.78                            | 18.6            | 6.26        | 0.8                | NA                         | NA                   |
| E        | 2/24/93 | Bailer (BioEnvir)  | -                                | 6.85                            | -                                | 18.5            | 6.70 (6.48) | 3.0                | 127 (124)                  | 56.7                 |
|          | 2/26/93 | PP-BH (RSKERL)     | 2.25                             | 6.52                            | 16.83                            | 17.5            | 6.17        | 1.3                | NA                         | NA                   |
| PL1      | 2/23/93 | Bailer (BioEnvir)  | -                                | 5.37                            | -                                | 23.1            | 6.80 (6.19) | 9.6                | 118 (116)                  | 35.5                 |
|          | 2/25/93 | PP-BH (RSKERL)     | 2.00                             | 5.24                            | 52.50                            | 20.5            | 6.64        | 1.1                | NA                         | NA                   |
| PL2      | 2/24/93 | Bailer (BioEnvir)  | -                                | 6.83                            | -                                | 21.8            | 6.90 (6.23) | 3.1                | 102 (102)                  | 20.3                 |
|          | 2/26/93 | PP-BH (RSKERL)     | 2.21                             | 6.54                            | 51.64                            | 18.9            | 6.35        | 1.0                | NA                         | NA                   |
| PL3      | 2/23/93 | Bailer (BioEnvir)  | -                                | 4.20                            | -                                | 21.7            | 7.20 (6.62) | NA                 | 129 (115)                  | 44.8                 |
|          | 2/25/93 | PP-BH (RSKERL)     | 2.00                             | 4.50                            | 41.30                            | 19.4            | 6.70        | 1.0                | NA                         | NA                   |
| R1       | 3/23/93 | PP-15' (RSKERL)    | 0.88                             | 4.46                            | -                                | 19.7            | 6.30        | 0.1                | 198                        | 88.3                 |
| R2       | 3/22/93 | PP-13' (RSKERL)    | 0.71                             | 1.98                            | -                                | 17.2            | 6.10        | 0.0                | 206                        | 96.7                 |
| R3       | 3/22/93 | PP-14' (RSKERL)    | 0.67                             | 3.40                            | -                                | 19.5            | 6.00        | 0.2                | 123                        | 55                   |
| R4       | 3/23/93 | Bailer (RSKERL)    | 0.46                             | 3.30                            | -                                | -               | -           | -                  | 130                        | 44.8                 |
|          | 3/23/93 | SP (RSKERL)        | 0.46                             | 3.30                            | -                                | 21.7            | 6.30        | 0.3                | 140                        | 65.2                 |
|          | 3/23/93 | PP (RSKERL)        | 0.46                             | 3.30                            | -                                | 21.1            | 6.40        | 0.1                | 135                        | 50.6                 |
|          | 3/23/93 | PP (RSKERL)        | 0.46                             | 3.30                            | -                                | -               | -           | -                  | 134                        | 47.1                 |
| I1 (RW1) | 3/23/93 | PP-14' (RSKERL)    | 3.50                             | 7.46                            | -                                | 19.7            | 6.60        | 0.1                | 126                        | 61.7                 |
| I2       | -       | -                  | 3.46                             | 7.86                            | -                                | -               | -           | -                  | -                          | -                    |
| EA1      | -       | -                  | 1.13                             | 2.92                            | -                                | -               | -           | -                  | -                          | -                    |

## Monitoring Well Demand for Eglin AFB Site

[illegible]

## Monitoring W for Eglin AFB Site

| Well     | Date    | Sample Information | CH4<br>(mg/L) | CO2<br>(mg/L) | O2-Hdspce<br>(mg/L) | N2<br>(mg/L) | N2O<br>(ug/L) | TOC<br>(mg/L) | BZ<br>(ug/L) | TOL<br>(ug/L) |
|----------|---------|--------------------|---------------|---------------|---------------------|--------------|---------------|---------------|--------------|---------------|
| A        | 2/23/93 | Bailer (BioEnvir)  | 9.68          | 126.00        | 1.60                | 12.3         | <0.36         | 50.2          | 3.9          | 3.7           |
|          | 2/25/93 | PP-BH (RSKERL)     | 9.16          | 125.00        | NA                  | NA           | NA            | 32.3          | 8.3          | 2.8           |
| B        | 2/23/93 | Bailer (BioEnvir)  | 3.71          | 110.00        | 4.20                | 15.2         | <0.36         | 7.0           | 18.5         | 0.6           |
|          | 2/25/93 | PP-BH (RSKERL)     | 4.65          | 122.00        | NA                  | NA           | NA            | 7.1           | 28.0         | 1.2           |
| C        | 2/23/93 | Bailer (BioEnvir)  | 7.34          | 114.00        | 2.38                | 13.3         | <0.36         | 30.3          | 0.2          | 22.2          |
|          | 2/25/93 | PP-BH (RSKERL)     | 8.51          | 118.00        | NA                  | NA           | NA            | 24.1          | 0.4          | 24.3          |
| D        | 2/23/93 | Bailer (BioEnvir)  | 6.54          | 118.00        | 3.47                | 13.0         | <0.36         | 11.2          | 4.9          | 550.0         |
|          | 2/25/93 | PP-BH (RSKERL)     | 7.25          | 123.00        | NA                  | NA           | NA            | 10.7          | 4.3          | 342.0         |
| E        | 2/24/93 | Bailer (BioEnvir)  | 6.98          | 98.90         | 4.32                | 12.9         | 0.64          | 11.2          | 1.5          | 0.7           |
|          | 2/26/93 | PP-BH (RSKERL)     | NA            | NA            | NA                  | NA           | NA            | 6.2           | 2.1          | 4.1           |
| PL1      | 2/23/93 | Bailer (BioEnvir)  | 0.39          | 72.50         | 2.83                | 17.0         | <0.36         | 7.2           | 3.0          | 0.2           |
|          | 2/25/93 | PP-BH (RSKERL)     | 0.62          | 82.30         | NA                  | NA           | NA            | 3.6           | 6.1          | 0.3           |
| PL2      | 2/24/93 | Bailer (BioEnvir)  | 0.36          | 56.00         | 4.93                | 16.3         | 3.68          | 2.3           | 1.3          | 0.1           |
|          | 2/26/93 | PP-BH (RSKERL)     | 4.71          | 120.00        | NA                  | NA           | NA            | 4.3           | 34.2         | 0.8           |
| PL3      | 2/23/93 | Bailer (BioEnvir)  | 0.85          | 72.60         | 4.74                | 16.3         | <0.36         | 7.2           | 0.1          | 0.2           |
|          | 2/25/93 | PP-BH (RSKERL)     | 1.13          | 72.10         | NA                  | NA           | NA            | 3.8           | 0.7          | 0.5           |
| R1       | 3/23/93 | PP-15' (RSKERL)    | 5.31          | 164.00        | 1.52                | 13.3         | ND            | 9.6           | 0.6          | 8.7           |
| R2       | 3/22/93 | PP-13' (RSKERL)    | 15.30         | 201.00        | 1.34                | 6.8          | ND            | 31.0          | 3.6          | 10.7          |
| R3       | 3/22/93 | PP-14' (RSKERL)    | 6.64          | 137.00        | 1.20                | 11.4         | ND            | 30.7          | 6.3          | 2.5           |
| R4       | 3/23/93 | Bailer (RSKERL)    | 0.78          | 69.90         | 2.30                | 14.8         | ND            | 11.2          | 0.0          | 0.0           |
|          | 3/23/93 | SP (RSKERL)        | 0.65          | 70.60         | 1.36                | 14.6         | ND            | 3.9           | 0.0          | 0.0           |
| I1 (RW1) | 3/23/93 | PP (RSKERL)        | 0.64          | 72.60         | 1.39                | 15.3         | ND            | 4.0           | 0.0          | 0.9           |
|          | 3/23/93 | PP (RSKERL)        | 0.62          | 75.30         | 0.99                | 14.5         | ND            | 4.7           |              |               |
| I2       | 3/23/93 | PP-14' (RSKERL)    | 2.44          | 99.20         | 1.44                | 14.3         | ND            | 8.6           | 0.6          | 8.8           |
| EA1      |         |                    |               |               |                     |              |               |               |              |               |

# Monitoring Well L for Eglin AFB Site

| Well     | Date    | Sample Information | ETBZ<br>(ug/L) | PXYL<br>(ug/L) | MXYL<br>(ug/L) | OXYL<br>(ug/L) | MESIT<br>(ug/L) | PSOU<br>(ug/L) | TMB<br>(ug/L) | BTEX<br>(ug/L) |
|----------|---------|--------------------|----------------|----------------|----------------|----------------|-----------------|----------------|---------------|----------------|
| A        | 2/23/93 | Bailer (BioEnvir)  | 20.8           | 74.7           | 145.0          | 78.7           |                 |                |               |                |
|          | 2/25/93 | PP-BH (RSKERL)     | 11.7           | 42.0           | 80.0           | 52.4           | 56.2            | 85.6           | 74.4          | 543.0          |
| B        | 2/23/93 | Bailer (BioEnvir)  | 3.6            | 6.7            | 6.5            | 0.5            |                 |                |               |                |
|          | 2/25/93 | PP-BH (RSKERL)     | 3.5            | 9.0            | 13.4           | 1.0            | 1.1             | 11.6           | 12.1          | 61.2           |
| C        | 2/23/93 | Bailer (BioEnvir)  | 166.0          | 324.0          | 707.0          | 155.0          |                 |                |               |                |
|          | 2/25/93 | PP-BH (RSKERL)     | 147.0          | 285.0          | 654.0          | 146.0          | 155.0           | 399.0          | 200.0         | 2128.4         |
| D        | 2/23/93 | Bailer (BioEnvir)  | 314.0          | 732.0          | 1640.0         | 781.0          |                 |                |               |                |
|          | 2/25/93 | PP-BH (RSKERL)     | 261.0          | 730.0          | 1645.0         | 494.0          | 130.0           | 284.0          | 179.0         | 4614.9         |
| E        | 2/24/93 | Bailer (BioEnvir)  | 21.2           | 149.0          | 456.0          | 8.4            |                 |                |               |                |
|          | 2/26/93 | PP-BH (RSKERL)     | 38.2           | 199.0          | 566.0          | 66.1           | 97.1            | 276.0          | 68.2          | 1078.1         |
| PL1      | 2/23/93 | Bailer (BioEnvir)  | 1.4            | 1.2            | 1.0            | 0.1            |                 |                |               |                |
|          | 2/25/93 | PP-BH (RSKERL)     | 2.7            | 1.9            | 1.7            | 0.2            | 0.1             | 0.6            | 0.2           | 7.8            |
| PL2      | 2/24/93 | Bailer (BioEnvir)  | 0.5            | 2.7            | 11.4           | 0.1            |                 |                |               |                |
|          | 2/26/93 | PP-BH (RSKERL)     | 5.4            | 50.9           | 263.0          | 1.3            | 85.4            | 217.0          | 0.4           | 14.6           |
| PL3      | 2/23/93 | Bailer (BioEnvir)  | 0.0            | 0.2            | 0.3            | 0.0            |                 |                |               |                |
|          | 2/25/93 | PP-BH (RSKERL)     | 1.3            | 2.4            | 5.1            | 1.5            | 0.3             | 3.0            | 0.7           | 4.8            |
| R1       | 3/23/93 | PP-15' (RSKERL)    | 59.1           | 84.6           | 126.0          | 21.6           |                 |                |               |                |
|          | 3/22/93 | PP-13' (RSKERL)    | 152.0          | 107.0          | 201.0          | 34.3           | 16.6            | 77.3           | 17.9          | 412.4          |
| R3       | 3/22/93 | PP-14' (RSKERL)    | 43.0           | 86.4           | 132.0          | 3.9            |                 |                |               |                |
|          | 3/23/93 | Bailer (RSKERL)    | 0.8            | 0.0            | 2.0            | 0.0            | 30.9            | 360.0          | 47.2          | 946.7          |
| R4       | 3/23/93 | SP (RSKERL)        | 0.7            | 0.8            | 2.3            | 0.0            |                 |                |               |                |
|          | 3/23/93 | PP (RSKERL)        | 6.8            | 13.1           | 20.0           | 5.0            | 32.5            | 103.0          | 51.4          | 461.0          |
| I1 (RW1) | 3/23/93 | PP-14' (RSKERL)    | 61.1           | 87.1           | 134.0          | 22.4           |                 |                |               |                |
|          |         |                    |                |                |                |                | 17.3            | 79.6           | 17.7          | 428.6          |
| I2       |         |                    |                |                |                |                |                 |                |               |                |
| EA1      |         |                    |                |                |                |                |                 |                |               |                |

# Monitoring Well for Eglin AFB Site

| Well     | Date    | Sample Information | Na-Filtered<br>(mg/L) | K-Filtered<br>(mg/L) | Ca-Filtered<br>(mg/L) | Mg-Filtered<br>(mg/L) | Fe-Filtered<br>(mg/L) | Fe- Filtr/Digst<br>(mg/L) | Fe(II)-Hach<br>(mg/L) |
|----------|---------|--------------------|-----------------------|----------------------|-----------------------|-----------------------|-----------------------|---------------------------|-----------------------|
| A        | 2/23/93 | Bailer (BioEnvir)  | 2.22                  | 2.70                 | 15.60                 | 1.98                  | 6.83                  | 7.40                      | NA                    |
|          | 2/25/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 6.10                  |
| B        | 2/23/93 | Bailer (BioEnvir)  | 3.23                  | <2.4                 | 21.60                 | 1.73                  | 6.43                  | 9.22                      | NA                    |
|          | 2/25/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 4.20                  |
| C        | 2/23/93 | Bailer (BioEnvir)  | 2.24                  | <2.4                 | 11.00                 | 0.65                  | 3.71                  | 5.25                      | NA                    |
|          | 2/25/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 3.20                  |
| D        | 2/23/93 | Bailer (BioEnvir)  | 3.83                  | 3.00                 | 12.00                 | 1.60                  | 3.72                  | 8.64                      | NA                    |
|          | 2/25/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 3.20                  |
| E        | 2/24/93 | Bailer (BioEnvir)  | 1.59                  | <2.4                 | 18.00                 | 1.04                  | 1.36                  | 4.25                      | NA                    |
|          | 2/26/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 1.30                  |
| PL1      | 2/23/93 | Bailer (BioEnvir)  | 4.45                  | 2.80                 | 11.80                 | 1.43                  | 6.51                  | 4.59                      | NA                    |
|          | 2/25/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 4.10                  |
| PL2      | 2/24/93 | Bailer (BioEnvir)  | 5.34                  | <2.4                 | 8.18                  | 1.92                  | 2.60                  | 2.94                      | NA                    |
|          | 2/26/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 6.00                  |
| PL3      | 2/23/93 | Bailer (BioEnvir)  | 3.88                  | <2.4                 | 14.70                 | 1.24                  | 7.05                  | 14.50                     | NA                    |
|          | 2/25/93 | PP-BH (RSKERL)     | NA                    | NA                   | NA                    | NA                    | NA                    | NA                        | 4.00                  |
| R1       | 3/23/93 | PP-15' (RSKERL)    | 3.16                  | 4.40                 | 32.00                 | 1.77                  | 0.02                  | NA                        | 3.50                  |
| R2       | 3/22/93 | PP-13' (RSKERL)    | 2.35                  | 2.70                 | 37.40                 | 1.44                  | 0.02                  | NA                        |                       |
| R3       | 3/22/93 | PP-14' (RSKERL)    | 1.68                  | 3.90                 | 17.90                 | 1.75                  | 0.36                  | NA                        |                       |
| R4       | 3/23/93 | Bailer (RSKERL)    | 4.26                  | 3.50                 | 12.70                 | 1.38                  | 0.02                  | NA                        | 5.30                  |
|          | 3/23/93 | SP (RSKERL)        | 4.54                  | 3.70                 | 12.50                 | 1.39                  | 0.05                  | NA                        | 5.30                  |
|          | 3/23/93 | PP (RSKERL)        | 4.06                  | 3.50                 | 12.40                 | 1.37                  | 0.02                  | NA                        | 5.30                  |
|          | 3/23/93 | PP (RSKERL)        | 4.56                  | 3.40                 | 12.70                 | 1.40                  | 0.02                  | NA                        | 5.50                  |
| I1 (RW1) | 3/23/93 | PP-14' (RSKERL)    | 1.32                  | 5.90                 | 19.80                 | 1.04                  | 0.02                  | NA                        | 3.00                  |
| I2       |         |                    |                       |                      |                       |                       |                       |                           |                       |
| EA1      |         |                    |                       |                      |                       |                       |                       |                           |                       |



# Cone Penetrometer Well Data for Eglin AFB Site

| Rice Location | EPA Location  | Date    | Grade Elev.<br>(ft MSL) | Bot. Screen<br>(ft from GS) | Top Screen<br>(ft from GS) | Bot. Screen<br>(ft MSL) | Top Screen<br>(ft MSL) | Water Table<br>(ft MSL) | BZ<br>(ug/L) | TOL<br>(ug/L) | ETBZ<br>(ug/L) |
|---------------|---------------|---------|-------------------------|-----------------------------|----------------------------|-------------------------|------------------------|-------------------------|--------------|---------------|----------------|
| CPT-1         |               |         |                         |                             |                            |                         |                        |                         |              |               |                |
| CPT-2         | Far E of 80K  |         | 13.81                   | 7.13                        | 2.63                       | 6.68                    | 11.18                  | 9.18                    |              |               |                |
| CPT-3         | 80E/80B       | 3/26/93 | 12.23                   | 7.41                        | 2.91                       | 4.82                    | 9.32                   | 7.32                    | 4.1          | 39.4          | 15.9           |
| CPT-4         | 80F/C/H/G     | 3/25/93 | 13.31                   | 7.25                        | 2.75                       | 6.06                    | 10.56                  | 8.56                    | 0.0          | 68.9          | 462.0          |
| CPT-5         | 80K           | 3/24/93 | 12.44                   | 9.68                        | 5.18                       | 2.76                    | 7.26                   | 5.26                    | 0.0          | 0.0           | 1.6            |
| CPT-6-03      | 80B           | 3/26/93 | 10.87                   | 3.50                        | 3.00                       | 7.37                    | 7.87                   | 8.50                    | 0.0          | 0.8           | 1.7            |
| CPT-6-05      | 80B           | 3/26/93 | 10.88                   | 5.50                        | 5.00                       | 5.38                    | 5.88                   | 8.46                    | 2.3          | 7.5           | 45.5           |
| CPT-6-07      | 80B           | 3/26/93 | 10.91                   | 7.50                        | 7.00                       | 3.41                    | 3.91                   | 8.49                    | 1.1          | 1.7           | 39.5           |
| CPT-6-09      | 80B           | 3/26/93 | 10.92                   | 9.50                        | 9.00                       | 1.42                    | 1.92                   | 8.45                    | 0.0          | 1.3           | 37.1           |
| CPT-6-11      | 80B           | 3/27/93 | 10.92                   | 11.50                       | 11.00                      | -0.58                   | -0.08                  |                         | 2.1          | 1.9           | 5.2            |
| CPT-7         | 80C/80H       | 3/25/93 | 12.29                   | 6.54                        | 2.04                       | 5.75                    | 10.25                  | 8.25                    | 0.0          | 20.3          | 6.9            |
| CPT-8-04      | 80H           |         | 12.55                   | 4.50                        | 4.00                       | 8.05                    | 8.55                   | 8.43                    |              |               |                |
| CPT-8-06      | 80H           | 3/26/93 | 12.73                   | 6.50                        | 6.00                       | 6.23                    | 6.73                   | 7.48                    | 0.6          | 8.7           | 5.4            |
| CPT-8-08      | 80H           | 3/26/93 | 12.63                   | 8.50                        | 8.00                       | 4.13                    | 4.63                   | 8.45                    | 56.5         | 1950.0        | 287.0          |
| CPT-8-10      | 80H           | 3/26/93 | 12.64                   | 10.50                       | 10.00                      | 2.14                    | 2.64                   | 5.46                    | 3.6          | 116.0         | 78.5           |
| CPT-8-12      | 80H           | 3/26/93 | 12.63                   | 12.50                       | 12.00                      | 0.13                    | 0.63                   | 7.79                    | 1.8          | 75.7          | 16.4           |
| CPT-9         | 80I           | 3/24/93 | 10.76                   | 5.77                        | 1.27                       | 4.99                    | 9.49                   | 7.49                    | 67.0         | 3.4           | 2.9            |
| CPT-10        | 80J           | 3/23/93 | 10.17                   | 5.45                        | 0.95                       | 4.72                    | 9.22                   | 7.22                    | 3.9          | 12.2          | 145.0          |
| CPT-11        | 80J/80L       | 3/25/93 | 9.93                    | 4.10                        | -0.40                      | 5.83                    | 10.33                  | 8.33                    | 2.9          | 1.1           | 93.7           |
| CPT-12        | 80L/80M       | 3/25/93 | 11.00                   | 6.75                        | 2.25                       | 4.25                    | 8.75                   | 6.75                    | 0.5          | 52.0          | 93.2           |
| CPT-13        | 80M           | 3/24/93 | 11.48                   | 5.63                        | 1.13                       | 5.85                    | 10.35                  | 8.35                    | 4.2          | 1.4           | 24.0           |
| CPT-14        | NE of 80M     | 3/25/93 | 10.58                   | 6.92                        | 2.42                       | 3.66                    | 8.16                   | 6.16                    | 1.2          | 18.9          | 87.3           |
| CPT-15        | West of 80K   |         | 10.60                   | 6.64                        | 2.14                       | 3.96                    | 8.46                   | 6.46                    |              |               |                |
| CPT-16        | East of 80L   | 3/25/93 | 9.08                    | 6.20                        | 1.70                       | 2.88                    | 7.38                   | 5.38                    | 5.5          | 1.1           | 55.9           |
| CPT-17-03     | Far W of 80H  |         | 9.58                    | 3.50                        | 3.00                       | 6.08                    | 6.58                   |                         |              |               |                |
| CPT-17-05     | Far W of 80H  |         | 9.51                    | 5.50                        | 5.00                       | 4.01                    | 4.51                   | 5.08                    |              |               |                |
| CPT-17-07     | Far W of 80H  |         | 9.56                    | 7.50                        | 7.00                       | 2.06                    | 2.56                   | 4.86                    |              |               |                |
| CPT-17-09     | Far W of 80H  |         | 9.47                    | 9.50                        | 9.00                       | -0.03                   | 0.47                   | 4.07                    |              |               |                |
| CPT-18        | Far W of 80J  |         | 6.86                    | 4.15                        | -0.35                      | 2.71                    | 7.21                   | 5.21                    |              |               |                |
| CPT-19-03     | Far W of 80L  |         | 7.03                    | 3.50                        | 3.00                       | 3.53                    | 4.03                   | 5.02                    |              |               |                |
| CPT-19-05     | Far W of 80L  |         | 6.98                    | 5.50                        | 5.00                       | 1.48                    | 1.98                   | 5.03                    |              |               |                |
| CPT-19-07     | Far W of 80L  |         | 6.94                    | 7.50                        | 7.00                       | -0.56                   | -0.06                  | 5.05                    |              |               |                |
| CPT-19-09     | Far W of 80L  |         | 6.92                    | 9.50                        | 9.00                       | -2.58                   | -2.08                  | 5.04                    |              |               |                |
| CPT-20        | Far W of 80M  |         | 7.95                    | 6.44                        | 1.94                       | 1.51                    | 6.01                   | 4.01                    |              |               |                |
| CPT-21        | Far W of 80H  |         | 9.51                    | 7.73                        | 3.23                       | 1.78                    | 6.28                   | 4.28                    |              |               |                |
| CPT-22        | Far SW of 80I |         | 9.70                    | 5.37                        | 0.87                       | 4.33                    | 8.83                   | 6.83                    |              |               |                |
| CPT-23        | Far W of 80J  |         | 6.35                    | 5.32                        | 0.82                       | 1.03                    | 5.53                   | 3.53                    |              |               |                |
| CPT-24        | Far W of 80M  |         | 6.95                    | 6.71                        | 2.21                       | 0.24                    | 4.74                   | 2.74                    |              |               |                |
| CPT-25        | Far W of 80J  |         | 5.65                    | 7.04                        | 2.54                       | -1.39                   | 3.11                   | 1.11                    |              |               |                |
| CPT-26        | Far W of 80J  |         | 6.10                    | 8.60                        | 4.10                       | -2.50                   | 2.00                   |                         |              |               |                |



# Cone Penetrometer W ata for Eglin AFB Site

| Rice Location | EPA Location  | PXYL<br>(ug/L) | MXYL<br>(ug/L) | OXYL<br>(ug/L) | MESIT<br>(ug/L) | PSCU<br>(ug/L) | TMB<br>(ug/L) | BTEX+ (RSKERL)<br>(ug/L) | BTEX (RSKERL)<br>(ug/L) | BTEX (Rice)<br>(ug/L) |
|---------------|---------------|----------------|----------------|----------------|-----------------|----------------|---------------|--------------------------|-------------------------|-----------------------|
| CPT-1         |               |                |                |                |                 |                |               |                          |                         |                       |
| CPT-2         | Far E of 80K  |                |                |                |                 |                |               |                          |                         | 2                     |
| CPT-3         | 80E/80B       | 28.9           | 50.9           | 12.7           | 24.8            | 75.9           | 52.3          | 305                      | 152                     | 2770                  |
| CPT-4         | 80F/C/H/G     | 736.0          | 1660.0         | 1380.0         | 181.0           | 581.0          | 291.0         | 5360                     | 4307                    | 158                   |
| CPT-5         | 80K           | 22.6           | 53.8           | 0.8            | 10.7            | 16.8           | 11.6          | 118                      | 79                      | 4550                  |
| CPT-6-03      | 80B           | 3.6            | 7.5            | 4.0            | 1.5             | 2.4            | 2.2           | 24                       | 18                      | 86                    |
| CPT-6-05      | 80B           | 102.0          | 214.0          | 131.0          | 116.0           | 304.0          | 155.0         | 1077                     | 502                     |                       |
| CPT-6-07      | 80B           | 87.3           | 188.0          | 153.0          | 86.1            | 199.0          | 107.0         | 863                      | 471                     | 529                   |
| CPT-6-09      | 80B           | 72.4           | 152.0          | 95.4           | 70.4            | 138.0          | 65.1          | 632                      | 358                     | 333                   |
| CPT-6-11      | 80B           | 22.3           | 21.6           | 25.1           | 34.6            | 13.7           | 36.7          | 163                      | 78                      | 370                   |
| CPT-7         | 80C/80H       | 20.2           | 32.7           | 36.6           | 190.0           | 257.0          | 185.0         | 749                      | 117                     | 76                    |
| CPT-8-04      | 80H           |                |                |                |                 |                |               |                          |                         |                       |
| CPT-8-06      | 80H           | 21.9           | 34.1           | 22.0           | 71.8            | 124.0          | 101.0         | 390                      | 93                      |                       |
| CPT-8-08      | 80H           | 648.0          | 667.0          | 1300.0         | 364.0           | 1100.0         | 478.0         | 6851                     | 4909                    | 84                    |
| CPT-8-10      | 80H           | 309.0          | 549.0          | 94.6           | 135.0           | 276.0          | 94.9          | 1657                     | 1151                    | 18100                 |
| CPT-8-12      | 80H           | 34.3           | 68.8           | 47.7           | 12.7            | 26.9           | 13.0          | 297                      | 245                     | 1130                  |
| CPT-9         | 80I           | 194.0          | 267.0          | 22.3           | 57.8            | 115.0          | 65.9          | 795                      | 557                     | 223                   |
| CPT-10        | 80J           | 294.0          | 637.0          | 15.1           | 127.0           | 278.0          | 172.0         | 1684                     | 1107                    | 23                    |
| CPT-11        | 80J/80L       | 158.0          | 163.0          | 0.8            | 108.0           | 290.0          | 94.7          | 912                      | 420                     | 1120                  |
| CPT-12        | 80L/80M       | 284.0          | 625.0          | 624.0          | 222.0           | 455.0          | 280.0         | 2636                     | 1679                    | 477                   |
| CPT-13        | 80M           | 86.7           | 122.0          | 0.9            | 57.8            | 166.0          | 82.8          | 546                      | 239                     | 1900                  |
| CPT-14        | NE of 80M     | 173.0          | 325.0          | 42.1           | 36.8            | 126.0          | 61.6          | 872                      | 648                     | 267                   |
| CPT-15        | West of 80K   |                |                |                |                 |                |               |                          |                         |                       |
| CPT-16        | East of 80L   | 13.3           | 21.4           | 2.4            | 7.1             | 102.0          | 11.5          | 220                      | 100                     | 24                    |
| CPT-17-03     | Far W of 80H  |                |                |                |                 |                |               |                          |                         | 112                   |
| CPT-17-05     | Far W of 80H  |                |                |                |                 |                |               |                          |                         |                       |
| CPT-17-07     | Far W of 80H  |                |                |                |                 |                |               |                          |                         | 208                   |
| CPT-17-09     | Far W of 80H  |                |                |                |                 |                |               |                          |                         | 111                   |
| CPT-18        | Far W of 80J  |                |                |                |                 |                |               |                          |                         | 205                   |
| CPT-19-03     | Far W of 80L  |                |                |                |                 |                |               |                          |                         | 7                     |
| CPT-19-05     | Far W of 80L  |                |                |                |                 |                |               |                          |                         |                       |
| CPT-19-07     | Far W of 80L  |                |                |                |                 |                |               |                          |                         | 12                    |
| CPT-19-09     | Far W of 80L  |                |                |                |                 |                |               |                          |                         | 12                    |
| CPT-20        | Far W of 80M  |                |                |                |                 |                |               |                          |                         | 45                    |
| CPT-21        | Far W of 80H  |                |                |                |                 |                |               |                          |                         | 41                    |
| CPT-22        | Far SW of 80I |                |                |                |                 |                |               |                          |                         | 4030                  |
| CPT-23        | Far W of 80J  |                |                |                |                 |                |               |                          |                         | 1                     |
| CPT-24        | Far W of 80M  |                |                |                |                 |                |               |                          |                         | 2                     |
| CPT-25        | Far W of 80J  |                |                |                |                 |                |               |                          |                         | 228                   |
| CPT-26        | Far W of 80J  |                |                |                |                 |                |               |                          |                         | 20                    |
|               |               |                |                |                |                 |                |               |                          |                         | 4                     |

## Eglin AFB microcosms

| Control Micorcosms           |                            |         | Live Microcosms |                          |             |
|------------------------------|----------------------------|---------|-----------------|--------------------------|-------------|
| Microcosm                    | Benzene                    | Toluene | Microcosm       | Benzene                  | Toluene     |
|                              | ---(ug/liter pore water)-- |         |                 | --ug/liter pore water)-- |             |
| Time Zero Microcosms         |                            |         |                 |                          |             |
| 83-1                         | 400                        | 60      | 83-21           | 385                      | 72          |
| 83-9                         | 456                        | 62      | 83-22           | 394                      | 70          |
| 83-10                        | 479                        | 61      | 83-30           | 427                      | 79          |
| Average                      | 445                        | 61      |                 | 402                      | 74          |
| After 34 weeks of incubation |                            |         |                 |                          |             |
| 83-2                         | 385                        | 79      | 83-31           | 319                      | <5          |
| 83-3                         | 268                        | 61      | 83-33           | 188                      | <5          |
| 83-12                        | 280                        | 62      | 83-36           | 187                      | <5          |
| 83-15                        | 323                        | 56      |                 |                          |             |
| Average                      | 313                        | 65      |                 | 231                      | <5          |
| Fraction remaining           | 0.703                      | 1.07    |                 | 0.575                    | <0.068      |
|                              |                            |         |                 |                          |             |
| First order rate of change   |                            |         |                 | -0.016/week              | -0.079/week |



Ref: 94-BN56/vg

October 27, 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 SAY

Dear Don:

Please find attached results for methane on Eglin AFB samples as per Service Request #SF-1-96. Samples were received on 10/20/94 and analyzed on 10/24/94. Samples were prepared and calculations were done as per RSKSOP-175 (draft). Analysis was performed as per RSKSOP-147.

If you have any questions, please feel free to see me.

Sincerely,

A handwritten signature in cursive script that reads "Bryan Newell".

Bryan Newell

xc: R.L. Cosby  
J.L. Seeley *JLS*  
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive  
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

ANALYZED 10/24/94

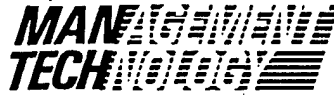
| SAMPLE             | METHANE |
|--------------------|---------|
| LAB BLANK          | BLQ     |
| EPA-83-1           | 1.410   |
| EPA-83-2           | 11.787  |
| EPA-83-3           | 5.483   |
| EPA-83-4           | 7.042   |
| EPA-83-5           | 4.672   |
| EPA-83-5 LAB DUP   | 4.364   |
| EPA-83-6           | 0.641   |
| EPA-83-6 FIELD DUP | 0.525   |
| EPA-83-7           | 5.858   |
| 10 PPM CH4         | 10.27   |
| 100 PPM CH4        | 99.97   |
| 990 PPM CH4        | 993.77  |
| 1 % CH4            | 1.01    |
| 10 % CH4           | 10.00   |
| 20 % CH4           | 20.15   |

LOWER LIMIT OF QUANTITATION

0.001

UNITS FOR THE SAMPLES ARE mg/L.  
UNITS FOR THE STANDARDS CORRESPOND  
TO THE UNITS IN THE SAMPLE COLUMN.

BLQ DENOTES BELOW LIMIT OF QUANTITATION.



Ref: 94-LP115/vg

October 27, 1994

Dr. Don Kampbell  
R.S. Kerr Environmental Research Lab  
U.S. Environmental Protection Agency  
Post Office Box 1198  
Ada, OK 74820

THRU: S.A. Vandegrift <sup>5<sup>th</sup></sup>

Dear Don:

Attached are inorganic results for a set of seven samples from Eglin AFB submitted to MERSC October 20 as a part of Service Request #SF-1-96. The samples were analyzed October 20 and 21 using EPA Methods 120.1, 310.1, and 353.1 and Water's capillary electrophoresis method N-601.

Blanks, spikes, duplicates, and known AQC samples were analyzed along with your samples for quality control.

If you have any questions concerning these results please feel free to contact me.

Sincerely,

*Lynda Pennington*  
Lynda Pennington

xc: R.L. Cosby  
J.L. Seeley *jls*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive  
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

| <u>Sample</u>  | <u>mg/L</u><br><u>NO<sub>2</sub><sup>-</sup>+NO<sub>3</sub><sup>-</sup>(N)</u> | <u>mg/L</u><br><u>Cl<sup>-</sup></u> | <u>mg/L</u><br><u>SO<sub>4</sub><sup>=</sup></u> | <u>μS/cm</u><br><u>Conductivity</u> | <u>mg/L</u><br><u>Alkalinity</u><br><u>(as CaCO<sub>3</sub>)</u> |
|----------------|--------------------------------------------------------------------------------|--------------------------------------|--------------------------------------------------|-------------------------------------|------------------------------------------------------------------|
| EPA-83-1       | 0.07                                                                           | 13.2                                 | 5.64                                             | 174                                 | 58                                                               |
| EPA-83-2       | 0.10                                                                           | 8.40                                 | 3.47                                             | 358                                 | 168                                                              |
| EPA-83-3       | 0.07                                                                           | 12.3                                 | 0.67                                             | 146                                 | 50                                                               |
| EPA-83-3 Dup   | 0.07                                                                           | -----                                | -----                                            | ---                                 | ---                                                              |
| EPA-83-4       | 0.07                                                                           | 2.36                                 | 3.93                                             | 44                                  | 14                                                               |
| EPA-83-4 Dup   | -----                                                                          | 2.30                                 | 3.93                                             | ---                                 | ---                                                              |
| EPA-83-5       | 0.08                                                                           | 8.26                                 | 1.27                                             | 66                                  | 14                                                               |
| EPA-83-6       | 0.07                                                                           | 3.62                                 | 5.69                                             | 46                                  | 7                                                                |
| EPA-83-7       | 0.09                                                                           | 1.37                                 | 2.59                                             | 21                                  | 2                                                                |
| EPA-83-7 Dup   | -----                                                                          | -----                                | -----                                            | 21                                  | 2                                                                |
| Blank          | <.05                                                                           | <.5                                  | <.5                                              | 1                                   | ---                                                              |
| WP031          | 2.69                                                                           | 41.1                                 | 92.8                                             | ---                                 | ---                                                              |
| WP031 T.V.     | 2.81                                                                           | 41.2                                 | 92.0                                             | ---                                 | ---                                                              |
| Spike Recovery | 100%                                                                           | 99%                                  | 100%                                             | ---                                 | ---                                                              |



Ref: 94-JH21/vg

October 27, 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 <sup>SN</sup>

Dear Don:

Attached are TOC results for a set of seven groundwater samples submitted to ManTech Environmental October 10, 1994 under Service Request #SF-1-96. TOC determinations were begun October 25, 1994 and completed October 26, 1994 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control. If you have any questions concerning this data, please feel free to contact me.

Sincerely,

  
Jeff Hickerson

xc: R.L. Cosby  
J.L. Seeley *jl*  
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive  
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

GROUNDWATER SAMPLES FROM EGLIN AFB FOR TOC (SR# SF-1-96)

| SAMPLE   | MG/L |           |
|----------|------|-----------|
|          | TOC  |           |
| EPA-83-1 | 6.9  |           |
| EPA-83-2 | 22.8 |           |
| EPA-83-3 | 8.4  |           |
| EPA-83-3 | 7.6  | field dup |
| EPA-83-4 | 19.8 |           |
| EPA-83-5 | 4.1  |           |
| EPA-83-6 | 13.0 |           |
| EPA-83-6 | 12.4 | field dup |
| EPA-83-7 | 11.4 |           |
| EPA-83-7 | 13.2 | lab dup   |
| WPO32-II | 9.7  |           |
|          | 9.9  |           |

TRUE VALUE: WPO32-II = 9.60 MG/L



Table 1. Quantitation Report for S.R. # SF-1-96 from Eglin AFB.

| Preliminary report 11/23/94 jad |          |  |          |  |          |  |          |  |          | Concentration = ppb |          |  |          |  |          |  |          |  |         |  |
|---------------------------------|----------|--|----------|--|----------|--|----------|--|----------|---------------------|----------|--|----------|--|----------|--|----------|--|---------|--|
| Compound                        | EPA-83-1 |  | EPA-83-2 |  | EPA-83-2 |  | EPA-83-3 |  | EPA-83-4 |                     | EPA-83-5 |  | EPA-83-6 |  | EPA-83-7 |  | EPA-83-7 |  | QC1102A |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
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|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |
|                                 |          |  |          |  |          |  |          |  |          |                     |          |  |          |  |          |  |          |  |         |  |

Dup = Duplicate    --- = Below Calibration Limit(1.0 ppb)    QC = Quality Control Std.    BL = Blank



EA ENGINEERING,  
SCIENCE, AND  
TECHNOLOGY, INC.

Southeast Regional Operations  
1900 Lake Park Drive, Suite 350  
Smyrna, Georgia 30080  
(404) 438-9894

# LETTER OF TRANSMITTAL

ATLANTA • BALTIMORE • CHICAGO • CINCINNATI • LINCOLN • NEW YORK • SAN FRANCISCO

TO

Todd H. Wiedemeier  
Engineering-Science, Inc.  
1700 Broadway, Suite 900  
Denver, Colorado 80290

|                         |                            |
|-------------------------|----------------------------|
| DATE<br>13 October 1993 | JOB NO.<br>EA 11206.55-603 |
| ATTENTION               |                            |
| RE:<br>SS-36, POL       |                            |
|                         |                            |
|                         |                            |
|                         |                            |
|                         |                            |
|                         |                            |
|                         |                            |

GENTLEMEN:

WE ARE SENDING YOU

☐ Attached ☐ Under separate cover via \_\_\_\_\_ the following items:

☐ Shop drawings

☐ Prints

☐ Plans

☐ Samples

☐ Specifications

☐ Copy of letter

☐ Change order

☐ \_\_\_\_\_

| COPIES | DATE     | NO. | DESCRIPTION                                             |
|--------|----------|-----|---------------------------------------------------------|
| 1      | 8 Oct 93 |     | Pace Incorporated Report of Laboratory Analysis         |
| 1      | 7 Oct 93 |     | EA Laboratories Report No. 931401                       |
| 1      | 30 Sep-  |     | Field Records of Well Gauging, Purging and Sampling for |
|        | 1 Oct 93 |     | EPA 83-1 through EPA 83-7                               |
|        |          |     |                                                         |
|        |          |     |                                                         |
|        |          |     |                                                         |
|        |          |     |                                                         |

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☐ For review and comment

☐ \_\_\_\_\_

☐ FOR BIDS DUE \_\_\_\_\_ 19\_\_\_\_\_

☐ PRINTS RETURNED AFTER LOAN TO US

REMARKS Todd, I need to locate the Fedex Airbill that goes with the Pace chain-of-

custody. Will forward that and remaining lab data when received. (My field notes are coming too!) Hope all is well with your data!

COPY TO \_\_\_\_\_

SIGNED \_\_\_\_\_

Joan Hutton

October 08, 1993

**RECEIVED**

OCT 12 1993

EA Engineering, Science, and Technology  
Smyrna, GA

Ms. Joan Hutton  
EA Engineering, Science and Technology  
1900 Lake Park Drive  
Suite 350  
Smyrna, GA 30080

RE: PACE Project No. 230923.526  
Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

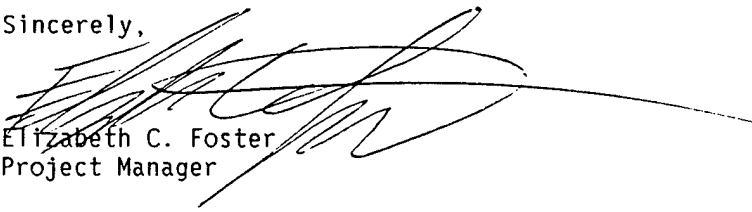
Dear Ms. Hutton:

Enclosed is the report of laboratory analyses for samples received  
October 02, 1993.

Footnotes are given at the end of the report.

If you have any questions concerning this report, please feel free  
to contact us.

Sincerely,

  
Elizabeth C. Foster  
Project Manager

Enclosures

## REPORT OF LABORATORY ANALYSIS

EA Engineering, Science and Technology  
1900 Lake Park Drive  
Suite 350  
Smyrna, GA 30080

October 08, 1993  
PACE Project Number: 230923526

Attn: Ms. Joan Hutton

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329504

Date Collected:

09/30/93

Date Received:

10/02/93

Equipment

Parameter

Units

PRI

Blank

DATE ANALYZED

### ORGANIC ANALYSIS

#### INDIVIDUAL PARAMETERS

1,2-Dichloroethane  
504-1,2-Dibromoethane  
Methyl Tert-Butyl Ether

ug/L

1.0

ND

10/07/93

ug/L

0.02

ND

10/08/93

ug/L

5.0

ND

10/07/93

**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 2

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329520

Date Collected:

09/30/93

Date Received:

10/02/93

Client Sample ID:

Trip Blank

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

1,2-Dichloroethane

ug/L

1.0

ND

10/07/93

504-1,2-Dibromoethane

ug/L

0.02

ND

10/08/93

Methyl Tert-Butyl Ether

ug/L

5.0

ND

10/07/93

## REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 3

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329431

Date Collected:

09/30/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-1

Parameter

Units

PRI

DATE ANALYZED

### ORGANIC ANALYSIS

#### INDIVIDUAL PARAMETERS

|                         |      |      |    |          |
|-------------------------|------|------|----|----------|
| 1,2-Dichloroethane      | ug/L | 1.0  | ND | 10/06/93 |
| 504-1,2-Dibromoethane   | ug/L | 0.02 | ND | 10/08/93 |
| Methyl Tert-Butyl Ether | ug/L | 5.0  | ND | 10/06/93 |

**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 4

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329440

Date Collected:

09/30/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-2

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

1,2-Dichloroethane  
504-1,2-Dibromoethane  
Methyl Tert-Butyl Ether

ug/L

1.0

ND

10/06/93

ug/L

0.02

ND

10/08/93

ug/L

5.0

ND

10/06/93

**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 5

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329458

Date Collected:

09/30/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-3

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

1,2-Dichloroethane  
504-1,2-Dibromoethane  
Methyl Tert-Butyl Ether

ug/L

1.0

ND

10/07/93

ug/L

0.02

ND

10/08/93

ug/L

5.0

ND

10/07/93



**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 6

October 08, 1993  
PACE Project Number: 230925526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329466

Date Collected:

09/30/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-4

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

1,2-Dichloroethane

ug/L

1.0

ND

10/07/93

504-1,2-Dibromoethane

ug/L

0.02

ND

10/08/93

Methyl Tert-Butyl Ether

ug/L

5.0

ND

10/07/93

**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 7

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329474

Date Collected:

10/01/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-5

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

1,2-Dichloroethane

ug/L

1.0

ND

10/07/93

504-1,2-Dibromoethane

ug/L

0.02

ND

10/08/93

Methyl Tert-Butyl Ether

ug/L

5.0

ND

10/07/93

**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 8

October 08, 1993  
PACE Project Number: 230924526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329482

Date Collected:

10/01/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-6

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

1,2-Dichloroethane  
504-1,2-Dibromoethane  
Methyl Tert-Butyl Ether

ug/L

1.0

ND

10/07/93

ug/L

0.02

ND

10/08/93

ug/L

5.0

ND

10/07/93

## REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 9

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329490

Date Collected:

10/01/93

Date Received:

10/02/93

Client Sample ID:

EPA 83-7

Parameter

Units

PRI

DATE ANALYZED

### ORGANIC ANALYSIS

#### INDIVIDUAL PARAMETERS

|                         |      |      |    |          |
|-------------------------|------|------|----|----------|
| 1,2-Dichloroethane      | ug/L | 1.0  | ND | 10/08/93 |
| 504-1,2-Dibromoethane   | ug/L | 0.02 | ND | 10/08/93 |
| Methyl Tert-Butyl Ether | ug/L | 5.0  | ND | 10/08/93 |

**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 10

October 08, 1993  
PACE Project Number: 230925526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

PACE Sample Number:

90 0329512

Date Collected:

09/30/93

Date Received:

10/02/93

Client Sample ID:

Duplicate

Parameter

Units

PRI

DATE ANALYZED

ORGANIC ANALYSIS

INDIVIDUAL PARAMETERS

|                         |      |      |        |          |
|-------------------------|------|------|--------|----------|
| 1,2-Dichloroethane      | ug/L | 5.0  | ND (1) | 10/08/93 |
| 504-1,2-Dibromoethane   | ug/L | 0.02 | ND     | 10/08/93 |
| Methyl Tert-Butyl Ether | ug/L | 25   | ND (1) | 10/08/93 |

These data have been reviewed and are approved for release.



Michael W. Palmer  
Manager, Organic Chemistry

Ms. Joan Hutton  
Page 11

FOOTNOTES  
for pages 1 through 10

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

ND Not detected at or above the PRL.  
PRL PACE Reporting Limit  
(1) Sample diluted due to the presence of elevated concentrations of target/ non-target compounds.

# REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 12

QUALITY CONTROL DATA

October 08, 1993  
PACE Project Number: 230925526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

1,2-Dichloroethane

Batch: 90 45437

Samples: 90 0329431, 90 0329440, 90 0329458, 90 0329466, 90 0329474

## METHOD BLANK:

| <u>Parameter</u>   | <u>Units</u> | <u>PRL</u> | <u>Method Blank</u> |
|--------------------|--------------|------------|---------------------|
| 1,2-Dichloroethane | ug/L         | 1.0        | ND                  |

## SPIKE AND SPIKE DUPLICATE:

| <u>Parameter</u>   | <u>Units</u> | <u>PRL</u> | 900329431<br><u>FPA 83-1</u> | <u>Spike</u> | <u>Spike Recv</u> | <u>Dupl Recv</u> | <u>RPD</u> |
|--------------------|--------------|------------|------------------------------|--------------|-------------------|------------------|------------|
| 1,2-Dichloroethane | ug/L         | 1.0        | ND                           | 20           | 120%              | 130%             | 8%         |

## LABORATORY CONTROL SAMPLE:

| <u>Parameter</u>   | <u>Units</u> | <u>PRL</u> | <u>Reference Value</u> | <u>Recv</u> |
|--------------------|--------------|------------|------------------------|-------------|
| 1,2-Dichloroethane | ug/L         | 1.0        | 20                     | 125%        |

# REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 13

QUALITY CONTROL DATA

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

1,2-Dichloroethane

Batch: 90 45483

Samples: 90 0329482, 90 0329490, 90 0329504, 90 0329512, 90 0329520

## METHOD BLANK:

| <u>Parameter</u>   | <u>Units</u> | <u>PRL</u> | <u>Method</u>      |
|--------------------|--------------|------------|--------------------|
| 1,2-Dichloroethane | ug/L         | 1.0        | <u>Blank</u><br>ND |

## SPIKE AND SPIKE DUPLICATE:

| <u>Parameter</u>   | <u>Units</u> | <u>PRL</u> | 900329482<br><u>EPA 83-6</u> | <u>Spike</u> | Spike<br><u>Recv</u> | Dupl<br><u>Recv</u> | <u>RPD</u> |
|--------------------|--------------|------------|------------------------------|--------------|----------------------|---------------------|------------|
| 1,2-Dichloroethane | ug/L         | 1.0        | ND                           | 20           | 110%                 | 120%                | 9%         |

## LABORATORY CONTROL SAMPLE:

| <u>Parameter</u>   | <u>Units</u> | <u>PRL</u> | Reference<br><u>Value</u> | <u>Recv</u> |
|--------------------|--------------|------------|---------------------------|-------------|
| 1,2-Dichloroethane | ug/L         | 1.0        | 20                        | 120%        |



**REPORT OF LABORATORY ANALYSIS**

Ms. Joan Hutton  
Page 14

QUALITY CONTROL DATA

October 08, 1993  
PACE Project Number: 230925526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

504-1,2-Dibromoethane

Batch: 90 45471

Samples: 90 0329431, 90 0329440, 90 0329458, 90 0329466, 90 0329474  
90 0329482, 90 0329490, 90 0329504, 90 0329512, 90 0329520

METHOD BLANK:

| <u>Parameter</u>      | <u>Units</u> | <u>PRL</u> | <u>Method</u><br><u>Blank</u> |
|-----------------------|--------------|------------|-------------------------------|
| 504-1,2-Dibromoethane | ug/L         | 0.02       | ND                            |

LABORATORY CONTROL SAMPLE:

| <u>Parameter</u>      | <u>Units</u> | <u>PRL</u> | <u>Reference</u><br><u>Value</u> | <u>Recy</u> |
|-----------------------|--------------|------------|----------------------------------|-------------|
| 504-1,2-Dibromoethane | ug/L         | 0.02       | 2.0                              | 90%         |

# REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 15

QUALITY CONTROL DATA

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

Methyl Tert-Butyl Ether

Batch: 90 45436

Samples: 90 0329431, 90 0329440, 90 0329458, 90 0329466, 90 0329474

## METHOD BLANK:

| <u>Parameter</u>        | <u>Units</u> | <u>PRI</u> | <u>Method</u><br><u>Blank</u> |
|-------------------------|--------------|------------|-------------------------------|
| Methyl Tert-Butyl Ether | ug/L         | 5.0        | ND                            |

## SPIKE AND SPIKE DUPLICATE:

| <u>Parameter</u>        | <u>Units</u> | <u>PRI</u> | 900329440<br><u>EPA 83-2</u> | <u>Spike</u> | Spike<br><u>Recv</u> | Spike<br><u>Dupl</u><br><u>Recv</u> | <u>RPD</u> |
|-------------------------|--------------|------------|------------------------------|--------------|----------------------|-------------------------------------|------------|
| Methyl Tert-Butyl Ether | ug/L         | 5.0        | ND                           | 20           | 80%                  | 85%                                 | 6%         |

## LABORATORY CONTROL SAMPLE:

| <u>Parameter</u>        | <u>Units</u> | <u>PRI</u> | Reference<br><u>Value</u> | <u>Recv</u> |
|-------------------------|--------------|------------|---------------------------|-------------|
| Methyl Tert-Butyl Ether | ug/L         | 5.0        | 20                        | 80%         |

# REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 16

QUALITY CONTROL DATA

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

Methyl Tert-Butyl Ether

Batch: 90 45484

Samples: 90 0329482, 90 0329490, 90 0329504, 90 0329512, 90 0329520

## METHOD BLANK:

| <u>Parameter</u>        | <u>Units</u> | <u>PRL</u> | <u>Method</u> |
|-------------------------|--------------|------------|---------------|
| Methyl Tert-Butyl Ether | ug/L         | 5.0        | Blank<br>ND   |

## SPIKE AND SPIKE DUPLICATE:

| <u>Parameter</u>        | <u>Units</u> | <u>PRL</u> | <u>900327552</u> | <u>Spike</u> | <u>Spike</u><br><u>Recv</u> | <u>Dupl</u><br><u>Recv</u> | <u>RPD</u><br><u>7%</u> |
|-------------------------|--------------|------------|------------------|--------------|-----------------------------|----------------------------|-------------------------|
| Methyl Tert-Butyl Ether | ug/L         | 5.0        | ND               | 20           | 75%                         | 70%                        | 7%                      |

## LABORATORY CONTROL SAMPLE:

| <u>Parameter</u>        | <u>Units</u> | <u>PRL</u> | <u>Reference</u><br><u>Value</u> | <u>Recv</u> |
|-------------------------|--------------|------------|----------------------------------|-------------|
| Methyl Tert-Butyl Ether | ug/L         | 5.0        | 20                               | 75%         |

## REPORT OF LABORATORY ANALYSIS

Ms. Joan Hutton  
Page 17

FOOTNOTES  
for pages 12 through 16

October 08, 1993  
PACE Project Number: 230923526

Client Reference: 11206.55/0603 Eglin AFB Initial SS-36POL

ND Not detected at or above the PRL.  
PRL PACE Reporting Limit  
RPD Relative Percent Difference



220803104-005

1288

CHAIN-OF-CUSTODY RECORD  
Analytical Request

Client EA ENG.  
Address 1400 Lakehurst Dr Ste 350  
Wilmington, CA 90780  
Phone 415 438-9894

Report To: Jean Hutton  
Bill To: \_\_\_\_\_  
P.O. # / Billing Reference EA11206155-0603  
Project Name / No Elgin AFB Init 55-36

Pace Client No. 900055  
Pace Project Manager ECF  
Pace Project No. 230923.526

\*Requested Due Date: \_\_\_\_\_

| ITEM NO. | SAMPLE DESCRIPTION | TIME    | MATRIX | PAGE NO. | PRESERVATIVES |                                |                  |     | ANALYSES REQUEST | REMARKS |
|----------|--------------------|---------|--------|----------|---------------|--------------------------------|------------------|-----|------------------|---------|
|          |                    |         |        |          | UNPRESERVED   | H <sub>2</sub> SO <sub>4</sub> | HNO <sub>3</sub> | VOA |                  |         |
| 1        | EP83-1             | 7/30/93 | GW     |          |               |                                |                  |     | J                | 32943.1 |
| 2        | EP83-2             | 9/30/93 |        |          |               |                                |                  |     | J                | 32944.0 |
| 3        | EP83-3             | 9/30/93 |        |          |               |                                |                  |     | J                | 32945.8 |
| 4        | EP83-4             | 9/30/93 |        |          |               |                                |                  |     | J                | 32946.6 |
| 5        | EP83-5             | 10/1/93 |        |          |               |                                |                  |     | J                | 32947.4 |
| 6        | EP83-6             | 10/1/93 |        |          |               |                                |                  |     | J                | 32948.2 |
| 7        | EP83-7             | 10/1/93 |        |          |               |                                |                  |     | J                | 32949.0 |
| 8        | EP83-8             | 9/30/93 |        |          |               |                                |                  |     | J                | 32950.4 |

| COOLER NOS. | BAILERS | SHIPMENT METHOD |                 | ITEM NUMBER | RELINQUISHED BY / AFFILIATION | ACCEPTED BY / AFFILIATION | DATE | TIME |
|-------------|---------|-----------------|-----------------|-------------|-------------------------------|---------------------------|------|------|
|             |         | OUT / DATE      | RETURNED / DATE |             |                               |                           |      |      |
| 93017       | 0       |                 |                 | 1-8 of 10   |                               |                           |      |      |

Additional Comments  
115-315

Vial lot # B3183030



EA ENGINEERING,  
SCIENCE, AND  
TECHNOLOGY, INC.

Southeast Regional Operations  
1900 Lake Park Drive, Suite 350  
Smyrna, Georgia 30080  
(404) 438-9894

# LETTER OF TRANSMITTAL

ATLANTA • BALTIMORE • CHICAGO • CINCINNATI • LINCOLN • NEW YORK • SAN FRANCISCO

TO Todd H. Wiedemeier  
Engineering-Science, Inc.  
1700 Broadway, Suite 900  
Denver, Colorado 80290

|                    |                     |
|--------------------|---------------------|
| DATE<br>8 Nov 1993 | JOB NO.<br>11206.55 |
| ATTENTION          |                     |
| RE:<br>SS-36, POL  |                     |
| Eglin AFB          |                     |
|                    |                     |
|                    |                     |
|                    |                     |
|                    |                     |

GENTLEMEN:

WE ARE SENDING YOU ☒ Attached ☐ Under separate cover via \_\_\_\_\_ the following items:

☐ Shop drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications

☐ Copy of letter ☐ Change order ☐ \_\_\_\_\_

| COPIES | DATE     | NO. | DESCRIPTION                                                                                   |
|--------|----------|-----|-----------------------------------------------------------------------------------------------|
| 1      | 10/30/93 |     | EA Laboratories, Inc. Report No. 931460 for 8 water samples collected on 9/30-10/1/93 at POL. |
| 1      |          |     | Field Notes                                                                                   |
|        |          |     |                                                                                               |
|        |          |     |                                                                                               |
|        |          |     |                                                                                               |
|        |          |     |                                                                                               |
|        |          |     |                                                                                               |
|        |          |     |                                                                                               |

THESE ARE TRANSMITTED as checked below:

☐ For approval ☐ Approved as submitted ☐ Resubmit \_\_\_\_\_ copies for approval

☒ For your use ☐ Approved as noted ☐ Submit \_\_\_\_\_ copies for distribution

☐ As requested ☐ Returned for corrections ☐ Return \_\_\_\_\_ corrected prints

☐ For review and comment ☐ \_\_\_\_\_

☐ FOR BIDS DUE \_\_\_\_\_ 19\_\_\_\_ ☐ PRINTS RETURNED AFTER LOAN TO US

REMARKS Todd -- Holler if we can be of further assistance.

Joan

Identification of Duplicate Soil/Water Samples:

Dupe-groundwater = EPA 83-2

Dupe-soil = EPA 83-7 (2.5-3 ft)

COPY TO \_\_\_\_\_

SIGNED Joan Fulton

EA 0110 4/23/85

If enclosures are not as noted, kindly notify us at once.

**EA Laboratories**

A Division of EA Engineering,  
Science, and Technology, Inc.

EA Laboratories  
19 Loveton Circle  
Sparks, MD 21152  
Telephone: 410-771-4920  
800-677-0706  
Fax: 410-771-4407



October 30, 1993

Ms. Joan Hutton  
EA Engineering, Science, and Technology, Inc.  
1900 Lake Park Drive, Suite 350  
Smyrna, GA 30080

**RECEIVED**

NOV 2 1993

EA Engineering, Science, and Technology  
Smyrna, GA

Re: Eglin AFB - SS 36- POL (11206.55)

Dear Ms. Hutton:

Enclosed is our report on the analysis of eight water samples and one equipment blank collected at the SS 36 - POL site for Eglin AFB on 30 September and 1 October 1993. The invoice is included.

Please contact me if you have any questions or require further information and refer to report 931460. Unless other arrangements are made, we reserve the right to dispose of your samples thirty (30) days from the date of this letter. We will retain the raw data for seven years from this date.

Sincerely,

A handwritten signature in cursive script that reads 'Joanne E. Heffleger'.

Joanne E. Heffleger  
Laboratory Project Manager

enclosure

**LABORATORY DATA REPORT**

**Prepared for:**

**EA Engineering, Science, and Technology, Inc.  
Eglin AFB**

**Prepared by:**

**EA Laboratories  
19 Loveton Circle  
Sparks, Maryland 21152**

**October 1993**



EA Laboratories  
ANALYTICAL NARRATIVE

Client: Eglin AFB  
Site: SS 36 - POL  
Project number: 11206.55

Laboratory Project Manager: Joanne E. Heffleger  
EA Laboratories Report: 931460  
Date: 1 November 1993

---

This report contains the results of the analysis of eight water samples and one equipment blank collected on 30 September and 1 October 1993 in support of the above referenced project. The samples and blank arrived by Federal Express at EA Laboratories on 2 October 1993. Upon receipt at the laboratory the samples and blank were inspected, compared with the chain of custody record, logged into the Laboratory Information Management System (LIMS) with assigned laboratory accession numbers and released for analysis.

| <u>CLIENT SAMPLE NAME</u> | <u>EA LAB NUMBER</u> |
|---------------------------|----------------------|
| EQB                       | 11458                |
| EPA 83-1                  | 11459                |
| DUPE 1                    | 11460                |
| EPA 83-2                  | 11461                |
| EPA 83-4                  | 11462                |
| EPA 83 3                  | 11463                |
| EPA 83 5                  | 11464                |
| EPA 83 6                  | 11465                |
| EPA 83 7                  | 11466                |

Table 1 lists the approved methods. Results are included in Tables 2 and 3, and in the summary forms which follow.

**Quality Control**

This section summarizes the general quality control activities performed by the laboratory which relate to laboratory method performance, sample matrix effects, and field quality control samples. Quality control samples specified by the project and in the analytical methods are analyzed and reported as required, and the data are validated by analyst, staff, and supervisor review.

EA Laboratories  
ANALYTICAL NARRATIVE

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Laboratory method performance: All quality control criteria for method performance must be met for data to be reported. These criteria generally apply to instrument tune, calibration, method blanks, and Laboratory Control Samples (LCS).

Sample matrix effects: Quality control samples are analyzed to determine any measurement bias due to the sample, and may include matrix spikes (MS), matrix spike duplicates (MSD), and laboratory duplicates (D). If criteria are not met, matrix interferences are confirmed either by reanalysis or by inspection of the LCS results to verify that laboratory method performance is in control. Data are reported with appropriate qualifiers or discussion.

Field quality control samples: Field duplicates, trip blanks, and rinsate blanks are used to evaluate information on field quality control activities. Unless specific laboratory performance criteria and corrective actions are identified in the project requirements, the laboratory treats these as any other field sample, and results are reported after routine laboratory data validation.

Volatiles - 8020

Sample EPA 83 7 (EA#11466) had high surrogate recovery above the QC limit. The sample required a 5X dilution and the surrogate was within QC limits demonstrating a matrix effect that was diluted out. This does not affect data usability.

Samples DUPE-1 (EA#11460) and EPA 83 7 (EA#11466) had corrupted electronic files therefore the chromatograms for these analyses could not be produced. These samples required

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dilutions and those chromatograms are present.

Semivolatiles

The recovery of surrogate nitrobenzene-d5 in samples EPA 83-7 (EA#11466) and EPA 83-7MS was greater than the upper QC limit of 114%. The recoveries were 125% and 130%. The recovery of surrogate 2-fluorophenol in samples EPA 83-7, EPA 83-7MS, and EPA 83-7MSD was greater than the upper QC limit of 110%. The recoveries were 191%, 159%, and 119%. The recovery of surrogate terphenyl-d14 in samples EPA 83-1 (EA#11459), DUPE 1 (EA#11460), and EPA 83-2 (EA#11461) was less than the lower QC limit of 33%. The recoveries were 23%, 32%, and 31%. The recovery of surrogate phenol-d5 in samples EPA 83-2 (EA#11461) and EPA 83-4 (EA#11462) was greater than the upper QC limit of 94%. The recoveries were 100% and 97%. The recoveries in the method blank and LCS were within QC limits indicating acceptable method performance.

The recoveries of the spike compounds acenaphthene (144%), 4-nitrophenol (274%), and 2,4-dinitrotoluene (159%) were greater than the upper QC limits of 188%, 80%, and 96%. The recoveries of the spike compounds acenaphthene (120%), 4-nitrophenol (189%), and 2,4-dinitrotoluene (126%) were greater than the upper QC limits of 188%, 80%, and 96%. All RPDS were within QC limits. The LCS recoveries were within QC limits indicating acceptable method performance.

EA Laboratories  
ANALYTICAL NARRATIVE

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Project number: 11206.55

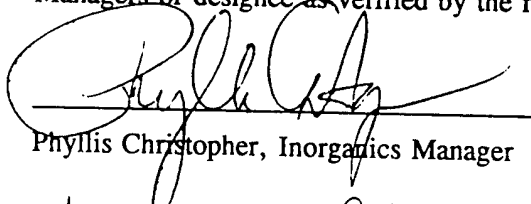
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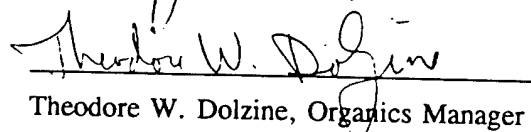
Certification of Results

The Laboratory certifies that this report meets the project requirements for analytical data as stated in the Analytical Task Order (ATO) and the chain of custody. In addition, the Laboratory certifies that the data as reported meets the Data Quality Objectives for precision, accuracy and completeness specified for this project or as stated in EA Laboratories Quality Assurance program for other than the conditions detailed above.

Release of the data contained in this report has been authorized by the appropriate Laboratory Managers or designee as verified by the following signatures.

  
Phyllis Christopher, Inorganics Manager

1 November 1993

  
Theodore W. Dolzine, Organics Manager

1 November 1993

TABLE 1. ANALYTICAL METHODS

Page 1 of 1

| Parameter                                  | Method                               | Method Number | Matrix | Reference |
|--------------------------------------------|--------------------------------------|---------------|--------|-----------|
| SAMPLE PREPARATION                         |                                      |               |        |           |
| Total Metals Digestion                     | Nitric Acid - Hydrochloric Acid      | 200.0         | W      | (1)       |
| Semivolatiles Organics Extraction          | Continuous Extraction                | 3520          | W      | (2)       |
| ORGANICS                                   |                                      |               |        |           |
| Acid Extractable Organic Compounds         | Gas Chromatography/Mass Spectrometry | 8270          | W, SO  | (2)       |
| Base-Neutral Extractable Organic Compounds | Gas Chromatography/Mass Spectrometry | 8270          | W, SO  | (2)       |
| Purgeable Aromatics                        | Gas Chromatography - PID             | 8020          | W, SO  | (2)       |
| Purgeable Halocarbons                      | Gas Chromatography - HSD             | 8010          | W, SO  | (2)       |
| Total Petroleum Hydrocarbons               | Spectrophotometric - Infrared        | 418.1         | W      | (1)       |
| METALS                                     |                                      |               |        |           |
| Lead                                       | Atomic Absorption - Furnace          | 239.2         | DW, W  | (1)       |

## Matrix codes:

W - Estuarine water, ground water, leachates, ocean water, surface water, and wastewater

## References:

- (1) United States Environmental Protection Agency. 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. U.S. EPA, Cincinnati, Ohio.
- (2) United States Environmental Protection Agency. 1986. Test Methods for Evaluating Solid Waste. Physical/Chemical Methods. EPA SW-846, 3rd edition. U.S. EPA, Washington, D.C.

TABLE 2.  
RESULTS FOR THE DETERMINATION OF TOTAL  
HYDROCARBONS IN EIGHT WATER SAMPLES AND  
ONE EQUIPMENT BLANK COLLECTED AT THE SS  
36-POL SITE FOR EGLIN AFB  
ON 30 SEPTEMBER AND 1 OCTOBER 1993

| Sample<br>Designation | Hydrocarbons,<br>Total<br>mg/L | Accession<br>Number |
|-----------------------|--------------------------------|---------------------|
| EQB                   | <0.60                          | 11458               |
| ERA 83 1              | 2.2                            | 11459               |
| DUPE 1                | 7.8                            | 11460               |
| EPA 83 2              | 6.1                            | 11461               |
| EPA 83 4              | 2.5                            | 11462               |
| EPA 83 2              | 1.3                            | 11463               |
| EPA 83 5              | <0.60                          | 11464               |
| EPA 83 6              | 0.68                           | 11465               |
| EPA 83 7              | 4.4                            | 11466               |

TABLE 3.  
RESULTS FOR THE DETERMINATION  
OF LEAD IN EIGHT WATER SAMPLES  
AND ONE EQUIPMENT BLANK  
COLLECTED AT EGLIN AFB ON 30  
SEPTEMBER AND 1 OCTOBER 1993

| Sample<br>Designation | Lead,<br>Total<br>ug/L | Accession<br>Number |
|-----------------------|------------------------|---------------------|
| EQB                   | <1.0                   | 11458               |
| ERA 83 1              | 1.0                    | 11459               |
| DUPE 1                | 1.8                    | 11460               |
| EPA 83 2              | <1.0                   | 11461               |
| EPA 83 4              | <1.0                   | 11462               |
| EPA 83 2              | <1.0                   | 11463               |
| EPA 83 5              | <1.0                   | 11464               |
| EPA 83 6              | <1.0                   | 11465               |
| EPA 83 7              | <1.0                   | 11466               |

[illegible]



## **APPENDIX C**

### **NATURAL ATTENUATION CALCULATIONS**

## C.1 CALCULATION OF RETARDATION COEFFICIENTS

The coefficient of retardation,  $R$ , is used to estimate the retarded contaminant velocity. The coefficient of retardation is determined from the distribution coefficient using the relationship:

$$R = 1 + \frac{\rho_b K_d}{n_e} \quad (\text{C.1.1})$$

Where:  $R$  = coefficient of retardation  
 $\rho_b$  = bulk density of aquifer  
 $K_d$  = distribution coefficient  
 $n_e$  = effective porosity

The retarded contaminant transport velocity,  $v_c$ , is given by:

$$v_c = \frac{v_x}{R} \quad (\text{C.1.2})$$

Where:  $v_c$  = retarded contaminant transport velocity  
 $v_x$  = advective groundwater velocity  
 $R$  = coefficient of retardation

Two methods are generally used to quantify the distribution coefficient and amount of sorption (and thus retardation) for a given aquifer/contaminant system. The first method involves estimating the distribution coefficient by using  $K_{oc}$  for the contaminants and the fraction of organic carbon comprising the aquifer matrix. The second method involves conducting batch or column tests to determine the distribution coefficient. For a study such as this, the first method is the only practical and cost-effective means.

Sorption is strongly dependent on the amount of organic carbon present in the aquifer matrix and the degree of hydrophobicity exhibited by the contaminant (Bailey and White, 1970; Karickhoff *et al.*, 1979; Kenaga and Goring, 1980; Brown and Flagg, 1981; Schwarzenbach and Westall, 1981; Hassett *et al.*, 1983; Chiou *et al.*, 1983). These researchers observed that the distribution coefficient,  $K_d$ , was proportional to the organic carbon fraction of the aquifer times a proportionality constant,  $K_{oc}$ , which effectively normalizes the distribution coefficient to the amount of organic carbon in the aquifer matrix. Because it is normalized to organic carbon, values of  $K_{oc}$  are dependent only on

the properties of the compound (not on the type of soil). Values of  $K_{oc}$  have been determined for a wide range of chemicals, including the BTEX compounds.

By knowing the value of  $K_{oc}$  for a contaminant and the fraction of organic carbon present in the aquifer ( $f_{oc}$ ), the distribution coefficient can be determined by using the relationship:

$$K_d = K_{oc} f_{oc} \quad (C.1.3)$$

Total organic carbon (TOC) concentrations in aquifer soil samples are used to estimate the amount of organic matter sorbed on soil particles or trapped in the interstitial passages of a soil matrix (i.e., to estimate  $f_{oc}$ ).

Although no soil TOC data were collected at this site, data from the technical literature and from another study performed in a similar geologic environment can be used to estimate a range of TOC concentrations that can be used for evaluation of sorption at the study site. Wiedemeier et al. (1995) summarize TOC data from multiple sources. For sediments similar to those observed at this site, TOC contents range from 0.026 to 0.7 percent; however, where peat or other organic matter is present, TOC concentrations may be as high as 25 percent. Soil TOC data were collected during an intrinsic remediation study at a site at Patrick AFB, Florida (Engineering-Science, Inc., 1994). Aquifer materials at that site were very similar to those in this study site, consisting of sand with interbedded peat units and interspersed organic matter deposited in a nearshore or onshore environment. At the Patrick AFB site, TOC concentrations ranged from 0.016 to 1.86 percent.

Retardation coefficients were calculated using these data and the relationships described above. Results of these calculations are presented in Table C.1. For these calculations, it was assumed that the effective porosity of the aquifer is 0.30, and that the bulk density of the aquifer matrix is 1.6 kilograms per liter (kg/L). It was also assumed that TOC concentrations ranged from 0.026 percent to 0.7 percent. This range was selected because it comes from the literature and it falls within the range of values observed at Patrick AFB. As indicated on Table C.1, calculated retardation coefficients for the study site range from 1.11 to 18.47.

TABLE C.1

CALCULATION OF RETARDATION COEFFICIENTS  
POL SITE SS-36  
INTRINSIC REMEDIATION  
EGLIN AFB, FLORIDA

| Compound     | $K_{oc}$<br>(L/kg <sup>a/</sup> ) | Maximum<br>Fraction<br>Organic<br>Carbon <sup>b/</sup> | Minimum<br>Fraction<br>Organic<br>Carbon <sup>b/</sup> | Average<br>Fraction<br>Organic<br>Carbon <sup>b/</sup> | Distribution Coefficient<br>$K_d$ (L/kg) |                        |                        | Bulk<br>Density<br>(kg/L) <sup>d/</sup> | Effective<br>Porosity <sup>a/</sup> | Coefficient of<br>Retardation |         |
|--------------|-----------------------------------|--------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|------------------------------------------|------------------------|------------------------|-----------------------------------------|-------------------------------------|-------------------------------|---------|
|              |                                   |                                                        |                                                        |                                                        | Maximum <sup>c1/</sup>                   | Minimum <sup>c2/</sup> | Average <sup>c3/</sup> |                                         |                                     | Maximum                       | Average |
| Benzene      | 79                                | 0.007                                                  | 0.00026                                                | 0.001                                                  | 0.553                                    | 0.021                  | 0.079                  | 1.60                                    | 0.30                                | 3.95                          | 1.11    |
| Toluene      | 190                               | 0.007                                                  | 0.00026                                                | 0.001                                                  | 1.330                                    | 0.049                  | 0.190                  | 1.60                                    | 0.30                                | 8.09                          | 1.26    |
| Ethylbenzene | 468                               | 0.007                                                  | 0.00026                                                | 0.001                                                  | 3.276                                    | 0.122                  | 0.468                  | 1.60                                    | 0.30                                | 18.47                         | 1.65    |
| m-xylene     | 405                               | 0.007                                                  | 0.00026                                                | 0.001                                                  | 2.835                                    | 0.105                  | 0.405                  | 1.60                                    | 0.30                                | 16.12                         | 1.56    |
| o-xylene     | 422                               | 0.007                                                  | 0.00026                                                | 0.001                                                  | 2.954                                    | 0.110                  | 0.422                  | 1.60                                    | 0.30                                | 16.75                         | 1.59    |
| p-xylene     | 357                               | 0.007                                                  | 0.00026                                                | 0.001                                                  | 2.499                                    | 0.093                  | 0.357                  | 1.60                                    | 0.30                                | 14.33                         | 1.50    |

## NOTES:

<sup>a/</sup> From technical protocol (Wiedemeier *et al.*, 1995)<sup>b/</sup> Taken from data summarized in technical protocol (Wiedemeier *et al.*, 1995)<sup>c1/</sup>  $K_d$  = Maximum Fraction Organic Carbon x  $K_{oc}$ <sup>c2/</sup>  $K_d$  = Minimum Fraction Organic Carbon x  $K_{oc}$ <sup>c3/</sup>  $K_d$  = Average Fraction Organic Carbon x  $K_{oc}$ <sup>d/</sup> Literature values

## C.2 CALCULATION OF BIODEGRADATION RATES

In order to ensure that observed decreases in contaminant concentrations can be attributed to biodegradation, measured concentrations of the BTEX compounds must be corrected for the effects of dispersion, dilution, and sorption. A convenient way of doing this is to use compounds present in the dissolved BTEX plume that have a Henry's law constants and soil sorption coefficients that are similar to those of BTEX and that are recalcitrant under anaerobic conditions. One such compound that is useful in some, but not all, groundwater environments is trimethylbenzene (TMB). The three isomers of this compound (1,2,3-TMB, 1,2,4-TMB, and 1,3,5-TMB) have Henry's Law constants and soil sorption coefficients that 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 groundwater and are fairly recalcitrant under anaerobic conditions. The degree of recalcitrance of TMB is site-specific and the use of this compound as a conservative tracer must be evaluated on a case-by-case basis.

The corrected concentration of a compound is the concentration of the compound that would be expected at one point (B) located downgradient from another point (A) after correcting for the effects of dispersion, dilution, and sorption between points A and B. One relationship that can be used to calculate the corrected contaminant concentration is:

$$C_{B,Corr} = C_B \left( \frac{TMB_A}{TMB_B} \right) \quad (C.2.1)$$

Where  $C_{B,Corr}$  = corrected concentration of compound of interest at Point B  
 $C_B$  = measured concentration of compound of interest at Point B  
 $TMB_A$  = measured concentration of trimethylbenzene at Point A  
 $TMB_B$  = measured concentration of trimethylbenzene 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 generally is not entirely recalcitrant under anaerobic conditions, and appears to degrade rapidly under aerobic conditions. The degree of recalcitrance of TMB is site-specific and the use of this compound must be evaluated on a case-by-case basis. However, if any TMB mass is lost to the processes of biodegradation or preferential sorption, this

equation becomes more conservative (i.e., lower mass losses due to biodegradation and lower biodegradation rate constants will be calculated).

As with a large number of biological processes, anaerobic biodegradation can generally be described using a first-order rate constant. In one dimension, first order decay is described by the following ordinary differential equation:

$$\frac{dC}{dt} = -\lambda C \quad (\text{C.2.2})$$

Where:  $C$  = concentration at time  $t$  [M/L<sup>3</sup>]

$\lambda$  = coefficient of anaerobic decay (first order rate constant) [1/T]

Solving this differential equation yields:

$$C = C_0 e^{-\lambda t} \quad (\text{C.2.3})$$

Table C.2 lists representative first-order decay rate constants.

**Table C.2**  
Representative First-Order Rate Constants

| Reference                        | Anaerobic Decay Rate (week <sup>-1</sup> ) |
|----------------------------------|--------------------------------------------|
| Chapelle (1994)                  | 0.07 <sup>a/</sup>                         |
| Buscheck <i>et al.</i> (1993)    | 0.007 to 0.07 <sup>a/</sup>                |
| Wiedemeier <i>et al.</i> (1995a) | 0.07 to 0.22 <sup>a/</sup>                 |
| Wiedemeier <i>et al.</i> (1995a) | 0.20 to 0.30 <sup>b/</sup>                 |
| Wiedemeier <i>et al.</i> (1995a) | 0.16 to 0.27 <sup>c/</sup>                 |
| Wiedemeier <i>et al.</i> (1995a) | 0.06 to 0.20 <sup>d/</sup>                 |
| Wiedemeier <i>et al.</i> (1995a) | 0.04 to 0.20 <sup>e/</sup>                 |
| Stauffer <i>et al.</i> (1994)    | 0.07 <sup>b/</sup> to 0.13 <sup>e/</sup>   |
| MacIntyre <i>et al.</i> (1994)   | 0.07 to 0.14 <sup>f/</sup>                 |
| MacIntyre <i>et al.</i> (1994)   | 0.049 to 0.084 <sup>b/</sup>               |
| MacIntyre <i>et al.</i> (1994)   | 0.044 to 0.083 <sup>f/</sup>               |

a/ for total BTEX

b/ for benzene

c/ for toluene

d/ ethylbenzene

e/ for xylene

f/ for naphthalene

Three methods for determining first-order biodegradation rates are presented herein. The first method involves the use of a conservative tracer. The second method was derived by Buscheck and Alcantar (1995) and is valid for steady-state plumes. Wiedemeier *et al.* (1995a) compares the use of these two methods. The third method is valid for retreating plumes (i.e., plumes in which concentrations are decreasing).

### Tracer Method

Substituting the TMB-corrected concentration,  $C_{B,corr}$ , at a downgradient point (B) for  $C$  in equation C.2.3, and the measured concentration,  $C_A$ , at an upgradient point (A) for  $C_o$ , this relationship becomes:

$$C_{corr} = C_{o,measured} e^{-\lambda t} \quad (C.2.4)$$

Where:  $C_{corr}$  = TMB-corrected contaminant concentration at time  $t$  at downgradient point  
 $C_{o, measured}$  = measured contaminant concentration at upgradient point  
 $\lambda$  = coefficient of anaerobic decay (first order rate constant) [1/T]

This relationship can be used to calculate the first-order biological decay rate constant between two points. Solving this relationship for  $\lambda$  gives:

$$\lambda = -\frac{\ln\left(\frac{C_{Corr}}{C_{o,measured}}\right)}{t} \quad (C.2.5)$$

The travel time,  $t$ , between two points is given by:

$$t = \frac{x}{v_x} \quad (C.2.6)$$

Where:  $x$  = distance between two points [L]  
 $v_x$  = advective groundwater velocity (or retarded velocity) [L/T]

Another way to determine the first-order rate constant from a set of TMB-corrected data is to make a log-linear plot of TMB-corrected total BTEX concentration (or the TMB-corrected concentration of a specific compound, such as benzene) versus travel time. If the data plot along a straight line, then the relationship is first order and an exponential regression analysis can be performed. The exponential regression analysis

gives the equation of the line of best fit for the data being regressed from a log-linear plot and has the general form:

$$y = be^{mx} \quad (C.2.7)$$

Where:  $y$  = y axis value  
 $b$  = y intercept  
 $m$  = slope of regression line  
 $x$  = x-axis value

When using TMB as a conservative tracer,  $y$  is the contaminant concentration,  $x$  is the downgradient travel time from point (A), and  $m$  is the biodegradation rate constant,  $\lambda$ . The correlation coefficient,  $R^2$ , is a measure of how well the regression relationship approximates the data. Values of  $R^2$  can range from 0 to 1 and the closer  $R^2$  is to 1, the more accurate the equation describing the trend in the data. Values of  $R^2$  greater than 0.80 are generally considered good and  $R^2$  values greater than 0.90 are considered excellent.

TMB-corrected total BTEX concentrations are listed and plotted on Figure C.1. As indicated by the regression, the slope of the line is 0.006, indicating an anaerobic degradation rate of  $0.006 \text{ day}^{-1}$ . For this regression, the  $R^2$  value is 0.86, indicating a very good fit between the equation and the data.

#### Method of Buscheck and Alcantar (1995)

Buscheck and Alcantar (1995) derive a relationship that allows calculation of first-order decay rate constants for steady-state plumes. This method involves coupling the regression of contaminant concentration (plotted on a logarithmic scale) versus distance downgradient (plotted on a linear scale) to an analytical solution for one-dimensional, steady-state, contaminant transport that includes advection, dispersion, sorption, and biodegradation. For a steady-state plume, the first-order decay rate is given by (Buscheck and Alcantar, 1995):

$$\lambda = \frac{v_c}{4\alpha_x} \left( \left[ 1 + 2\alpha_x \left( \frac{k}{v_x} \right) \right]^2 - 1 \right) \quad (C.2.8)$$

Where:  $\lambda$  = first-order decay rate  
 $v_c$  = retarded contaminant velocity in the x-direction  
 $\alpha_x$  = dispersivity

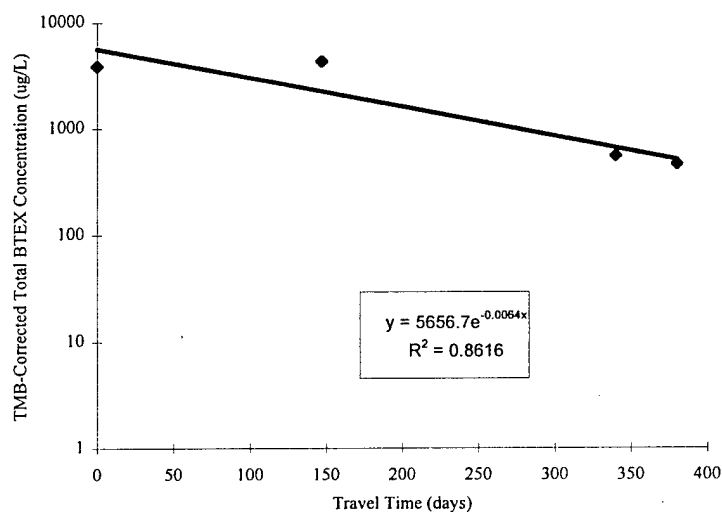


**FIGURE C.1**  
**FIRST-ORDER RATE CONSTANT CALCULATION**  
**USING TMB AS A CONSERVATIVE TRACER**  
**POL SITE SS-36**  
**INTRINSIC REMEDIATION TS**  
**EGLIN AFB, FLORIDA**

| Point  | Distance<br>Downgradient<br>(ft) | Travel Time<br>Between<br>Upgradient and<br>Downgradient<br>Point<br>(days) | Measured<br>Total<br>BTEX<br>Concentration<br>( $\mu\text{g/L}$ ) | Total<br>Trimethylbenzene<br>Concentration<br>( $\mu\text{g/L}$ ) | Trimethylbenzene-<br>Corrected<br>Total BTEX<br>Concentration<br>( $\mu\text{g/L}$ ) |
|--------|----------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| 83-H-1 | 0                                | 0                                                                           | 3863                                                              | 1345                                                              | 3863                                                                                 |
| 83-Z-2 | 103                              | 147                                                                         | 2263                                                              | 716                                                               | 4251                                                                                 |
| 83-R-3 | 238                              | 340                                                                         | 109                                                               | 144                                                               | 542                                                                                  |
| 83-U-3 | 266                              | 380                                                                         | 228                                                               | 358                                                               | 456                                                                                  |

$v_c =$  0.7 ft/day (average for all BTEX compounds)

**PLOT OF TMB-CORRECTED TOTAL BTEX  
CONCENTRATION VERSUS TIME**



$k/v_x$  = slope of line formed by making a log-linear plot of contaminant concentration versus distance downgradient along flow path

The first step is to make sure that the contaminant plume has reached a steady-state configuration. This is done by analyzing historical data to make sure the plume is no longer migrating downgradient and contaminant concentrations are not changing significantly through time. This is generally the case for older spills where the source has not been removed. The next step is to make a log-linear plot of contaminant concentration versus distance downgradient.

Using linear regression, the ratio  $k/v$  is determined and entered into equation C.2.8. Exponential regressions were completed for each of the BTEX compounds and total BTEX along each flow path using the relationship shown in equation C.2.7. When using the method of Buscheck and Alcantar (1995),  $y$  in the regression analysis is the contaminant concentration,  $x$  is the distance downgradient from point (A), and  $m$  is the ratio  $k/v$ . The value of  $k/v$  determined from the regression analysis is entered into equation C.2.8 and the biodegradation rate constant,  $\lambda$ , is calculated.

Data from Site SS-36 were used in this manner to calculate a biodegradation rate constant. Total BTEX data from Geoprobe<sup>®</sup> points 83-H-1, 83-Z-2, 83-R-3, and 83-U-3 (all along a flow path in the plume center) were plotted on a semi-log plot and an exponential regression was performed. This is shown on Figure C.2. After entering the slope of the regression line (as  $k/v_x$ ) into Equation C.2.8, the resulting rate constant was  $0.01 \text{ day}^{-1}$ , or 1 percent per day. The  $R^2$  value for this regression is 0.88, indicating a very good fit between the data and the line.

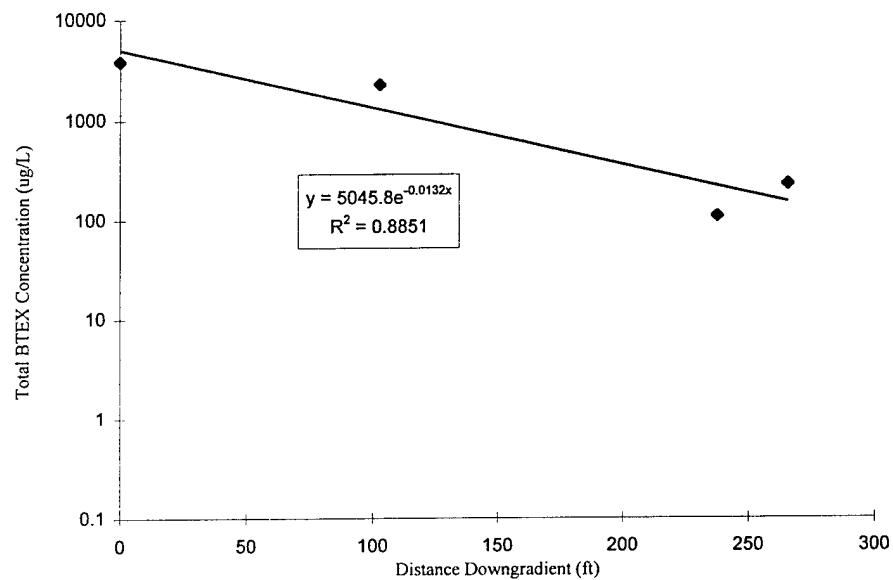
### **Shrinking Plume Method**

It is possible that this plume is not at steady-state conditions. Although the plume was 8 years old when last sampled and the source (i.e., residual LNAPL) remains, it appears the plume may be shrinking, as suggested by Figures 4.4 and 4.5. Buscheck and Alcantar (1995) note that if the plume is shrinking, then the decay rate may simply be calculated by using the relationship shown in Equation C.2.5 above and substituting the initial concentration for  $C_0$ , the concentration measured at a later date for  $C_{\text{corr}}$ , and the time between sampling events for  $t$ . This was done for all the wells at the study site, as shown on Table C.3.

FIGURE C.2  
 FIRST-ORDER RATE CONSTANT CALCULATION  
 USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)  
 POL SITE SS-36  
 INTRINSIC REMEDIATION TS  
 EGLIN AFB, FLORIDA

| Point  | Distance     | BTEX (µg/L) |
|--------|--------------|-------------|
|        | Downgradient | Sep-93      |
| 83-H-1 | 0            | 3863        |
| 83-Z-2 | 103          | 2263        |
| 83-R-3 | 238          | 109         |
| 83-U-3 | 266          | 228         |

PLOT OF TOTAL BTEX CONCENTRATION  
 VERSUS DISTANCE



$$\lambda = v_c / 4\alpha_x ([1 + 2\alpha_x (k/v_x)]^2 - 1)$$

where  $v_c = 0.7$   
 $\alpha_x = 10$   
 $k/v = 0.013$

therefore  $\lambda = 0.010$

**TABLE C.3**  
**CALCULATION OF DECAY RATES**  
**USING THE SHRINKING-PLUME METHOD**  
**POL SITE SS-36**  
**EGLIN AFB, FLORIDA**

| Well         | C(t) [1994]<br>(µg/L) | C <sub>i</sub> [1993]<br>(µg/L) | Time Between<br>Samples (days) | Decay Constant (k)<br>(day <sup>-1</sup> ) |
|--------------|-----------------------|---------------------------------|--------------------------------|--------------------------------------------|
| EPA 83-1     | 44.7                  | 1045                            | 383                            | 0.008                                      |
| EPA83-1(dup) | 44.7                  | 2661                            | 383                            | 0.011                                      |
| EPA 83-2     | 625.3                 | 1792                            | 383                            | 0.003                                      |
| EPA 83-3     | 112.6                 | 56.6                            | 383                            | --                                         |
| EPA 83-4     | 1.4                   | 1.2                             | 383                            | --                                         |
| EPA 83-5     | 1                     | 1.3                             | 382                            | 0.001                                      |
| EPA 83-6     | <1                    | <1                              | 382                            | --                                         |
| EPA 83-7     | 2.9                   | 104.5                           | 382                            | 0.009                                      |

Average 0.008

Assumes first-order decay:  $C(t) = C_i e^{-kt}$   
or  
 $k = -\ln(C(t)/C_i)/t$

where: C(t) = concentration at time t  
C<sub>i</sub> = initial concentration  
t = time interval between measurement of C<sub>i</sub> and C(t)  
k = decay constant

### C.3 PARTITIONING EQUATIONS

LNAPL (mobile or residual) present at a site represents a continuing source of contamination because BTEX and other aromatic compounds will partition from the LNAPL into the groundwater. In such cases, it is generally necessary to estimate the dissolved concentration of BTEX expected in groundwater near the LNAPL. Partitioning calculations can be performed at sites with NAPL to quantify contaminant loading from the NAPL into the groundwater. Such calculations allow estimation of the impact of continuing sources of contamination on dissolved BTEX concentrations. The results of partitioning calculations may show that even if the NAPL is allowed to remain in the ground, dissolved contaminant concentrations will remain below regulatory guidelines. This is especially true when weathered NAPLs are present. Partitioning calculations made by Wiedemeier *et al.* (1993) showed that NAPL present in the subsurface at a fueling facility near Denver, Colorado was incapable of producing dissolved BTEX concentrations in groundwater above regulatory guidelines.

When found in the saturated zone, residual LNAPL is extremely difficult to remove. Maximum BTEX concentrations resulting from such partitioning will occur when the groundwater and LNAPL reach equilibrium. Assuming that equilibrium is reached gives the most conservative modeling results. This procedure is described below.

#### ***Equilibrium Partitioning of BTEX from Mobile LNAPL into Groundwater***

The fuel-water partitioning coefficient,  $K_{fw}$ , is defined as the ratio of the concentration of a compound in the fuel to the compound's equilibrium concentration in water in contact with the fuel.

$$K_{fw} = \frac{C_f}{C_w} \quad (\text{C.3.1})$$

Where:  $K_{fw}$  = fuel-water partitioning coefficient [dimensionless]

$C_f$  = concentration of the compound in the fuel [M/L<sup>3</sup>]

$C_w$  = concentration of the compound dissolved in groundwater [M/L<sup>3</sup>]

Table C.4 lists values of  $K_{fw}$  for BTEX and TMB in jet fuel and gasoline. The relationships relating  $K_{fw}$  to the aqueous solubility of a pure compound in pure water,  $S$ , presented in Table C.5 can be used to estimate  $K_{fw}$  for compounds not listed in this table.

**Table C.4**

Fuel-Water Partitioning Coefficients ( $K_{fw}$ ) for those Compounds most Commonly found in the Aqueous Phase in Water in Contact with Jet Fuel or Gasoline

| Compound               | $K_{fw}^{a/}$<br>(JP-4 Jet Fuel) | $K_{fw}^{b/}$<br>(Gasoline) | $K_{fw}^{c/}$<br>(Gasoline) |
|------------------------|----------------------------------|-----------------------------|-----------------------------|
| Benzene                | 2,455                            | 231                         | 350                         |
| Toluene                | 2,754                            | 895                         | 1,250                       |
| Ethylbenzene           | 4,786                            | 3,411                       | 4,500                       |
| o-xylene               | 7,079                            | 3,162                       | 3,630                       |
| m-xylene               | 3,715                            | 3,539                       | 4,350                       |
| p-xylene               | 7,586                            | 2,961                       | 4,350                       |
| 1,2,3-Trimethylbenzene | NA                               | NA                          | 13,800                      |
| 1,2,4-Trimethylbenzene | 8,913                            | 12,270                      | NA                          |
| 1,3,5-Trimethylbenzene | NA                               | 6,493                       | NA                          |

a/ From experiments conducted by Smith *et al.*, 1981 (For JP-4)

b/ Model of Bruce *et al.*, 1991 (for gasoline)

c/ Model of Cline *et al.*, 1991 (for gasoline)

NA = not analyzed

**Table C.5**

Relationships Relating Fuel-Water Partitioning Coefficients ( $K_{fw}$ ) to Pure Aqueous-Phase Solubility

| LNAPL Type | Relationship Relating $S$ to $K_{fw}^{a/}$ | Reference                  |
|------------|--------------------------------------------|----------------------------|
| JP-4       | $\log K_{fw} = -0.797\log S + 1.681$       | Smith <i>et al.</i> , 1981 |
| JP-5       | $\log K_{fw} = -0.746\log S + 1.757$       | Smith <i>et al.</i> , 1981 |
| JP-8       | $\log K_{fw} = -0.864\log S + 1.508$       | Smith <i>et al.</i> , 1981 |
| Gasoline   | $\log K_{fw} = -1.15\log S + 6.099$        | Bruce <i>et al.</i> , 1991 |
| Gasoline   | $\log K_{fw} = -1.00\log S + 0.85$         | Cline <i>et al.</i> , 1991 |

a/ determined using linear regression on data for dissolved compound concentrations in a fuel-water mix

Using the definition of  $K_{fw}$  presented above, the maximum (equilibrium) total dissolved BTEX concentration resulting from the partitioning of BTEX compounds NAPL into groundwater is given by:

$$C_w = \frac{C_f}{K_{fw}} \quad (C.3.2)$$

This relationship predicts the concentration of dissolved BTEX in the groundwater if the LNAPL is allowed to remain in contact with the groundwater long enough so that equilibrium between the two phases is reached.

To complete partitioning calculations, samples of the residual or mobile LNAPL must be collected and analyzed to determine the type of fuel and the mass fraction of BTEX present in the fuel. From the mass fraction BTEX data, the concentration of each BTEX compound in the fuel on a volumetric basis,  $C_f$ , can be calculated by using the relationship:

$$C_f = F_f \rho_f \quad (C.3.3)$$

Where:  $\rho_f$  = Density of fuel  
 $F_f$  = Mass fraction of compound in the fuel

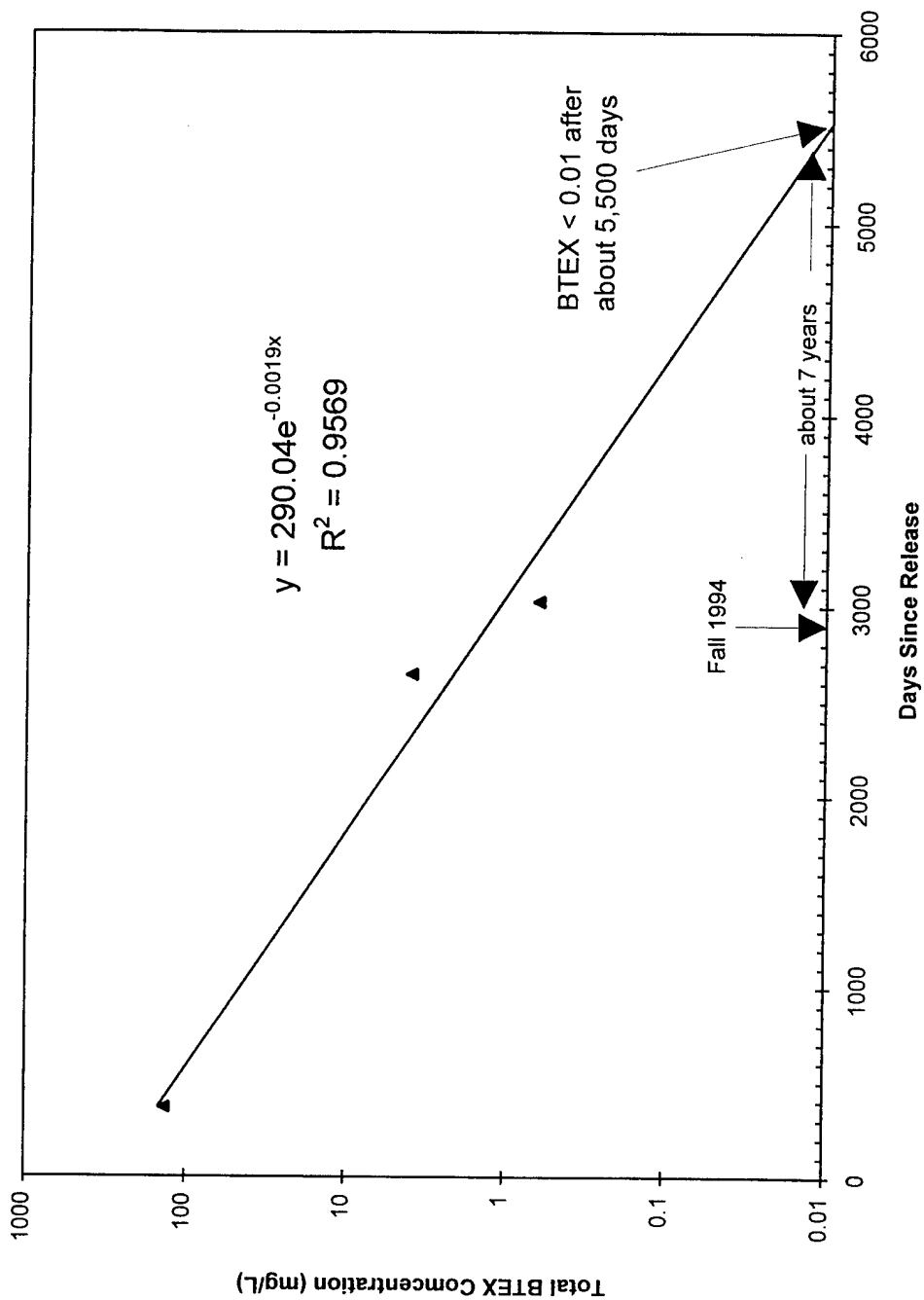
Using mass fraction BTEX data from LNAPL analyses, and the fuel-water partitioning coefficients presented in Table C.4, the maximum dissolved benzene, toluene, ethylbenzene, and total xylene concentrations expected in groundwater caused by the partitioning of these compounds from the LNAPL can be calculated using Equation C.3.2.

**APPENDIX D**

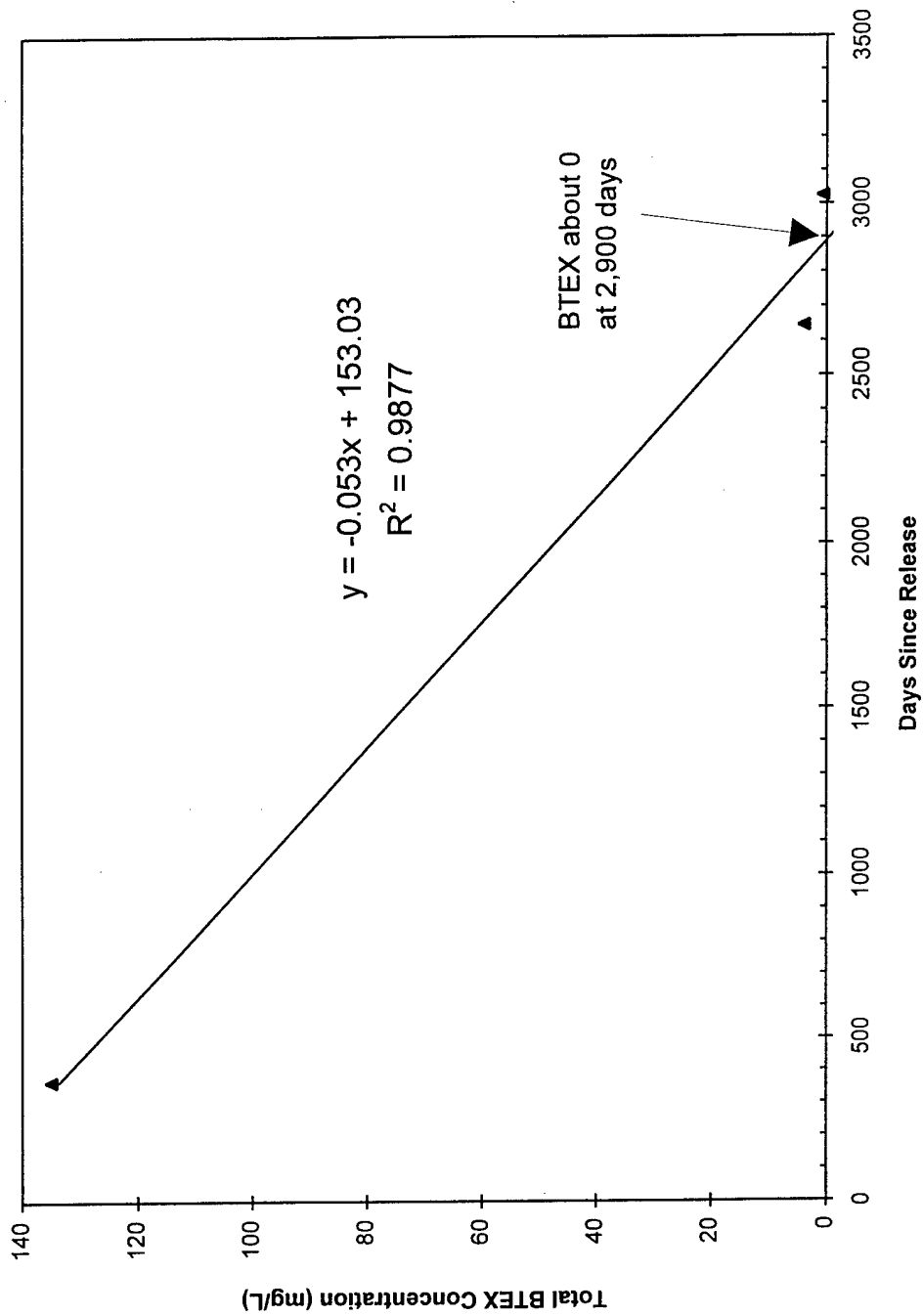
**MODEL INPUT AND OUTPUT FILES, AND  
RELATED CALCULATIONS**



Semi-log Plot of Total Dissolved BTEX vs. Time  
for Locations EPA 83-2 and 83-H-1



Linear Plot of Total Dissolved BTEX vs. Time  
at Locations EPA 83-2 and 83-H-1



RMS Error Calculations for Calibrated Flow Model  
Eglin AFB, POL Site SS-36

| Well/CPT                                                                                    | Cell Location<br>(layer, column) | Measured Head<br>Hm | Simulated Head<br>Hs | Hm - Hs | $(Hm - Hs)^2$ |
|---------------------------------------------------------------------------------------------|----------------------------------|---------------------|----------------------|---------|---------------|
| EPA 83-2                                                                                    | 3,8                              | 7.83                | 7.68                 | 0.1500  | 0.0225        |
| EPA 83-1                                                                                    | 11,8                             | 4.92                | 5.20                 | -0.2800 | 0.0784        |
| EPA 83-7                                                                                    | 4,15                             | 4.19                | 4.67                 | -0.4800 | 0.2304        |
| EPA 83-4                                                                                    | 5,23                             | 1.76                | 2.00                 | -0.2400 | 0.0576        |
| EPA 83-3                                                                                    | 11,23                            | 2.62                | 2.80                 | -0.1800 | 0.0324        |
| Sum of Squares of Remainders                                                                |                                  |                     |                      |         | 0.421         |
| Average of Squares of Remainders                                                            |                                  |                     |                      |         | 0.0843        |
| RMS                                                                                         |                                  |                     |                      |         | 0.2903        |
| RMS as a percentage of the head drop over the model domain<br>(Head Drop is about 8.0 feet) |                                  |                     |                      |         | 3.63          |