
DRAFT

Intrinsic Remediation Engineering Evaluation/Cost Analysis for the Hangar 10 Site



**Elmendorf Air Force Base
Alaska**

Prepared For

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

and

**Elmendorf Air Force Base
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08/08/2000

EXECUTIVE SUMMARY

This report presents the results of an engineering evaluation/cost analysis (EE/CA) performed by Parsons Engineering Science, Inc. (Parsons ES) at Elmendorf Air Force Base, Alaska to evaluate the use of intrinsic remediation (natural attenuation) with long-term monitoring (LTM) as a remedial option for dissolved-phase benzene, toluene, ethylbenzene, and xylene (BTEX) contamination in the shallow saturated zone in the vicinity of Hangar 10. Soil and ground water contamination is known to occur at the site, with contamination being present in the dissolved and gaseous phases and as residual light nonaqueous-phase liquid (LNAPL) within the aquifer matrix. There is no evidence of mobile LNAPL (free product) at this site. This study focused on the impact of dissolved-phase BTEX on the shallow ground water system at the site. Site history and the results of soil and ground water investigations conducted previously are also summarized in this report.

An important component of this study was an assessment of the potential for contamination in ground water to migrate from the Hangar 10 site to potential receptors. The Bioplume II model was used to estimate the rate and direction of dissolved-phase BTEX movement through the shallow saturated zone under the influence of advection, dispersion, sorption, and biodegradation. Input parameters for the Bioplume II model were obtained from existing site characterization data, supplemented with data collected by Parsons ES in conjunction with personnel from the United States Environmental Protection Agency (USEPA) Robert S. Kerr Environmental Research Laboratory. Extensive site-specific data were used for model implementation. Model parameters that were not measured at the site were estimated using reasonable literature values.

The results of this study suggest that dissolved-phase BTEX contamination present in ground water poses no significant risk to human health or the environment in its present, or predicted future, concentration and distribution. Parsons ES therefore recommends that intrinsic remediation with LTM be implemented for dissolved-phase BTEX contamination found in ground water at this site.

To verify the Bioplume II model predictions, Parsons ES recommends using four LTM wells and three point-of-compliance (POC) monitoring wells to monitor the long-term migration and degradation of the dissolved-phase BTEX plume. Regular sampling and analysis of ground water from these sampling points will allow the effectiveness of intrinsic

remediation to be monitored and should allow sufficient time to implement engineering controls to contain the plume if BTEX compounds are detected in the POC wells. Based on modeled contaminant fate and transport, these wells should be sampled on a semiannual basis for at least 10 years. Along with other analyses used to verify the effectiveness of intrinsic remediation, the ground water samples should be analyzed for BTEX compounds by USEPA Method SW8020. If BTEX concentrations in ground water from the POC wells exceed the federal regulatory standards of 5 micrograms per liter ($\mu\text{g/L}$) for benzene, 1,000 $\mu\text{g/L}$ for toluene, 700 $\mu\text{g/L}$ for ethylbenzene, or 10,000 $\mu\text{g/L}$ for total xylenes, additional corrective actions may be required to remediate ground water at the site.

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SECTION 1

INTRODUCTION

This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) and presents the results of an engineering evaluation/cost analysis (EE/CA) conducted to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated ground water at the Hangar 10 Site, Elmendorf Air Force Base (AFB), Alaska. Previous investigations determined that fuel hydrocarbons had been released into the soil and shallow ground water at the site. The main emphasis of the work described herein was to evaluate the potential for naturally occurring degradation mechanisms to reduce dissolved-phase benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations in ground water to levels that are protective of human health and the environment.

1.1 SCOPE AND OBJECTIVES

Parsons ES, in conjunction with researchers from the United States Environmental Protection Agency (USEPA) Robert S. Kerr Environmental Research Laboratory (RSKERL), was retained by the United States Air Force Center for Environmental Excellence (AFCEE) to conduct site characterization and ground water modeling in support of intrinsic remediation with long-term monitoring (LTM).

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

- Reviewing existing hydrogeologic and soil and ground water quality data for the site;
- Conducting supplemental site characterization activities to determine the nature and extent of soil and ground water 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 naturally occurring processes of contaminant destruction are occurring in ground water at the site;

- Performing contaminant fate and transport modeling based on site hydrogeologic conditions using the Bioplume II model;
- 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 naturally occurring processes are sufficient to minimize BTEX plume expansion so that ground water quality standards can be met at a downgradient point of compliance (POC);
- Developing 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
- Providing an LTM plan that includes LTM and POC well locations and a sampling and analysis plan.

Site characterization activities in support of intrinsic remediation included soil borehole drilling with soil sample collection and analysis, monitoring well installation, and sampling and analysis of ground water from newly installed and existing monitoring wells.

Site-specific data were used to develop a fate and transport model for the site using Bioplume II and to conduct a preliminary exposure pathways analysis. The Bioplume II model was used to simulate the movement and BTEX in the shallow saturated zone under the influence of advection, dispersion, sorption, and biodegradation. As part of the EE/CA, this modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase 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 with LTM remedial option during regulatory negotiations, as appropriate.

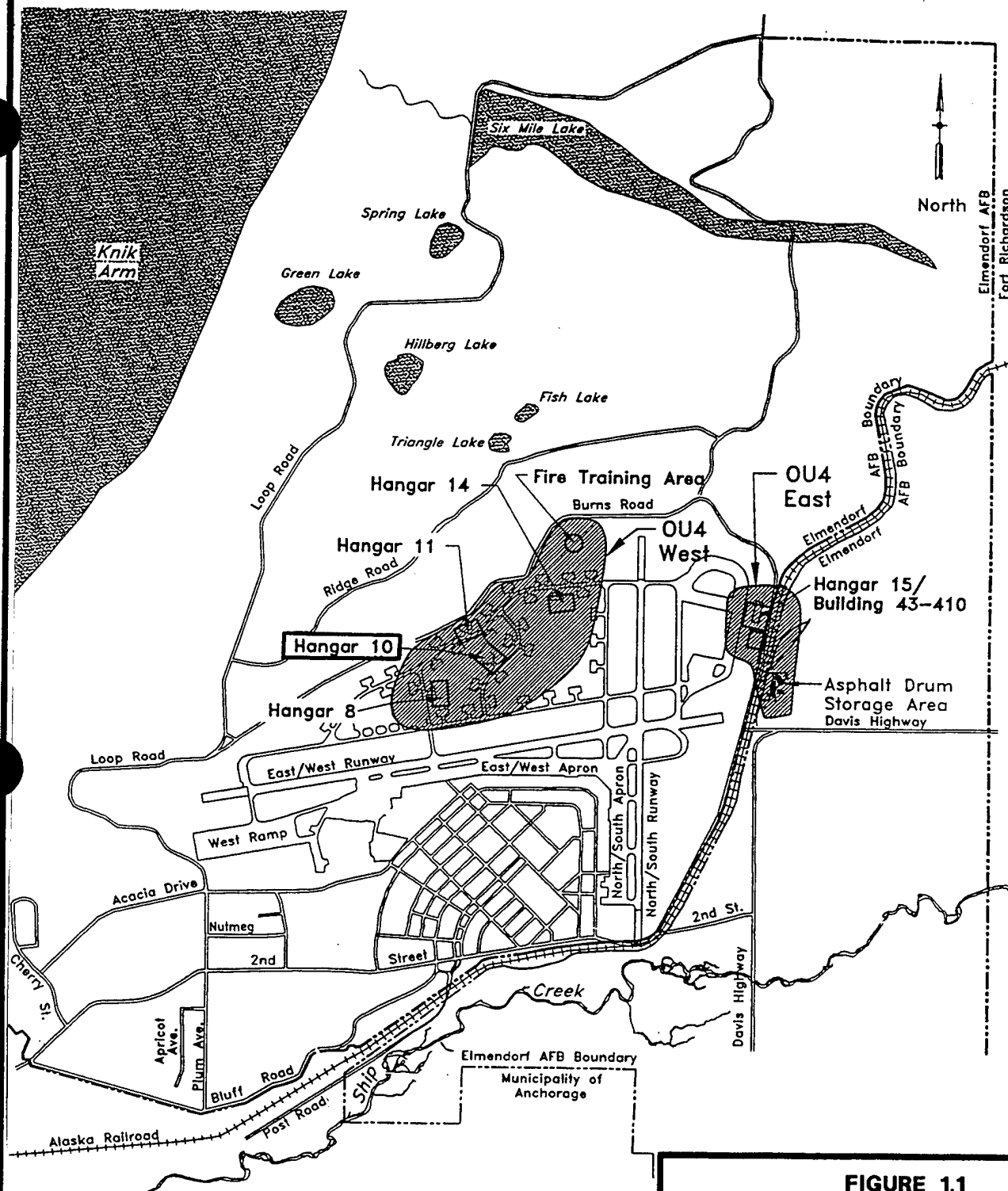
Biosparging and natural contaminant attenuation with LTM were evaluated during this EE/CA. All hydrogeologic and ground water chemical data necessary to evaluate these remedial options were collected under this program; however, the field work conducted under this program was oriented toward the collection of hydrogeologic data to be used as input into the Bioplume II ground water model in support of intrinsic remediation with LTM for restoration of fuel-hydrocarbon-contaminated ground water.

This report contains nine sections, including this introduction, and four appendices. Section 2 summarizes site characterization activities. Section 3 summarizes the physical characteristics of the study area. Section 4 describes the nature and extent of soil and ground water contamination and the geochemistry of soil and ground water at the site. Section 5 describes the Bioplume II model and design of the conceptual model for the site, lists model assumptions and input parameters, and describes sensitivity analysis, model output, and the results of the Bioplume II modeling. Section 6 presents a comparative analysis of remedial alternatives. Section 7 presents the LTM 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 and well completion diagrams. Appendix B presents soil and ground water analytical results. Appendix C contains model input parameters and calculations related to model calibration. Appendix D contains Bioplume II model input and output in ASCII format on a diskette.

1.2 FACILITY BACKGROUND

The Hangar 10 site is located in the south-central portion of Elmendorf AFB. This site is part of an area referred to as Operable Unit (OU) 4 West under the Air Force Installation Restoration Program (IRP). In earlier phases of IRP work, individual buildings were investigated as potential source areas, and Hangar 10 was known as source area SD-24. Figure 1.1 is a site location map showing the position of the Hangar 10 site relative to Elmendorf AFB and the surrounding area. Figure 1.2 is a site map showing the layout of the Hangar 10 area. Locations of potential sources are presented on Figure 1.3. Several potential sources have been identified in the area, including petroleum, oil, and lubricant (POL) pipelines, a pump house (Pump House 2) and a valve pit for the POL lines, and a 1,000-gallon underground storage tank (UST) with unknown contents, located immediately southwest of Hangar 10.

For the purposes of this work plan, the Hangar 10 site refers to an area that includes Hangar 10 and the plume of fuel-hydrocarbon-contaminated ground water extending south-southwest from the area immediately southwest of the hangar to the east and southeast of Hangar 8. Soil and ground water contamination in this area was first observed during a Phase III stage 3 remedial investigation/feasibility study (RI/FS) (Black & Veatch, 1990).



ELMENDORF AFB

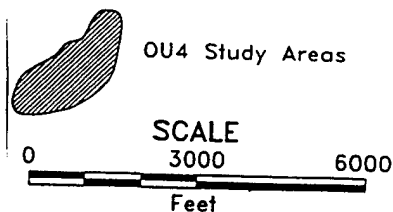


FIGURE 1.1

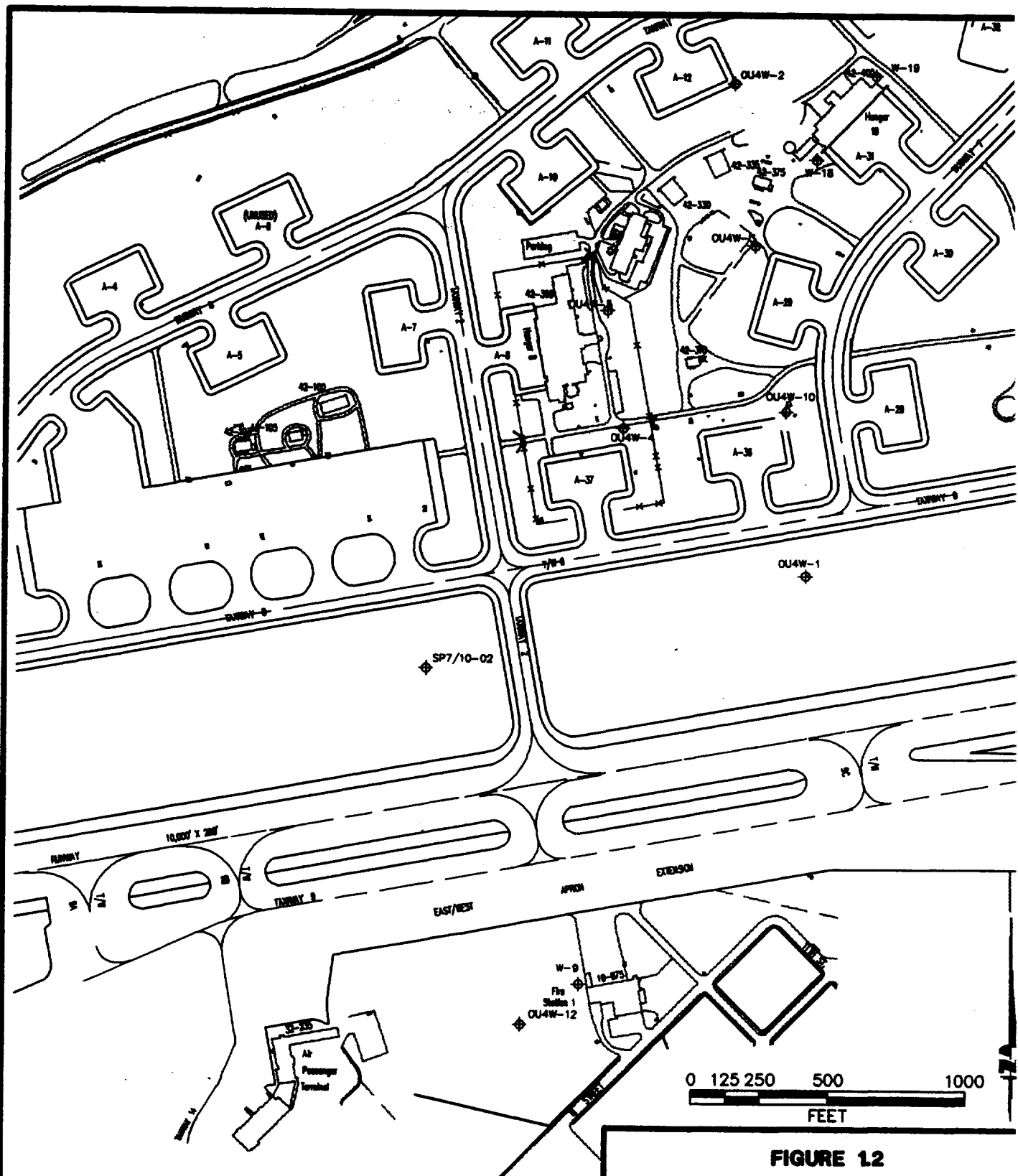
SITE LOCATION MAP

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

(Source: Radian, 1994)



LEGEND

◆ OU4W-1 MONITORING WELL LOCATION (JUNE 1993)

FIGURE 12

SITE LAYOUT

Hangar 10 Intrinsic Remediation EE/C/
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC

Denver, Colorado

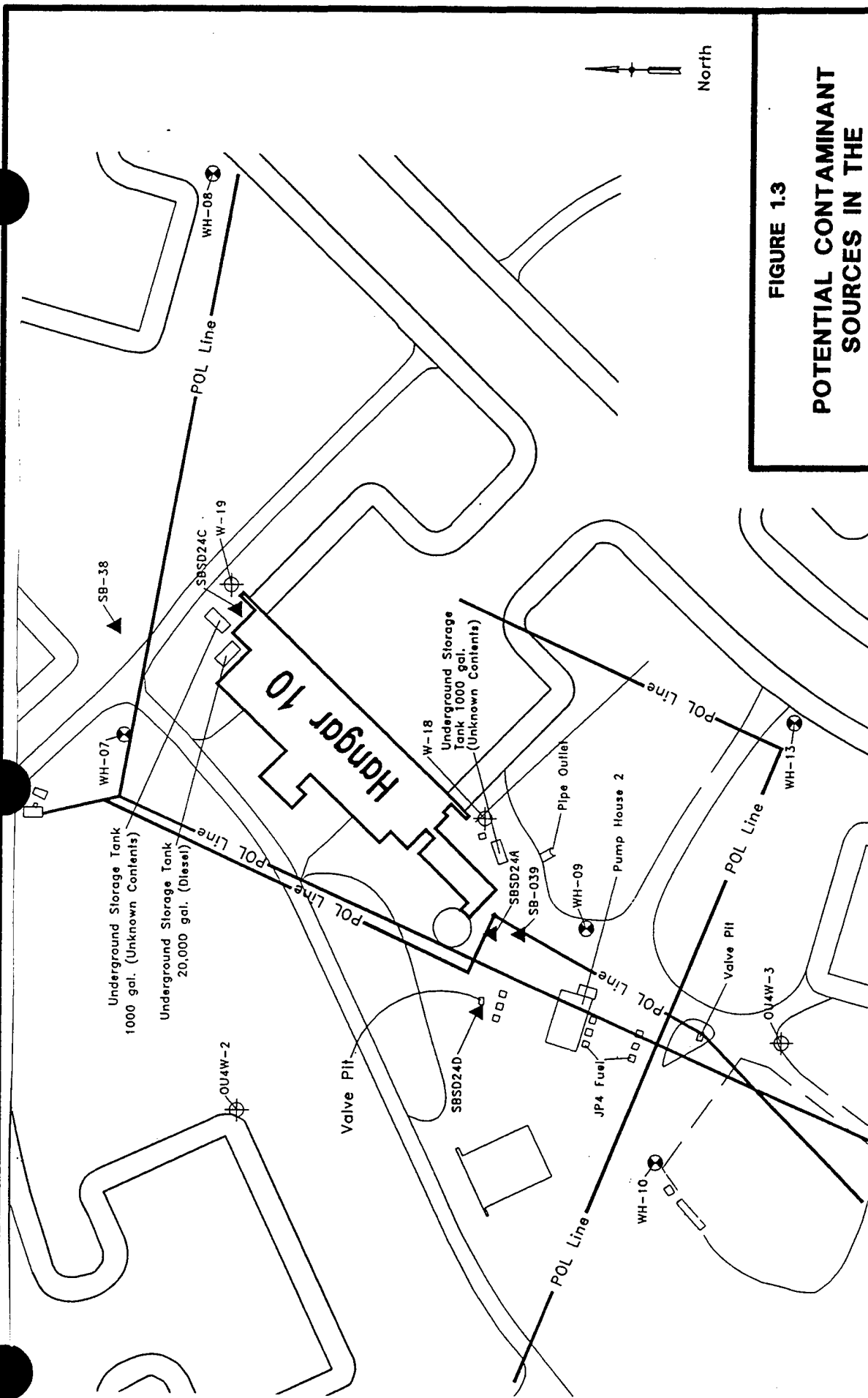


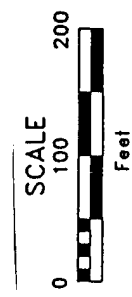
FIGURE 1.3

POTENTIAL CONTAMINANT SOURCES IN THE HANGER 10 AREA

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

- SP7/10-02 WELL LOCATION
- WH-20 HYDROPUNCH LOCATION
- SB-25 SOIL BORING LOCATION



(Based on Data from Radian, 1994)

Several additional IRP investigations that included the Hangar 10 site have been conducted. The results of these investigations are covered in several reports, including:

- Stage 3 RI/FS (Black & Veatch, 1990);
- IRP Site Summary (Battelle, 1991);
- Draft OU4 Limited Field Investigation Report (CH2M Hill, 1992);
- Management Action Plan (Jacobs Engineering Group, 1993);
- OU4 Final Management Plan (Radian, 1993);
- Basewide Monthly Water Level Data Package for January 1994 (Jacobs Engineering Group, 1994a);
- Basewide Monthly Water Level Program Fourth Quarterly Technical Memorandum. Period: October - December 1993 (Jacobs Engineering Group, 1994b);
- OU4 Remedial Investigation Report (Radian, 1994).

The site-specific data presented in Sections 3, 4, and 5 are based on a review of these documents and on data collected by Parsons ES and researchers from the RSKERL under this program. A full synopsis of other site characterization activities conducted to date is provided by Radian (1994).

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

This section presents the methods used by Parsons ES and RSKERL personnel to collect site-specific data at Elmendorf AFB, Alaska. To meet the requirements of the intrinsic remediation demonstration, several investigative techniques, including soil and ground water sampling, 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 sampling of ground water via monitoring wells and HydroPunch[®] sampling devices. Ground water sampling was accomplished during this investigation using newly installed and previously existing monitoring wells. Aquifer tests conducted previously at the site included pumping tests (Radian, 1994).

In addition to the work conducted under this program, Radian (1994) collected soil and ground water data as part of an RI/FS for OU4. Data collected by Radian and data collected under this program 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 EE/CA:

- Depth from measurement datum to the water table or potentiometric surface in monitoring wells and monitoring points;
- Location of potential ground water recharge and discharge areas;
- Stratigraphic analysis of subsurface media;
- Dissolved oxygen (DO), nitrate, ferrous iron, sulfate, methane, chloride, and total organic carbon (TOC) concentrations in ground water;
- Temperature, specific conductance, reduction/oxidation (redox) potential, total alkalinity, and pH of ground water;

- BTEX and trimethylbenzene (TMB) concentrations in ground water;
- BTEX, TMB, and total petroleum hydrocarbon (TPH) concentrations in soil; and
- TOC concentrations in select soil samples.

The following sections describe the procedures that were followed when collecting site-specific data. The applied drilling, soil sampling, lithologic logging, and monitoring well development procedures are described in Section 2.1. Ground water sampling procedures are described in Section 2.2. Additional details regarding investigative activities are presented in the draft work plan (Engineering-Science, Inc., 1994).

2.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

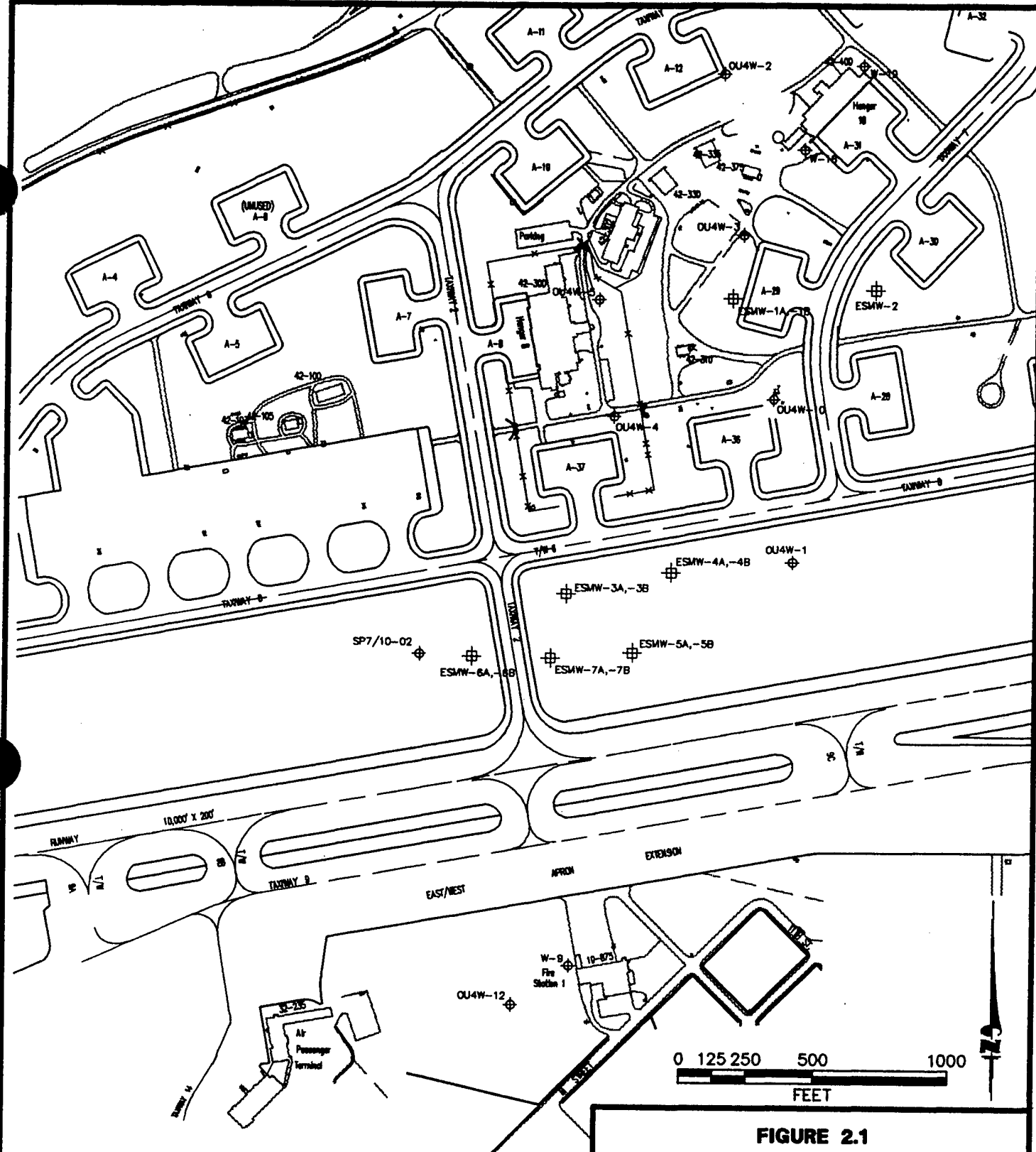
Field work occurred during June 1994, and consisted of drilling, soil sampling, and monitoring well installation at ESMW-1 through ESMW-7. These activities were performed according to the procedures described in the work plan (Engineering-Science, Inc., 1994) and in the following sections.

2.1.1 Well Locations and Completion Intervals

Thirteen new ground water monitoring wells were installed to help characterize the shallow ground water flow system in the vicinity of Hangar 10. These wells are identified as ESMW-1A, ESMW-1B, ESMW-2, ESMW-3A, ESMW-3B, ESMW-4A, ESMW-4B, ESMW-5A, ESMW-5B, ESMW-6A, ESMW-6B, ESMW-7A, and ESMW-7B. The new monitoring wells were installed in the locations shown on Figure 2.1. Table 2.1 presents well completion details. Nested wells (e.g., ESMW-1A and ESMW-1B) were installed adjacent to each other, with one well (designated by the suffix "A") screened across the water table, and with the other well screened 5 to 18 feet below bottom of the first well. Well locations and completion intervals were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model and to support intrinsic remediation.

2.1.2 Well Drilling and Soil Sampling Procedures

This section describes the procedures that were used for drilling and installation of new monitoring wells. All new monitoring wells were installed in accordance with general



LEGEND

- MONITORING WELL LOCATION (JUNE 1993)
- MONITORING WELL LOCATION (JUNE 1994)

FIGURE 2.1 **MONITORING WELL LOCATIONS**

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

TABLE 2.1
WELL COMPLETION DATA
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

Well Location	State Plane Coordinates		Datum ^{a/} Elevation (ft msl) ^{b/}	Ground Elevation (ft msl)	Total Depth (ft bgs) ^{c/}	Screen length (feet)	Depth to Screen	
	Easting	Northing					Top (ft bgs)	Bottom (ft bgs)
ESMW-1A	1672847.38	2650825.96	183.09	183.2	27	5	22.0	27.0
ESMW-1B	1672847.74	2650831.76	183.12	183.2	40.5	5	35.5	40.5
ESMW-2	1673376.46	2650857.04	184.19	184.3	30	10	20.0	30.0
ESMW-3A	1672241.45	2649740.16	175.67	175.7	25	5	20.0	25.0
ESMW-3B	1672242.72	2649735.86	175.69	175.6	37.5	5	32.5	37.5
ESMW-4A	1672626.43	2649819.46	177.41	177.6	25	5	20.0	25.0
ESMW-4B	1672626.31	2649814.67	177.41	177.5	38.25	5	33.3	38.3
ESMW-5A	1672486	2649525.82	170.20	170.2	18	5	13.0	18.0
ESMW-5B	1672479.14	2649525.7	170.15	170.2	31	5	26.0	31.0
ESMW-6A	1671892.36	2649409.82	168.19	168.1	19	5	14.0	19.0
ESMW-6B	1671894.55	2649403.31	168.32	168.3	29	5	24.0	29.0
ESMW-7A	1672187.73	2649508.63	171.18	171.3	20	5	15.0	20.0
ESMW-7B	1672184.33	2649503.97	171.1	171.2	33	5	28.0	33.0
OU4W-1	1673077.65	2649859.28	179.10	179.97	34	15	18.0	33.0
OU4W-2	1673077.65	2651647.25	186.32	186.33	40	15	23.0	38.0
OU4W-3	1672886.91	2651058.48	183.08	183.00	37.5	15	21.5	36.5
OU4W-4	1672412.22	2650392.80	179.04	179.19	35.5	15	18.0	33.0
OU4W-5	1672353.52	2650820.95	180.61	180.70	35	15	19.0	34.0
OU4W-10	1673002.25	2650456.49	184.60	181.84	36	15	20.2	35.2
SP-7/10-02	NA ^{d/}	NA	NA	NA	26	NA	NA	NA
W-9	NA	NA	NA	NA	40	25	11.0	36.0
W-18	1673107.94	2611371.93	186.24	NA	47.5	28	20.0	48.0
W-19	1673322.59	2611677.59	186.97	NA	45	25	25.0	50.0

^{a/} Datum is top of PVC casing

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

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

^{d/} NA = Data not available

procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (USEPA, 1987).

2.1.2.1 Pre-Drilling Activities

All necessary digging, drilling, and ground water monitoring well installation permits were obtained prior to mobilizing to the field. In addition, all utility lines were located, and proposed drilling locations were cleared prior to any drilling activities.

Water used in drilling, equipment cleaning, or grouting was obtained from an onsite potable water supply. Water use approval was verified by contacting the appropriate facility personnel.

2.1.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each drilling location, the augers, drilling rods, bits, casing, samplers, tools and other downhole equipment were decontaminated using a high-pressure, steam/hot water wash. Only potable water was used for decontamination.

During drilling operations, the drill rig, augers, and any downhole drilling and/or sampling equipment were decontaminated at the Elmendorf AFB decontamination pad. Water from the decontamination operations was allowed to collect in the decontamination pad collection sump, then pumped into holding tanks. After conditioning (using granular carbon canisters), water from the holding tanks was released to the sanitary sewer. Precautions were taken to minimize any impact to the area surrounding the decontamination pad that might result from the decontamination operations.

All sampling tools were cleaned onsite, prior to use and between each sampling event, with a clean water/phosphate-free detergent mix and a clean water rinse. All well completion materials were factory sealed. All decontamination activities were conducted in a manner so that the excess water was controlled and not allowed to flow into any open borehole.

Fuel, lubricants, and other similar substances were handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials were not stored near or in areas which could be affected by these substances.

2.1.2.3 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. Where two wells were installed adjacent to each other (i.e., nested), only the deeper well was logged. In many instances, sand heave below the water table prevented collection of continuous samples. 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. One soil sample was removed from the lower 10 to 12 inches of the spoon and placed in a clean glass jar for laboratory analysis. In addition, a portion of the soil sample was placed in an unused, sealable plastic bag for photoionization detector (PID) headspace measurements for volatile organic compounds (VOCs). Soil remaining in the spoon was used for lithologic and stratigraphic logging. Bags containing soil samples collected for the headspace procedure were quickly sealed and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements were made by puncturing the bag seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The PID 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:

- Sampled 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, 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).

At five borehole locations, one or two soil samples from the vicinity of the water table were selected for laboratory analysis. Where no elevated PID headspace readings were encountered, samples were collected from immediately above and/or immediately below the water table. Where PID readings were elevated, one of the samples submitted for laboratory analysis was from the interval giving the highest reading.

Sample containers and appropriate container lids were provided by the EPA Mobile Laboratory. The sample containers were filled as full as possible to eliminate creation of headspace in the jars, and the container lids were tightly closed. A sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Sample identification;
- Sample depth;
- Sampling date; and,
- Sample collector's initials.

After the samples were sealed and labeled, they were placed in a cooler with ice and held for transport to the onsite EPA Mobile Laboratory (while the laboratory was at the base). Samples collected after EPA personnel left the site on June 14, 1994 were packaged for shipment to the RSKERL. After EPA personnel left the site, the following packaging and labeling procedures were followed:

- Samples were packaged to prevent leakage or vaporization from the containers;
- Samples were cushioned to avoid breakage; and
- Ice was added to the container to keep the samples cool.

The packaged samples were delivered by overnight courier to the RSKERL. Delivery occurred as soon as possible after sample acquisition. Samples were analyzed for BTEX and TMBs, TPH, and TOC.

Soils exhibiting petroleum hydrocarbon contamination based on PID screening were drummed and stored onsite during the drilling operations. A total of four drums of contaminated soil were collected at the Hangar 10 Site. Upon completion of daily drilling activities, the drums were taken to the decontamination pad/staging area for storage.

Disposal of these soils will be coordinated by Elmendorf AFB personnel. Soil that did not display contamination (based on PID readings at or below background) was thin-spread in the vicinity of the borehole.

2.1.3 Monitoring Well Installation

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

2.1.3.1 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 casing, sand, bentonite, and concrete mix 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.

2.1.3.2 Well Casing

Upon completion of drilling to the proper boring termination depth, 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. Monitoring well installation forms for the Hangar 10 site are presented 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 lockable top cap constructed of the same type of material as the well casing. Because all wells were constructed with flush-mount protective casings, the top caps were of an expandable design to prevent water that might collect in the protector pipe from leaking down 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.

2.1.3.3 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 and so that mobile LNAPL (if present) could be detected. Well 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.

2.1.3.4 Sand Filter Pack

A graded sand filter was placed around the screened interval from the bottom of the casing to approximately 2 feet above the top of the screen. Number 10-20 Colorado silica sand was used for the sand filter pack.

2.1.3.5 Annular Sealant

An annular seal of sodium bentonite pellets was placed above the sand pack. The pellet seal was a minimum of 2 feet thick and, where placed above the water table, was hydrated in place with potable water. In all wells at the Hangar 10 site, the pellet seal was overlain with a sodium bentonite grout extending from the top of the pellet seal to approximately 1.5 feet below ground surface (bgs). Bentonite grout was used rather than a bentonite and cement grout mixture to minimize the potential for frost heave. The sodium bentonite grout mix consisted of one 50-pound sack of granular bentonite for each 15 gallons of water used. The grout was overlaid with filter sand to approximately 8 inches bgs. The sand was placed to allow any water that might leak into the protective casing to drain out into the native soil. Above the sand is a concrete pad that extends to 4 inches above the ground surface. The concrete pad is approximately 1 foot thick and extends out approximately 8 inches from the edge of the protective casing.

2.1.3.6 Flush-Mount Protective Cover

Each monitoring well was completed with an at-grade protective cover. Each cover was placed 4 inches above grade, with a concrete pad surrounding the cover. To facilitate runoff during precipitation events, all pads were finished so that the surface slopes gently away from the protective casing. A set of dies was used to stamp the well name onto each cover.

2.1.4 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.

Well development was accomplished using a Grundfos Redi-Flo 2[®] submersible pump. The pump was regularly raised and lowered in the well so that fines were agitated and removed from the well in the development water. Development was continued until a minimum of 10 casing volumes of water were removed from the well and the temperature and DO concentration of the ground water had stabilized. All well development waters were collected in a 400-gallon polyethylene tank and transported to the Elmendorf AFB water conditioning facility for conditioning and disposal.

2.2 GROUND WATER SAMPLING

This section describes the procedures used for collecting ground water quality samples. In order to maintain a high degree of quality control (QC) during this sampling event, the procedures described in the site work plan (Engineering-Science, Inc., 1994) and summarized in the following sections were followed.

Ground water sampling occurred during June 1994 and consisted of collecting ground water samples from new and existing monitoring wells. Personnel from Parsons ES and USEPA RSKERL participated in ground water sampling. USEPA RSKERL was responsible for sample analysis. The procedures used to sample ground water monitoring wells is described in Section 2.2.3.2. In addition to the sampling events conducted under this program, Radian (1994) have conducted several ground water sampling events at this site as part of the RI activities.

Activities that occurred during ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including
 - Protective cover, cap and lock,
 - External surface seal and pad,
 - Well casing, cap, and datum reference, and
 - Internal surface seal;
- Ground water sampling, including
 - Water level measurements,
 - Visual inspection of water,
 - Well casing evacuation, and
 - Sampling;
- Sample preservation and packaging, including
 - Sample preparation,
 - Onsite measurement of physical parameters, and
 - Sample labeling;
- Completion of sampling records; and
- Sample delivery to the USEPA Mobile Laboratory or RSKERL in Ada, Oklahoma.

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

2.2.1 Ground Water Sampling Locations

Ground water samples were collected from existing and newly installed monitoring wells by Parsons ES and USEPA RSKERL personnel. Thirteen new monitoring wells, including six nested well pairs, 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. Ten previously existing monitoring wells were also sampled under this program. Existing wells that were sampled included OU4W-1, OU4W-2, OU4W-3, OU4W-4, OU4W-5, OU4W-10, SP7/10-02, W-9, W-18, and W-19. Well completion data for the newly installed and previously installed wells are provided on Table 2.1.

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 the water level probe and cable, lifting lines, test equipment for onsite use, and other equipment that contacted the samples. The following cleaning protocol was used:

- Cleaned with potable water and phosphate-free laboratory detergent;
- Rinsed with potable water;
- Rinsed with distilled or deionized water;
- Rinsed with reagent-grade acetone; and
- Air dried prior to use.

Any deviations from these procedures were documented in the field scientist's field notebook and on the ground water sampling form.

2.2.2.2 Equipment Calibration

As required, field analytical equipment was calibrated according to the manufacturers' specifications prior to field use. This requirement applied to equipment used for onsite chemical measurements of DO and temperature.

2.2.3 Sampling Procedures

Special care was taken to prevent contamination of the ground water 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 Ground Water Monitoring Well Sampling

2.2.3.1.1 *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.

2.2.3.1.2 *Water Level and Total Depth Measurements*

Prior to removing any water from the well the static water level was measured. An electrical water level probe was used to measure the depth to ground water below the well 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 to be purged from the wells was calculated.

2.2.3.1.3 *Well Bore Purging*

Three times the calculated casing volume was removed from each well prior to sampling. All purge water was placed in a 400-gallon polyethylene tank and transported to the Elmendorf AFB conditioning unit for conditioning and disposal. A peristaltic pump with dedicated polyethylene tubing was used for well evacuation.

2.2.3.1.4 *Sample Extraction*

A peristaltic pump with dedicated polyethylene tubing was used to extract ground water samples from the well. The sample was transferred directly into the appropriate sample container. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Sample bottles for BTEX and TMB analysis were filled so that there was no headspace or air bubbles within the container.

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 in a flow-through cell at the outlet of the peristaltic pump. DO concentrations were recorded after the readings stabilized, and in all cases represent the lowest DO concentration observed.

2.2.4.2 pH and Temperature Measurements

Because the pH and temperature of the ground water change significantly within a short time following sample acquisition, these parameters were measured in the field or at the EPA Mobile Laboratory as soon as possible after acquisition. The measurements were made in a clean glass container separate from those intended for laboratory analysis, and the measured values were recorded in the ground water 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 collection of samples.

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, and the container lids were tightly closed. 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 (ground water);
- 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 transport to the onsite USEPA Mobile Laboratory while the laboratory was at the base. Samples collected after USEPA personnel left the site on June 14, 1994, were packaged for shipment to RSKERL in Ada, Oklahoma.

While the USEPA Mobile Laboratory was onsite, the following packaging and labeling procedures were followed:

- Sample was packaged to prevent leakage or vaporization from its container;
- Shipping container was labeled with
 - Sample collector's name, address, and telephone number;
 - Description of sample;
 - Quantity of sample; and
 - Date of shipment.

The packaged samples were hand-delivered to the EPA Mobile Laboratory. Delivery occurred shortly after sample acquisition.

After USEPA personnel left the site, the following packaging and labeling procedures were followed:

- Sample was packaged to prevent leakage or vaporization from its container;
- Samples were cushioned to avoid breakage; and
- Ice was added to the container to keep the samples cool.

The packaged samples were delivered by overnight courier to the RSKERL. Delivery occurred as soon as possible after sample acquisition.

2.3 AQUIFER TESTING

Slug tests were not conducted at the Hangar 10 site. Slug tests are single-well hydraulic tests used to determine the hydraulic conductivity of aquifer materials in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Based on previous aquifer pumping test data for the site (Radian, 1994), the transmissivity of the aquifer materials in the vicinity of Hangar 10 exceeds 7,000 ft^2/day . Slug tests in such materials often yield results that are suspect or impossible to interpret.

It was noted during well development that pumping at a rate of 4 gallons per minute produced a drawdown of less than 0.1 foot. Based on this observation, it was decided that slug tests were not likely to produce meaningful data, and that use of the existing pumping test data would be more appropriate.

2.4 SURVEYING

After completion of field work, all new monitoring well locations and elevations were surveyed by a professional land surveyor. The horizontal locations were measured relative to existing monitoring wells. 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 existing wells tied to a US Geological Survey (USGS) mean sea level (msl) datum. Horizontal location was surveyed to the nearest 0.1 foot. Datum and ground surface elevations were surveyed to the nearest 0.01 foot. Horizontal control was based on previous data for wells OU4W-3 and OU4W-1, and the previously reported elevation for the PVC casing of well OU4W-3 (Radian, 1993) was used as a local elevation benchmark.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section incorporates data collected during investigations as summarized by Radian (1994) and more recent investigations conducted by Parsons ES in conjunction with researchers from USEPA RSKERL in June 1994. Investigative techniques used by Parsons ES and RSKERL researchers to determine the physical characteristics of the Hangar 10 Site are discussed in Section 2.

3.1 SURFACE FEATURES

3.1.1 Topography and Surface Water Hydrology

Hangar 10 is located on a broad, relatively level surface formed by glacial outwash deposits. This plain was formed as glacial melt water deposited its sediment load downstream of a melting glacier. Surface topography at the site slopes very gently to the south-southwest, although the natural topography has been altered by construction of runways, taxiways, and hangars.

There are no naturally occurring surface water bodies in the immediate vicinity of Hangar 10. There are, however, manmade features at or near the site that influence surface water runoff. These features are discussed in Section 3.1.2.

3.1.2 Manmade Features

Surface cover at Hangar 10 and adjacent areas consists of asphalt paving, grass, concrete aircraft pads and runways, and buildings. Precipitation either infiltrates directly into the ground or runs off of covered or paved areas. Figure 1.2 shows the location of buildings and paved areas.

3.2 REGIONAL GEOLOGY AND HYDROGEOLOGY

Elmendorf AFB is located immediately north of Anchorage, Alaska, west of the Chugach Mountain Front. The base lies within the Cook Inlet - Susitna Lowland physiographic province, referred to as the "Anchorage Lowland." The Anchorage Lowland is a large alluvial fan on the eastern shore of the Knik Arm of the Cook Inlet, surrounded by the Kenai, Chugach, and Talkeetna mountains. Local topography is generally flat, with a slight regional rise toward the east. Ship Creek flows along the southern boundary of the base, approximately 1.5 miles south of Hangar 10 (Figure 1.1). There are no surface water bodies in the immediate vicinity of Hangar 10.

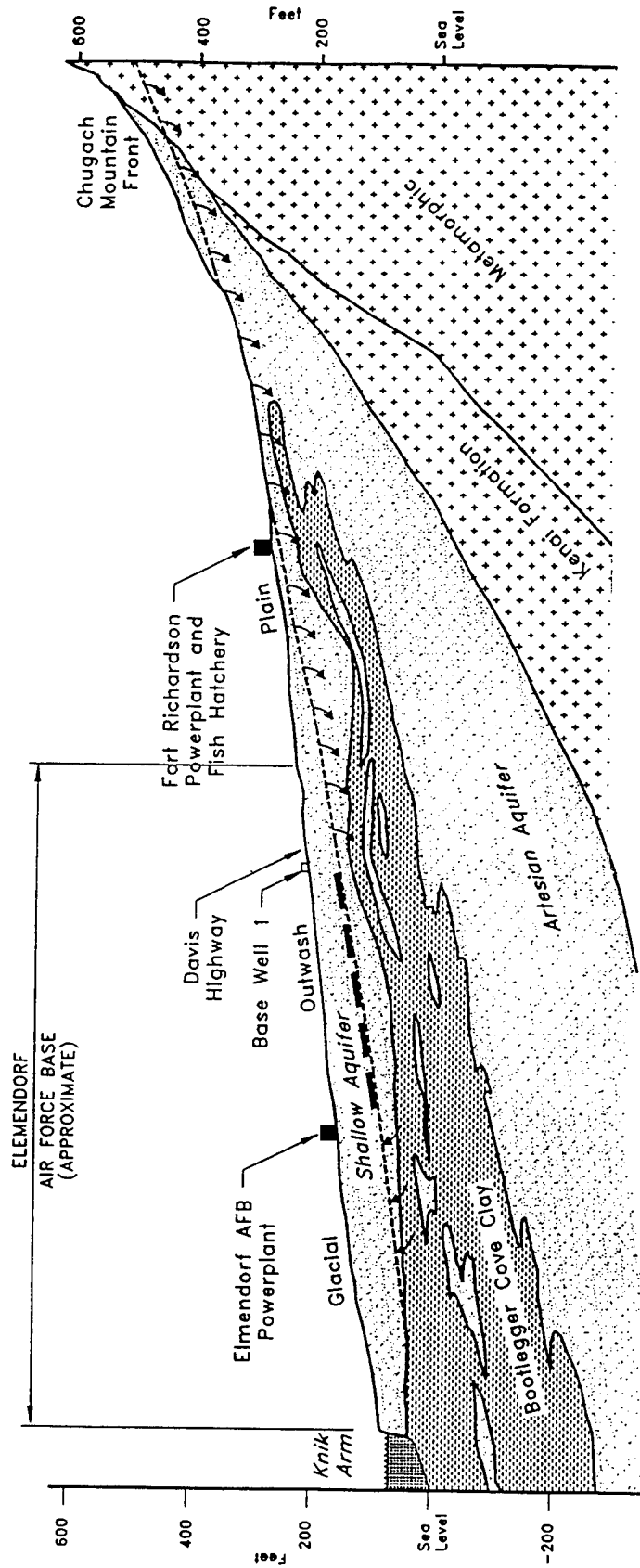
Surficial deposits in the vicinity of Elmendorf AFB consist of Pleistocene glacial drift that was deposited during several glacial advances and retreats. During the most recent phase of glaciation, the ice reached a position overlying the current location of Elmendorf AFB. The ice temporarily stagnated, and poorly sorted sediment (till) was deposited at the ice front. Deposition of till produced a terminal moraine, called the Elmendorf Moraine. The moraine is expressed topographically as a broad, northeast-to-southwest trending ridge immediately to the northwest of OU4 West. After the ice retreated, meltwaters moving away from the ice margin deposited sediment (mostly sand and gravel), producing a relatively flat, broad outwash plain upon which most of the base facilities (including Hangar 10) are located.

Two aquifers are present in the vicinity of Elmendorf AFB. In order of increasing depth, these aquifers are 1) the shallow aquifer (in either till or outwash deposits, depending on location); and 2) the deep confined aquifer, comprised of sand and gravel outwash deposits, alluvial sand, and mixed deposits of glacial till. Between the shallow and deep aquifers is a regional aquitard known as the Bootlegger Cove Formation. This unit consists of interbedded silt and clay deposits and is approximately 50 feet thick. The upper portion of the Bootlegger Cove Formation is generally silty, while the lower unit is generally clayey. A generalized cross-section showing the relationships between the shallow (outwash) aquifer, the Bootlegger Cove Formation, and the deep aquifer is presented in Figure 3.1. The shallow outwash aquifer ranges from 35 to over 120 feet thick, while the depth to ground water ranges from 5 to 50 feet bgs. The shallow till aquifer in the vicinity of the moraine ranges from 1 to 60 feet thick, with depth to ground water ranging between 1 and 30 feet bgs.

There is apparently no communication between the shallow and deep aquifers. A hydraulic communication test between the two aquifers was performed in 1992. Data from this test

(WEST)

(EAST)



ELMENDORF AFB LEGEND

-  Permeable coarse-grained deposits
-  Relatively impermeable fine-grained deposits
-  Bedrock
-  Area where Ship Creek may either be losing water or gaining water to/from the shallow aquifer depending on stream flow.
-  Ship Creek profile with diversion dam structure. Arrows indicate direction of groundwater movement to or from the creek.

Vertical Exaggeration $\pm 20X$
(Modified From Jacobs Engineering, 1993)

(Source: Radian, 1994)

FIGURE 3.1

GENERALIZED HYDROGEOLOGIC CROSS-SECTION

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

indicate that there is no correlation between flow directions or water level elevations and elevation changes in the shallow and deep aquifers (Jacobs Engineering Group, 1993). In addition, a review of analytical data from several base water supply wells screened in the deep aquifer was conducted by Radian (1994). This review concluded that minor contamination observed in the deep aquifer was not attributable to the sources of shallow ground water contamination observed in OU4, and given the results of the 1992 communication test, that the Bootlegger Cove Formation is an effective confining unit.

Basewide ground water elevation data collected throughout 1993 indicate that flow in the shallow outwash aquifer is generally to the south and southwest, toward Ship Creek (Jacobs Engineering Group, 1994b). Water levels are highest in late spring, decreasing through the summer until fall, when rains cause another rise. This rise continues through late fall, and is followed by decreasing levels through the winter, until the spring thaw.

Data from previous studies indicate that the outwash aquifer is unconfined throughout the OU4 area, although it is possible that scattered deposits of fine-grained materials create local areas of confined or semiconfined conditions. Relatively impermeable silts and clays of the Bootlegger Cove Formation form the basal boundary of this aquifer. The Bootlegger Cove Formation is also the principal confining layer for the deep aquifer, although this aquifer may be overlain by additional thicknesses of other fine-grained deposits. In the Hangar 10 area, the top of the Bootlegger Cove Formation ranges from approximately 90 feet deep (near Hangar 10) to 35 feet deep (southwest of Hangar 8) (Radian, 1994).

3.3 SITE GEOLOGY AND HYDROGEOLOGY

Characterization of the vadose zone and shallow aquifer system in the Hangar 10 vicinity has been the objective of several investigations. Prior to 1994, 14 soil borings and 10 ground water monitoring wells were completed in the vicinity of Hangar 10 and the hydrocarbon plume emanating from that area. Figure 2.1 shows the locations of most of the previous soil borings, wells, and HydroPunch[®] sampling points in the vicinity of the Hangar 10 plume. During June 1994, Parsons ES, in conjunction with RSKERL, drilled 13 soil borings in which ground water monitoring wells were installed. These soil boreholes/monitoring wells are designated ESMW-1A, ESMW-1B, ESMW-2, ESMW-3A, ESMW-3B, ESMW-4A, ESMW-4B, ESMW-5A, ESMW-5B, ESMW-6A, ESMW-6B, ESMW-7A, and ESMW-7B. Locations of these wells are presented on Figure 2.1. Table 2.1 presents available well completion information.

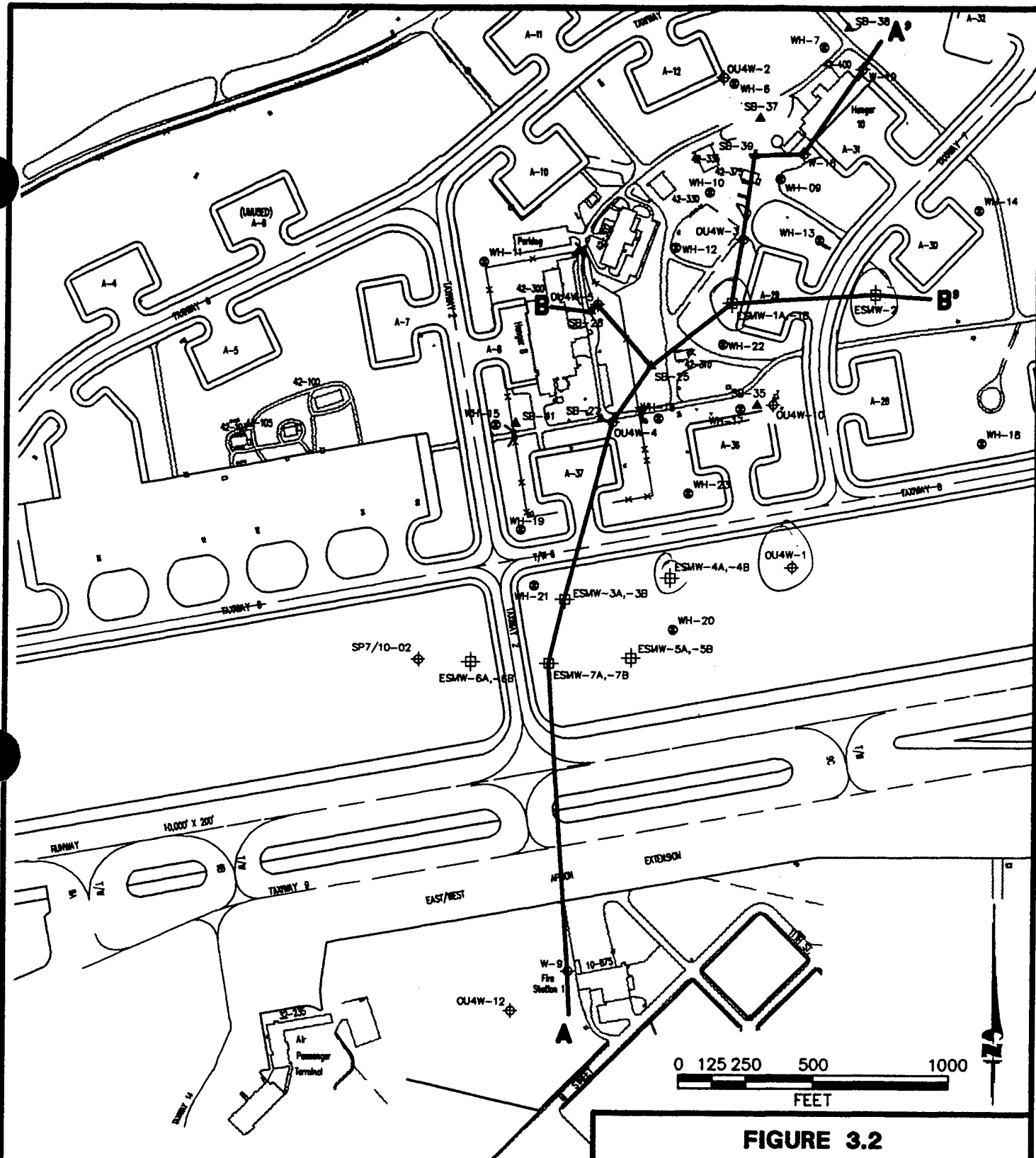
3.3.1 Lithology and Stratigraphic Relationships

Subsurface soil in the Hangar 10 area consists mostly of sand and gravel in varying proportions, with occasional silty intervals near the ground surface. The sand and gravel is relatively uniform, with the percentages of sand and gravel varying slightly from location to location, as well as at different depths in the same location. The observed horizontal and vertical variations in soil texture are commonly encountered in glacial outwash environments. These deposits overlie a thicker sequence of unconsolidated glacial and surficial material deposited prior to the most recent glaciation, including the Bootlegger Cove Formation and the deep confined aquifer materials.

Soils encountered during drilling activities conducted by Parsons ES in June 1994 consisted mostly of outwash sand and gravel. Generally these deposits contained less than 5 percent silt. In many of the boreholes, gravelly sand and sandy gravel was encountered from the ground surface to depths of 20 to 30 feet bgs. Beneath the gravel-bearing units, a relatively well-sorted sand unit was encountered. This sand unit was generally medium to coarse grained, with occasional silty or gravelly intervals. Occasionally in this unit, and more frequently in the overlying unit, cobbles were encountered. Minor sandy units were also encountered within the gravelly units. In previously installed borings such as SB-37, OU4W-5, OU4W-3, and W-18, sand units were also encountered from the surface to depths of 2 to 20 feet. In the borehole for well W-19, sand was encountered from the surface to a depth of approximately 40 feet; no gravel units were encountered (Radian, 1994; CH2M Hill, 1992).

Clay and silt of the Bootlegger Cove Formation was encountered in the borehole for well ESMW-6B, at a depth of approximately 29 feet. The Bootlegger Cove Formation was encountered in only one other borehole in the vicinity of Hangar 10. At borehole SB-39 (just south of the hangar), the Bootlegger Cove was encountered at a depth of 90 feet (Radian, 1994).

These stratigraphic relationships are illustrated by hydrogeologic sections A - A' and B - B', which include data from previously installed wells and newly installed wells. Figure 3.2 shows the locations of these sections. Figure 3.3 presents hydrogeologic section A - A', which is approximately parallel to the direction of ground water flow. Figure 3.4 presents hydrogeologic section B - B', which is approximately perpendicular to the direction of ground water flow.



LEGEND

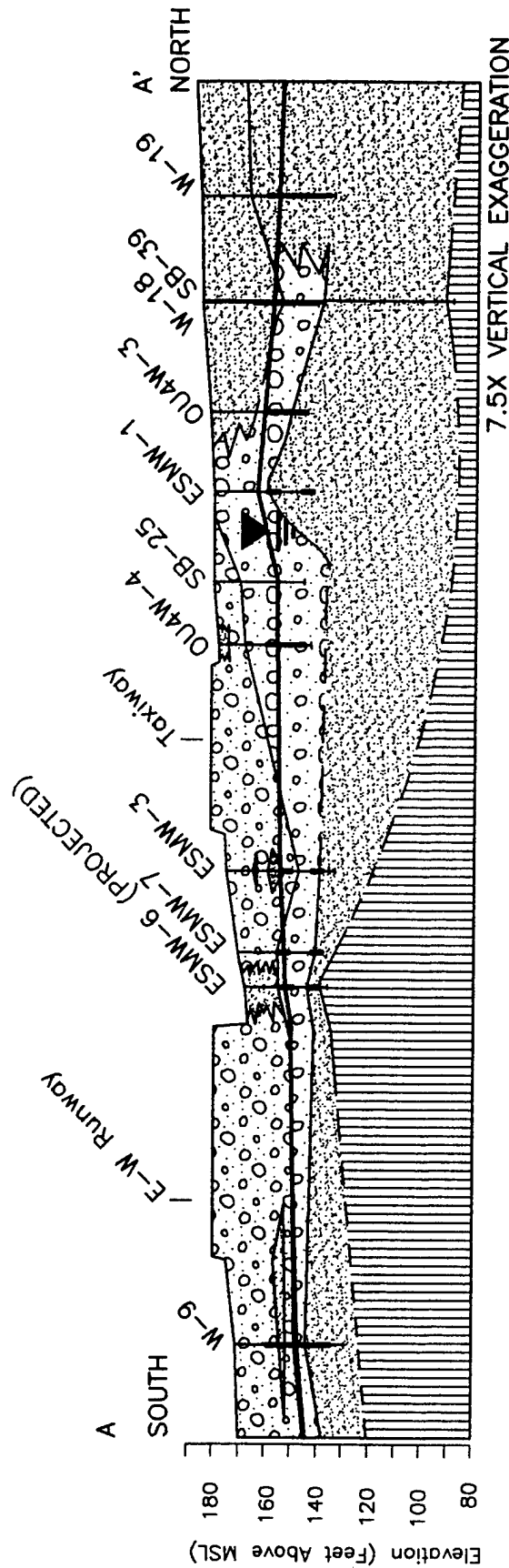
- OU4W-1 MONITORING WELL LOCATION (JUNE 1993)
- WH-20 HYDROPUNCH LOCATION (JUNE 1993)
- ESMW-5A, -5B MONITORING WELL LOCATION (JUNE 1994)
- SB-39 SOIL BORING (JUNE 1993)
- A-A' HYDROGEOLOGIC CROSS-SECTION

FIGURE 3.2
LOCATION OF HYDROGEOLOGIC
CROSS-SECTIONS

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado



LEGEND

- Brown sandy GRAVEL. Cobble and pebbles present. Some silt.
- Brown medium- to coarse-grained SAND. Silt, cobbles, gravel, and pebbles present.
- Brown, gravelly SAND. Medium- to coarse-grained sand with cobbles, pebbles, and silt.
- Bootlegger Cove Formation. Grey, dense, highly plastic CLAY.
- Contact
- Approximate Contact

- Well Identification
- Well Borehole
- Well Screen
- Bottom of Borehole
- Location of Water Table



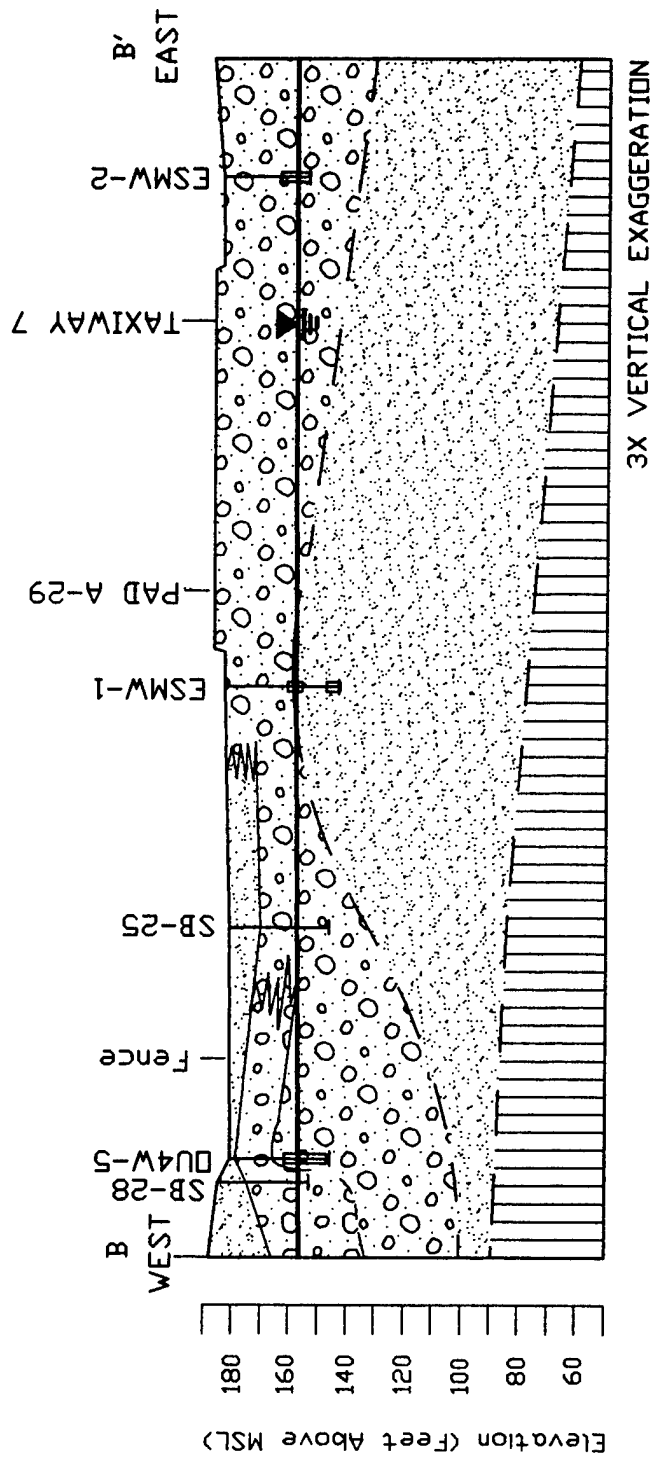
FIGURE 3.3

HYDROGEOLOGIC CROSS-SECTION A-A'

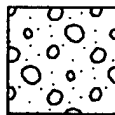
Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

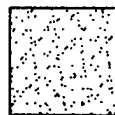
Denver, Colorado



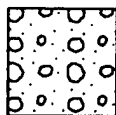
LEGEND



Brown sandy GRAVEL.
Cobbles and pebbles present.
Some silt.



Brown medium- to coarse-grained SAND. Silt, cobbles, gravel, and pebbles present.



Brown, gravelly SAND. Medium- to coarse-grained sand with cobbles, pebbles, and silt.



Bootlegger Cove Formation.
Grey, dense, highly plastic CLAY.

Well Identification

ESMW-1

Well

Well Screen

Bottom of Borehole

Location of Water Table

Contact

Approximate Contact



FIGURE 3.4

HYDROGEOLOGIC CROSS-SECTION B-B'

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

3.3.2 Grain Size Distribution

Grain size analyses were performed by Radian (1994) on soil samples from the soil borings SB-27 (sample collected from approximately 3 feet bgs) and SB-37 (sample collected from approximately 12 feet bgs). Both samples are representative of the sand and gravel outwash aquifer. The samples contained 24 to 50 percent gravel and 42 to 72 percent sand, with up to 8 percent silt and clay. In addition to the samples from the aquifer, a sample was collected from the Bootlegger Cove Formation in soil boring SB-41. This sample contained 61 percent clay, 2 percent sand, and 37 percent silt (Radian, 1994).

3.3.3 Ground Water Hydraulics

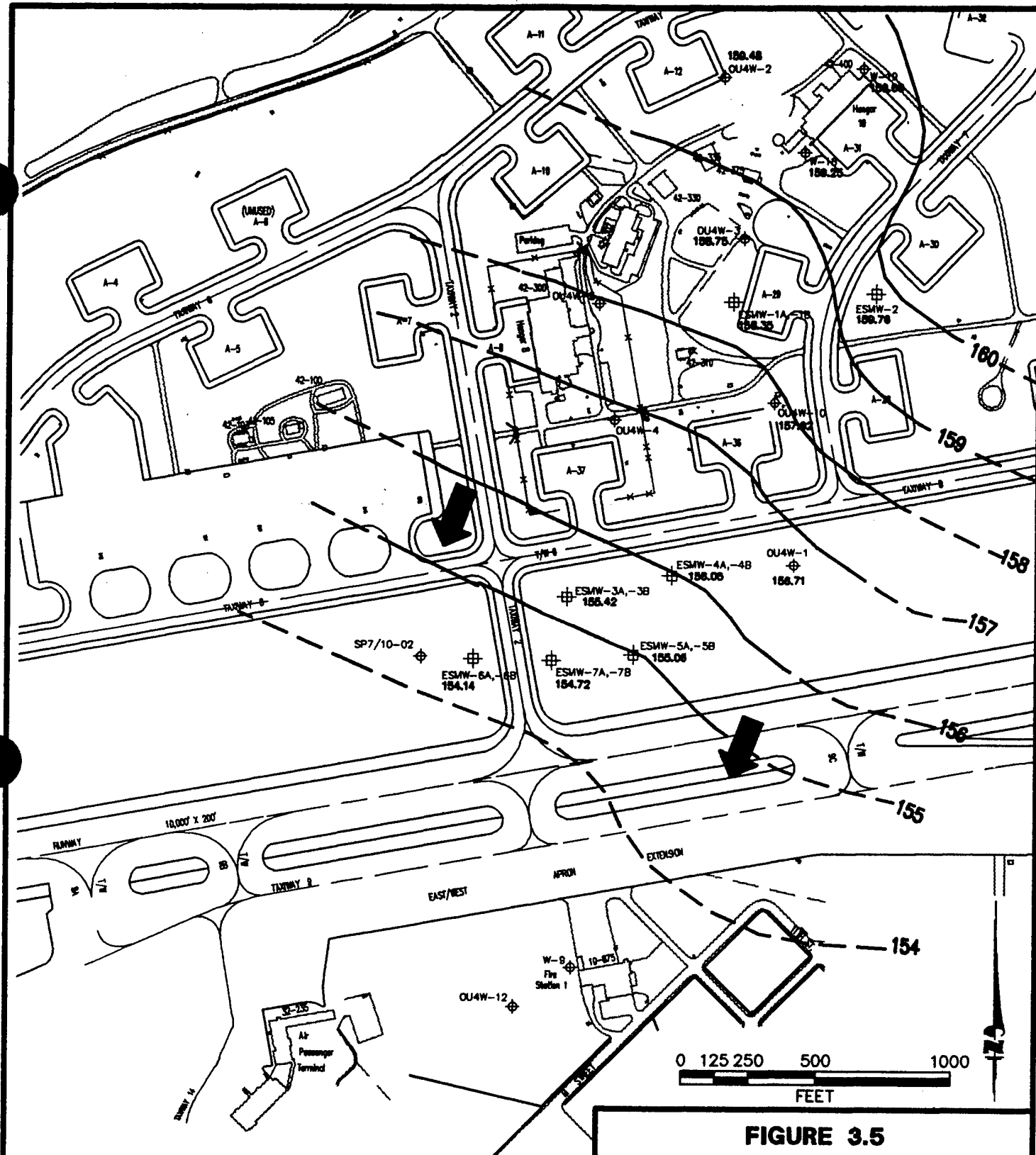
3.3.3.1 Flow Direction and Gradient

Depth to ground water in the vicinity of Hangar 10 ranges from 14 to 26 feet bgs. Ground water flow in the vicinity of Hangar 10 is to the south-southwest, with an average horizontal gradient of approximately 0.0022 foot per foot (ft/ft) (Figure 3.5). Table 3.1 presents available ground water elevation data. There is no evidence for significant vertical flow gradients within the shallow aquifer at this site, with vertical gradients (computed at well nests) varying from -0.002 (upward) to 0.002 (downward).

Results of previous site investigations show that there are slight seasonal variations in the ground water gradient at the site (Jacobs Engineering Group, 1994b). Horizontal hydraulic gradients in OU4 vary from 0.0016 to 0.0028 ft/ft, generally increasing and decreasing as the water levels rise and fall. Water levels are highest in late spring, decreasing through the summer until fall, when rains cause another rise. This rise continues through late fall, and is followed by decreasing levels through the winter, until the spring thaw. Significant changes in flow direction have not been observed (Jacobs Engineering Group, 1994b).

3.3.3.2 Hydraulic Conductivity

One pumping test was conducted in 1988 in the sand and gravel unit of the outwash aquifer (Black & Veatch, 1990). The data were reanalyzed by Radian (1994). These results indicated a hydraulic conductivity range of approximately 0.2 to 0.6 foot per minute (ft/min) [0.1 to 0.3 centimeters per second (cm/sec)].



LEGEND

OU4W-1
186.71

MONITORING WELL LOCATION (JUNE 1993)
WITH GROUND WATER ELEVATION (FEET ABOVE NSL)

ESMW-5A-5B
184.14

MONITORING WELL LOCATION (JUNE 1994)
WITH GROUND WATER ELEVATION (FEET ABOVE NSL)

GROUND WATER FLOW DIRECTION

156

LINE OF EQUAL GROUND WATER ELEVATION
(DASHED WHERE INFERRED)

FIGURE 3.5

GROUND WATER ELEVATION MAP

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

TABLE 3.1

**WATER LEVEL ELEVATION DATA
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

Well Location	Date	State Plane Coordinates		Datum ^{a/} Elevation (ft msl) ^{b/}	Ground Elevation (ft msl)	Total Depth (ft bgs) ^{c/}	Depth to Water (ft btoc) ^{d/}	Water Elevation (ft msl)
		Easting	Northing					
ESMW-1A	6/24/94	1672847.38	2650825.96	183.09	183.2	27	24.72	158.37
ESMW-1B	6/24/94	1672847.74	2650831.76	183.12	183.2	40.5	24.74	158.38
ESMW-2	6/24/94	1673376.46	2650857.04	184.19	184.3	30	25.43	158.76
ESMW-3A	6/24/94	1672241.45	2649740.16	175.67	175.7	25	20.25	155.42
ESMW-3B	6/24/94	1672242.72	2649735.86	175.69	175.6	37.5	20.3	155.39
ESMW-4A	6/24/94	1672626.43	2649819.46	177.41	177.6	25	21.36	156.05
ESMW-4B	6/24/94	1672626.31	2649814.67	177.41	177.5	38.25	21.38	156.03
ESMW-5A	6/24/94	1672486.00	2649525.82	170.20	170.2	18	15.14	155.06
ESMW-5B	6/24/94	1672479.14	2649525.70	170.15	170.2	31	15.09	155.06
ESMW-6A	6/24/94	1671892.36	2649409.82	168.19	168.1	19	14.05	154.14
ESMW-6B	6/24/94	1671894.55	2649403.31	168.32	168.3	29	14.21	154.11
ESMW-7A	6/24/94	1672187.73	2649508.63	171.18	171.3	20	16.46	154.72
ESMW-7B	6/24/94	1672184.33	2649503.97	171.1	171.2	33	16.4	154.7
OU4W-1	6/24/94	1673077.65	2649859.28	179.10	179.97	34	22.39	156.71
OU4W-2	6/24/94	1673077.65	2651647.25	186.32	186.33	40	26.84	159.48
OU4W-3	6/24/94	1672886.91	2651058.48	183.08	183.00	37.5	24.33	158.75
OU4W-4	6/9/94	1672412.22	2650392.80	179.04	179.19	35.5	21.62	157.44
OU4W-5	6/9/94	1672353.52	2650820.95	180.61	180.70	35	22.5	158.11
OU4W-10	6/24/94	1673002.25	2650456.49	184.60	181.84	36	26.68	157.92
SP-7/10-02	6/24/94	NA ^{e/}	NA	NA	NA	26	14.38	NA
W-9	6/24/94	NA	NA	NA	NA	40	21.22	NA
W-18	6/24/94	1673107.9	2611371.93	186.24	NA	47.5	26.99	159.25
W-19	6/24/94	1673322.6	2611677.59	186.97	NA	45	27.31	159.66

^{a/} Datum is top of PVC casing.

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

^{c/} feet bgs = Feet below ground surface

^{d/} feet btoc = feet below top of casing

^{e/} NA = Not available

3.3.3.3 Effective Porosity

Because of the difficulty involved in accurately determining effective porosity, accepted literature values for the type of soil comprising the shallow saturated zone were used. Freeze and Cherry (1979) give a range of porosity for sand and/or gravel of 0.25 to 0.50. The effective porosity for sediments of the shallow saturated zone is assumed to be 0.35.

3.3.3.4 Advective Ground Water Velocity

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

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

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

K = Hydraulic conductivity [L/T] (0.4 ft/min)

dH/dL = Gradient [L/L] (0.0027 ft/ft)

n_e = Effective porosity (0.35).

Using this relationship in conjunction with site-specific data, the average advective ground water velocity at the site is 4.4 feet per day (ft/day), or approximately 1,600 feet/year.

3.3.3.5 Preferential Flow Paths

No preferential contaminant migration pathways were identified during the field work phase of this project. The depth to the water table and the high hydraulic conductivity of the aquifer materials prevent manmade features such as utility trenches or storm sewers from providing preferential flow paths. In addition, stratigraphic data do not indicate the presence of any high-conductivity zones of material that could influence subsurface flow. However, the thinning of the outwash caused by the local high spot of the Bootlegger Cove Formation observed at ESMW-3 may locally affect ground water flow.

3.3.4 Ground Water Use

Ground water from the shallow aquifer at Elmendorf AFB is not extracted for potable uses. Water supplementing on-base requirements is obtained from deep supply wells tapping the

confined unconsolidated deposits. Previous investigations (Jacobs Engineering Group, 1993; and Radian, 1994) have indicated that the Bootlegger Cove Formation is a competent confining unit, and that contamination from the shallow aquifer is unlikely to reach the deep aquifer.

3.4 CLIMATOLOGICAL CHARACTERISTICS

Climatic information contained in this section was compiled by Black & Veatch (1990). Elmendorf AFB is located in a transitional climatic zone, located between the maritime climatic zone to the south and the interior or continental zone to the north (Selkregg, 1972). The St. Elias and Chugach Mountains to the south act as a barrier to the influence of the northern Pacific Ocean, while the Alaska Range to the north protects the area from the extremely cold Arctic air masses of the state's interior region. As a result, the area experiences a moderate climate lacking extremes in precipitation or temperature. However, because of the northern latitude the area has reduced solar radiation, resulting in low mean annual temperatures.

Monthly mean high temperatures range from about 12°F in January to about 58°F in July. Record extreme high and low temperatures for the period from 1941 through 1984 were 86°F and -43°F, respectively (Leslie, 1986). Mean annual precipitation is 15.9 inches, of which 36 percent falls as snow.

SECTION 4

NATURE AND EXTENT OF CONTAMINATION AND SOIL AND GROUND WATER GEOCHEMISTRY

4.1 SOURCE OF CONTAMINATION

The source of contamination at the Hangar 10 site is not known with any degree of certainty, nor is it known how much fuel has leaked into the subsurface. Several potential sources have been identified in the Hangar 10 area. These sources, identified in Section 1.2, include POL pipelines, a pump house and a valve pit for the POL lines, and a 1,000-gallon UST with unknown contents. Locations of these potential sources are indicated on Figure 1.3. Radian (1994) identified two probable sources for the ground water contamination observed in the area. These include Pump House 2 and/or the POL lines located immediately downgradient of Hangar 10, and the UST immediately southwest of the hangar. Radian (1994) reported that all active fuel lines and tanks in the Hangar 10 area recently passed individual leak tests, but that a test of the entire system (including valve pits and pump houses) was not performed.

4.2 SOIL CHEMISTRY

4.2.1 Residual-Phase Contamination

Residual-phase light nonaqueous-phase liquid (LNAPL) is defined as the LNAPL that is trapped in the aquifer 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.

Previous evidence suggested that mobile LNAPL was present on the ground water and in the capillary fringe in the vicinity of monitoring well W-18 (Black & Veatch, 1990).

However, soil boring SB-39 was installed nearby in July 1993, and a zone of mobile LNAPL was not encountered. In 1993, no mobile LNAPL was detected in W-18 (Radian, 1994). A trace of mobile LNAPL was reported in W-19 (northwest of the hangar) in October 1993 (Jacobs Engineering Group, 1994b). Also, a petroleum sheen was noted on water that collected in boring SB-25 (Radian, 1994). Mobile LNAPL was not detected in any of the wells in the Hangar 10 area during this investigation. Residual-phase LNAPL contamination has been detected at the Hangar 10 site and is described in the following sections.

4.2.1.1 Previous Soil Quality Data

Prior to this investigation, 14 soil borings and 10 ground water monitoring wells have been completed in the vicinity of the Hangar 10 site and the associated hydrocarbon plume (Radian, 1994). In addition, 41 soil gas samples have been collected. None of these data suggest a definite source area for the contamination, nor are any contiguous areas of soil contamination indicated. In general, most soil contamination was detected in the area southwest of Hangar 10, in the vicinity of Pump House 2 and the UST.

Laboratory analytical results for soil samples collected during investigations at the site prior to 1993 indicated that petroleum hydrocarbon contamination was present in the subsurface soil west and southwest of Hangar 10, in the vicinity of the POL line, Pump House 2, and the UST immediately southwest of Hangar 10. A soil sample collected from a well installed just west of the hangar in 1989 (and abandoned in 1993) contained 907 milligrams per kilogram (mg/kg) of TPH (Black & Veatch, 1990). Soil from borehole SBSD24D, drilled in 1992 near the location of SB-39, contained diesel-range organics (DRO) and gasoline-range organics (GRO) in concentrations of 29,900 mg/kg and 35,500 mg/kg, respectively. Several petroleum-related semivolatile organic compounds (SVOCs) were also detected at that location, but there was no evidence of mobile LNAPL (CH2M Hill, 1992).

Soil gas sampling in 1993 indicated potential soil contamination immediately southwest of the hangar, as well as northeast of the hangar. Borehole SB-39 was drilled to confirm the presence of contamination to the southwest (in the vicinity of former borehole SBSD24D). In that borehole, unknown petroleum hydrocarbons were detected at concentrations up to 20 mg/kg at a depth of 25 to 27 feet bgs, and xylenes and other VOCs were detected at the same depth at concentrations up to 0.4 mg/kg. Also,

petroleum odors were observed during the drilling of WH-9, but no sample was collected because the augers were lost down the hole. Soil contamination northeast of the hangar was not confirmed in samples from soil borehole SB-38 (Radian, 1994). Soil borehole SB-37 was drilled just west of the hangar, near where a TPH concentration of 907 mg/kg was detected in 1989. In that boring approximately 0.085 mg/kg of total BTEX was detected, but only in the sample from 3.5 to 5 feet bgs. TPH compounds were also detected in SB-37, but only from 0 to 2 feet bgs.

Where the plume of ground water contamination is present in the vicinity of Hangar 8, little or no soil contamination was detected (Radian, 1994). A soil gas sample collected near the location of borehole SB-41 suggested the presence of contamination, but no significant concentrations of petroleum compounds VOCs were detected in soil samples from SB-41.

4.2.1.2 Soil BTEX Contamination

One to two soil samples from the vicinity of the water table in boreholes for wells ESMW-1B, ESMW-2, ESMW-4B, ESMW-5B, and ESMW-7B were submitted for laboratory analysis of BTEX and TMBs using method RSKSOP-124 (RSKSOP refers to RSKERL standard operating procedures). Table 4.1 presents soil BTEX data. Only one sample, from 26 to 28 feet bgs in borehole ESMW-1B, contained quantifiable concentrations of BTEX compounds. Toluene was detected at a concentration of 0.0078 mg/kg in that sample. TMBs were not detected.

4.2.1.3 Soil TPH Contamination

Table 4.1 also presents soil TPH data. TPH concentrations were quantified by comparison to a JP-4 fuel standard, using a modified version of EPA method 418.1. TPH concentrations were below the laboratory's quantification limit of 14.79 mg/kg in all soil samples collected from monitoring well boreholes at the Hangar 10 site.

4.2.2 Total Organic Carbon

TOC concentrations are used to estimate the amount of organic matter sorbed on soil particles or trapped in the interstitial passages of a soil matrix. The TOC concentration in the saturated zone is an important parameter used to estimate the amount of contaminant

TABLE 4.1

**FUEL HYDROCARBON COMPOUNDS DETECTED IN SOIL
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

Sample Location	Sample Depth (feet)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	p-Xylene (mg/kg)	m-Xylene (mg/kg)	o-Xylene (mg/kg)	Total Xylenes (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 JP-4 ^{a/} (mg/kg)	TOC (percent)
ESMW-1B	22-24	ND ^{b/}	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	ND	ND	BLQ ^{c/}	3.25
	26-28	<0.02	0.0078	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	<0.02	ND	BLQ	0.125
ESMW-2	22-24	ND	<0.02	ND	ND	<0.02	ND	<0.02	<0.02	ND	ND	ND	BLQ	NA ^{d/}
	24-26	ND	<0.02	ND	ND	<0.02	ND	<0.02	<0.02	ND	ND	ND	BLQ	NA
ESMW-4B	20-22	ND	<0.02	ND	ND	ND	<0.02	<0.02	<0.02	ND	ND	ND	BLQ	NA
	24-26	ND	<0.02	ND	ND	<0.02	ND	<0.02	<0.02	ND	ND	ND	BLQ	NA
ESMW-5B	14-16	ND	<0.02	ND	ND	ND	ND	ND	<0.02	ND	ND	ND	BLQ	NA
	17-18	ND	<0.02	ND	ND	ND	<0.02	<0.02	<0.02	ND	ND	ND	BLQ	NA

^{a/} TPH JP-4 = Total petroleum hydrocarbons quantified against a JP-4 fuel standard, using modified EPA Method 418.1

^{b/} ND = Not detected

^{c/} BLQ = Below limit of quantitation (14.79 mg/kg)

^{d/} NA = Data not available

Note: BTEX and TMB compounds in soil were analyzed using RSKSOP-124 (GC/MSD)

that could potentially be sorbed to the aquifer matrix. Sorption results in retardation of the contaminant plume relative to the average advective ground water velocity. Measurements of TOC were taken for two soil samples obtained from the vicinity of the water table at ESMW-1. The TOC content of the soil at this location was 3.25 percent at a depth of 22 to 24 feet bgs, and 0.125 percent at a depth of 26 to 28 feet bgs (Table 4.1).

These samples come from a location where BTEX and TPH compounds were detected, but the sample from 26 to 28 feet bgs likely represents a good estimation of the aquifer TOC. The toluene concentration in that sample was only 0.0078 mg/kg, and the TPH concentration was below the laboratory quantitation limit. In addition, this sample was collected below the water table, where the presence of residual LNAPL was less likely. The sample from 22 to 24 feet bgs was in the vicinity of the capillary fringe, and residual-phase hydrocarbons may have artificially increased the natural TOC concentration.

4.3 GROUND WATER CHEMISTRY

Three lines of evidence can be used to document the occurrence of natural attenuation: 1) documented loss of contaminant mass at the field scale; 2) geochemical evidence; and 3) laboratory microcosm studies. The first two lines of evidence (documented loss of contaminants and geochemical evidence) are used herein to support the occurrence of natural attenuation, as described in the following sections. Because these two lines of evidence strongly suggest that natural attenuation is occurring at this site, laboratory microcosm studies were not deemed necessary.

4.3.1 Dissolved-Phase BTEX Contamination

Laboratory analytical results for ground water samples collected during previous site investigations indicated the presence of fuel hydrocarbon and VOC contamination in the shallow saturated zone in the vicinity of Hangar 10. Table 4.2 summarizes previous ground water contaminant data collected by Radian (1994). Ground water samples collected in June 1994, by Parsons ES and RSKERL personnel confirmed these results. Table 4.3 summarizes ground water contaminant data for these samples.

Figure 4.1 is an isopleth map that shows the distribution of total BTEX dissolved in ground water as indicated by ground water screening data collected by Radian (1994) in

PREVIOUS GROUND WATER ANALYTICAL RESULTS
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

Location	Sample Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylene (µg/L)	Total BTEX (µg/L)	TPH as Gasoline (µg/L)	Unk. * Gasoline (µg/L)	Unk. ** Jet Fuel (µg/L)	TPH as Kerosene (µg/L)	Unk. *** Diesel (µg/L)	1,1,1-TCA ^v (µg/L)	1,1-DCA ^v (µg/L)
Monitoring Well Samples													
OU4W-1	07/31/93	ND ^d	0.579 B ^e	0.564	1.17	2.313	ND	ND	ND	ND	35.8	ND	ND
OU4W-2	07/29/93	ND	ND	0.877	1.76	2.637	ND	ND	ND	ND	39 B	ND	0.047
OU4W-3	07/29/93	2.53 P ^e	ND	10	24.1	36.63	0.549	924 I ^v	355 I	ND	ND	ND	0.702
OU4W-4	07/29/93	238	12.4 B	110	257 B	617.4	3.84	3360 I	1140 I	ND	ND	ND	ND
OU4W-5	07/29/93	0.18	1.87 B	1.04	2.1	5.19	ND	ND	ND	ND	43.4 B	3.32	1.46
OU4W-10	07/28/93	2.96 P	19.2 B	8.16	15	43.32	5880	ND	ND	780	ND	1.74	1.61
OU4W-12	07/29/93	ND	1.03 B	0.546	0.916	2.492	ND	ND	ND	ND	32.9 I	0.166	0.081
W-18	07/30/93	0.0701	0.482 B	0.0751 P	1.52	2.1472	ND	298 I	139 I	ND	ND	ND	2.13
W-19	07/30/93	ND	0.138	ND	0.195	0.333	ND	ND	ND	ND	28.6 B	3.13	5.81
SP7/10-02	07/31/93	ND	0.504 B	0.253	0.764	1.521	ND	ND	ND	ND	ND	1.39	1.14
HydroPunch Samples													
WH-7	06/04/93	ND	ND	ND	ND	0	NA ^f	NA	NA	NA	NA	0.05	ND
WH-10	06/06/93	1700	12000	1700	6800	22200	NA	NA	NA	NA	NA	ND	ND
WH-11	06/10/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	ND	ND
WH-12	06/06/93	4900	5600	1700 J ^v	6400 J	18600	NA	NA	NA	NA	NA	230	ND
WH-13	06/06/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	ND	ND
WH-14	06/11/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	ND	ND
WH-15	06/10/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	1.3	ND
WH-16	06/09/93	ND	0.4 J	ND	ND	0.4	NA	NA	NA	NA	NA	0.02 J	ND
WH-17	06/07/93	520	2800	810	3400	7530	NA	NA	NA	NA	NA	ND	ND
WH-18	06/11/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	0.031	ND
WH-19	06/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	ND	ND
WH-20	06/03/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	ND	ND
WH-21	07/07/93	ND	91	8.3	134	233.3	NA	NA	NA	NA	NA	ND	ND
WH-22	07/11/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	0.09	ND
WH-23	07/11/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	0.033	ND
Soil Boring Grab Samples													
SB-27	06/25/93	710	130	440	1450	2730	NA	NA	NA	NA	NA	ND	ND
SB-28	06/26/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	3.9	ND
SB-35	07/21/93	ND	39.8	ND	ND	39.8	NA	NA	NA	NA	NA	ND	ND
SB-37	07/15/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	0.27	ND
SB-38	07/16/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	0.21	ND
SB-39	07/17/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	ND	ND
SB-41	07/10/93	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	7	ND

Source: Radian, 1994

^f NA = Not Analyzed
^v J = Results are less than stated detection limit

Note: All compounds, except 1,1,1-TCA and 1,1-DCA, were analyzed using modified EPA Method SW8015.

1,1,1-TCA and 1,1-DCA were analyzed using method SW8010.

^b 1,1-DCA = 1,1-dichloroethane
^c ND = Not Detected

^d B = Compound detected in instrument blank

^e P = Presence of compound confirmed, concentration estimated

^f I = Unknown compounds quantified as the listed components; compounds may be the result of decomposition of fuel

* Unknown compounds within the gasoline range

** Unknown compounds within the jet fuel range

*** Unknown compounds within the diesel range

^v 1,1,1-TCA = 1,1,1-trichloroethane

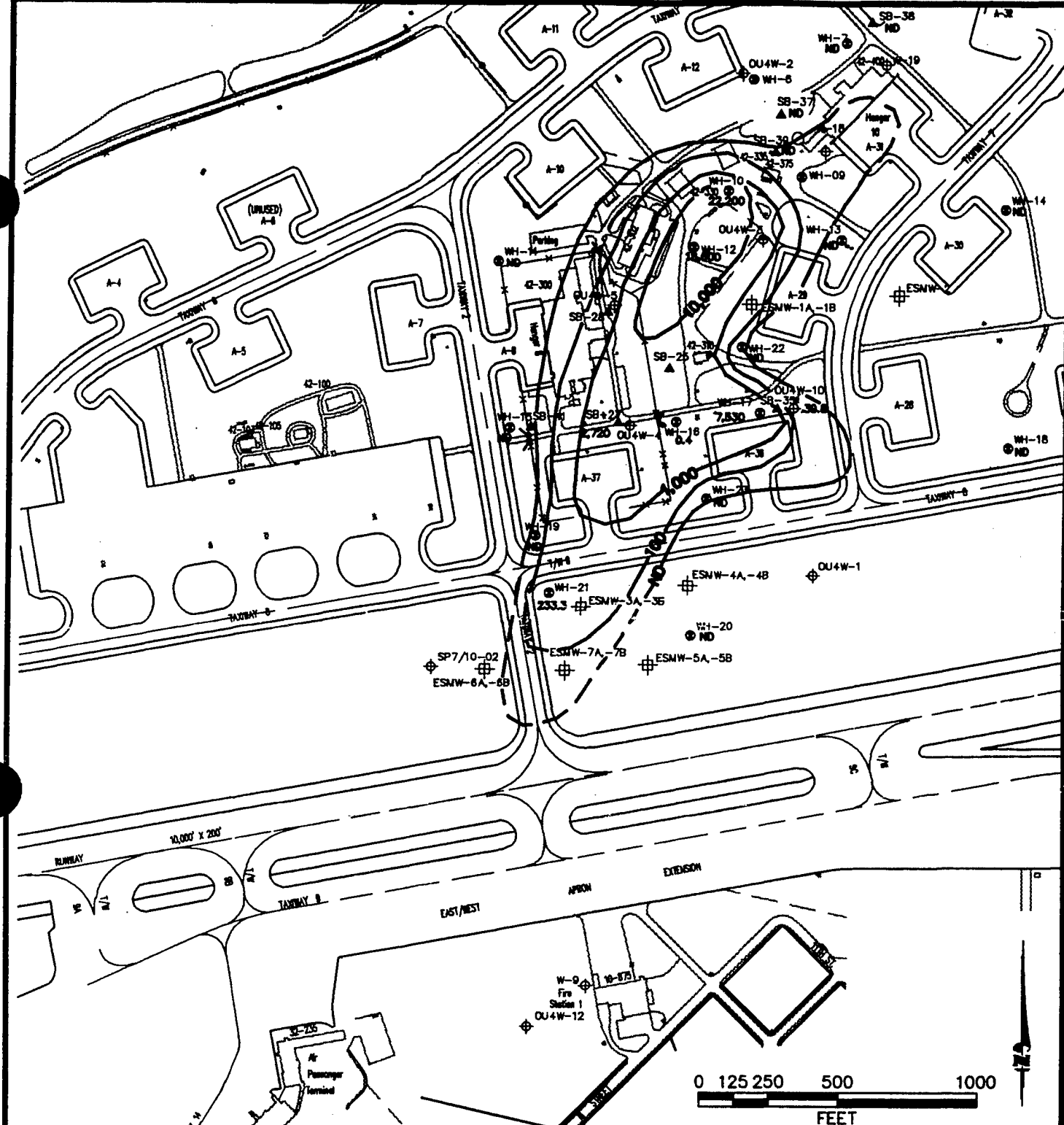
TABLE 4.3

FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUND WATER - JUNE 1994
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

Well Location	Sample Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)
ESMW-1A	6/11/94	<1	ND	ND ^{a/}	ND	<1	ND	<1	<1	ND	ND	ND
ESMW-1B	6/11/94	5.3	2.35	29.7	43.3	42.4	53.7	139.4	176.75	22.7	71.7	38.6
ESMW-2	6/17/94	2.15	2.29	1.5	1.53	1.36	1.09	3.98	9.92	1.54	1.61	1.79
ESMW-3A	6/14/94	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	<1
ESMW-3B	6/14/94	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND
ESMW-4A	6/13/94	1.52	1.54	ND	ND	ND	ND	ND	3.06	ND	ND	ND
ESMW-4B	6/13/94	ND	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND
ESMW-5A	6/16/94	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND
ESMW-5B	6/16/94	ND	1.34	ND	ND	<1	ND	<1	1.34	ND	ND	ND
ESMW-6A	6/15/94	ND	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND
ESMW-6B	6/15/94	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND
ESMW-7A	6/16/94	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND
ESMW-7B	6/16/94	<1	0.965	ND	ND	ND	ND	ND	0.965	ND	ND	ND
W-09	6/24/94	1.26	1.81	0.906	<1	1.37	1.07	2.44	6.416	<1	<1	<1
W-18	6/24/94	7.01	34.5	10.8	9.33	26.3	11.3	46.93	99.24	2.39	8.63	3.35
W-19	6/24/94	18.3	60.8	17.1	15	40.2	17.3	72.5	168.7	4.76	12.8	6.45
OU4W-1	6/24/94	2.16	3.02	1.61	1.07	3.52	1.61	6.2	12.99	<1	2.75	1.41
OU4W-2	6/24/94	2.84	16.8	5.27	4.33	12.6	6.05	22.98	47.89	1.32	5.01	2.26
OU4W-3	6/24/94	1.36	2.8	1.79	1.88	3.94	1.9	7.72	13.67	<1	2.63	1.71
OU4W-4	6/24/94	203	8.84	65.8	55.8	81.8	62.4	200	477.64	15.4	42.6	24.5
OU4W-5	6/24/94	1.48	3.82	2.8	2.4	6.82	3.16	12.38	20.48	<1	3.45	1.42
OU4W-10	6/24/94	1.41	2.21	1.39	1.07	2.97	1.31	5.35	10.36	<1	2.22	1.86
SP-710-02	6/24/94	<1	ND	ND	ND	0.969	ND	ND	0.969	ND	<1	<1

^{a/} ND Not detected at a detection limit of 1 µg/L

Note: BTEX and TMB compounds analyzed using method RSKSOP-133



LEGEND

- MONITORING WELL LOCATION (JUNE 1993)
- HYDROPUNCH LOCATION (JUNE - JULY 1993)
 WITH TOTAL BTEX CONCENTRATION (µg/L) (JUNE 1993)
- MONITORING WELL LOCATION (JUNE 1994)
- SOIL BORING (JUNE 1993)
 WITH TOTAL BTEX CONCENTRATION (µg/L) (JUNE 1993)
- LINE OF EQUAL BTEX CONCENTRATION (µg/L)
 (DASHED WHERE INFERRED)
- CONTOUR INTERVAL VARIABLE
- ND = BELOW DETECTION LIMIT
 CONCENTRATION AT WH-16 WAS IGNORED
 WHEN ISOPLETHS DRAWN

FIGURE 4.1
TOTAL BTEX ISOPLETH MAP
FOR GROUND WATER
(HYDROPUNCH AND GRAB
SCREENING SAMPLES)
JUNE - JULY 1993

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

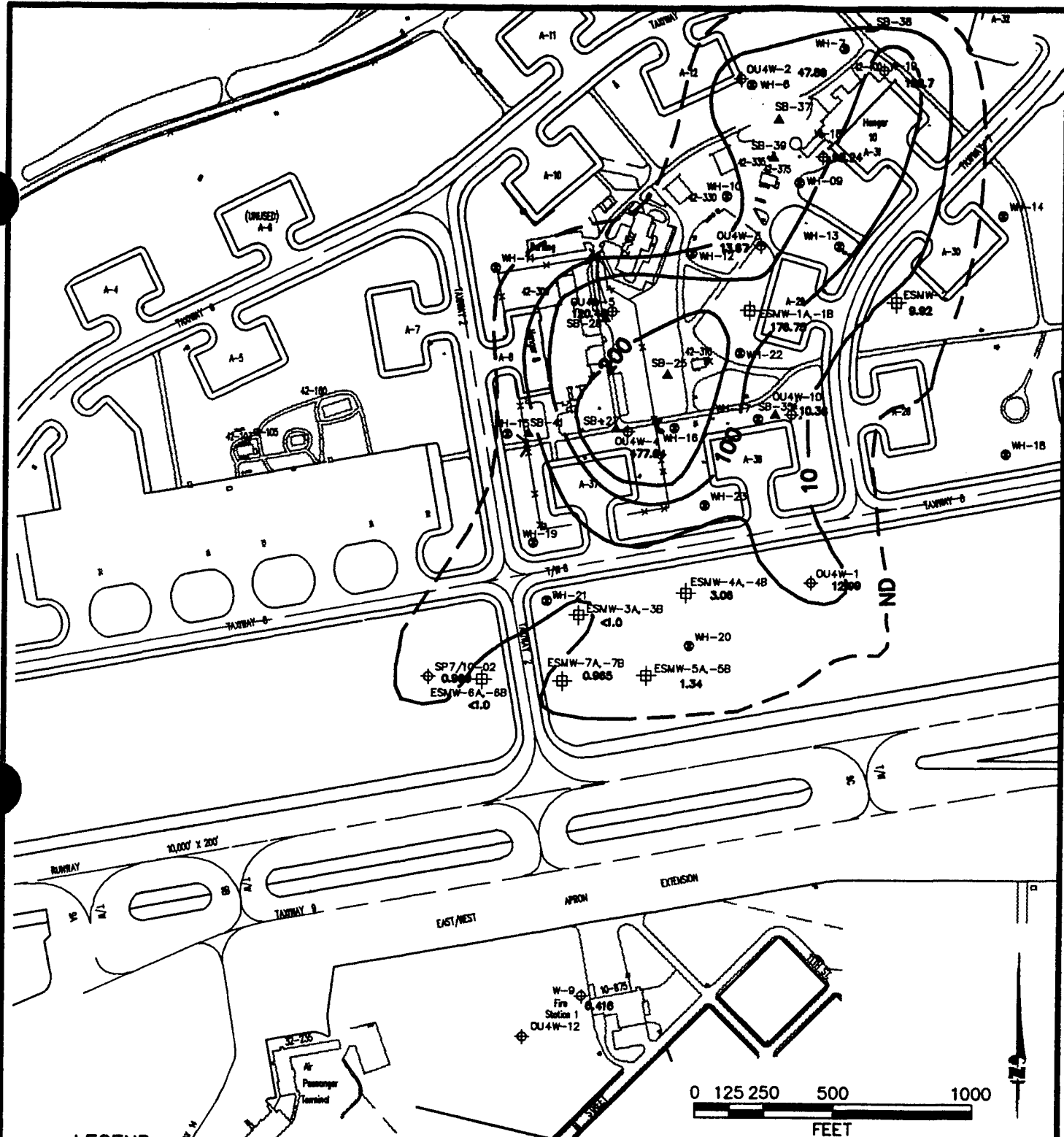
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June and July 1993. Except for samples from wells W-18 and W-19, these data are for grab samples collected from soil borings and for samples collected using the HydroPunch[®] method. Samples from monitoring wells installed in June and July 1993 are not included because they generally indicate lower total BTEX concentrations, particularly in locations adjacent to screening sample locations. Also, screening data were used because the screening samples covered a much larger area of the site. The BTEX plume observed in June 1993 was approximately 2,700 feet long and 900 feet wide at its widest point. The maximum observed total BTEX concentration was 22,200 micrograms per liter ($\mu\text{g/L}$) at HydroPunch[®] location WH-10.

Figure 4.2 is an isopleth map showing the distribution of total BTEX dissolved in ground water in June 1994. Where nested wells are present, isopleths are drawn based on the maximum concentration detected at each location. Comparison of Figures 4.1 and 4.2 suggests that minimal downgradient migration of BTEX compounds occurred during the 1-year period, with the plume at most 300 feet longer than that observed in 1993. However, it appears that significant lateral spreading has occurred, with the plume now approximately 1,500 feet wide at its widest point. In addition, it appears that total BTEX concentrations have generally decreased in the wells downgradient from OU4W-3. In 1994, the maximum observed BTEX concentration was 477 $\mu\text{g/L}$, in the sample collected from OU4W-4. This is downgradient of the highest concentrations observed in 1993. Benzene concentrations, where detected, ranged from 1.26 to 203 $\mu\text{g/L}$.

The lack of significant downgradient migration suggests that natural attenuation is limiting BTEX plume migration. Based on the estimated advective ground water velocity calculated in Section 3.3.3.4 (1,600 ft/yr), it is reasonable to expect that the plume would extend much further downgradient than was observed between 1993 and 1994. However, the 1994 data suggest that the plume has spread no more than 300 feet further downgradient. Actual spreading may be less, because the downgradient limit of the 1993 plume was not well defined. In addition, the core of the plume (the area with the highest concentrations) appears to have moved downgradient between 1993 and 1994. This suggests that the source for the observed BTEX contamination is no longer contributing significant hydrocarbon concentrations into the ground water. In addition, the decrease in BTEX concentrations between June 1993 and June 1994 suggests that significant degradation and attenuation of the plume occurred during that time.



LEGEND

OU4W-1
8.92
WH-20

MONITORING WELL LOCATION (JUNE 1993)
WITH TOTAL BTEX CONCENTRATION ($\mu\text{g/L}$) (JUNE 1994)
HYDROPUNCH LOCATION (JUNE - JULY 1993)

ESMW-5A-5B
1.34
SB-39

MONITORING WELL LOCATION (JUNE 1994)
WITH TOTAL BTEX CONCENTRATION ($\mu\text{g/L}$) (JUNE 1994)
SOIL BORING (JUNE 1993)

10

LINE OF EQUAL BTEX CONCENTRATION ($\mu\text{g/L}$)
(DASHED WHERE INFERRED)

CONTOUR INTERVAL = VARIABLE

ND = BELOW DETECTION LIMIT

NOTE: AT NESTED WELLS, THE HIGHEST TOTAL BTEX CONCENTRATION IS LISTED.

FIGURE 4.2

TOTAL BTEX ISOPLETH MAP FOR GROUND WATER JUNE 1994

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

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It is noteworthy that total BTEX concentrations in wells upgradient of OU4W-3 (i.e., in the immediate vicinity of Hangar 10) increased slightly compared to the 1993 results. This may indicate a possible upgradient source, or it may indicate increased dissolution of BTEX from a small, undiscovered body of contaminated soil.

It is possible that some of the difference in BTEX concentrations between 1993 and 1994 might be accounted for by the different analytical methods used in each investigation. Samples collected in 1993 were analyzed using a modified Method SW8015, while samples collected in 1994 were analyzed using RSKSOP-124.

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 Hangar 10 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, ferrous 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 use electron acceptors in the following order of preference: nitrate, ferric iron hydroxide, sulfate, and finally carbon dioxide.

Depending on the types and concentrations of electron acceptors present (e.g., nitrate, 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 the 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.

Hangar 10 ground water data for electron acceptors such as nitrate and sulfate suggest that intrinsic remediation of hydrocarbons in the shallow aquifer by denitrification and sulfate reduction is occurring. In addition, data for ferrous iron (Fe^{2+}) and methane suggest that anaerobic degradation via ferric iron reduction and methanogenesis is occurring. Geochemical parameters for Hangar 10 ground water are discussed in the following sections.

4.3.2.1 Dissolved Oxygen

DO concentrations were measured at monitoring wells in June 1994. Table 4.4 summarizes DO concentrations. Figure 4.3 is an isopleth map showing the distribution of DO concentrations in ground water. Comparison of Figures 4.2 and 4.3 shows graphically that areas with elevated total BTEX concentrations correlate with areas with depleted DO concentrations. This is an indication that aerobic biodegradation of the BTEX compounds is occurring at the site. Based on the low DO levels measured at the site (0.8 mg/L maximum, measured near the downgradient portion of the plume), it appears that DO may not be the most important electron acceptor in the Hangar 10 vicinity. Anaerobic processes likely play a more significant role in the natural attenuation of petroleum hydrocarbons.

The observed DO concentrations, including those from the upgradient well OU4W-2, appear uncharacteristically low, given the high porosity and permeability of the aquifer and the low ground water temperatures (DO solubility increases with decreasing temperature). In addition, DO concentrations measured in ground water in the vicinity of the ST41 site at Elmendorf AFB (approximately 1.5 miles west of Hangar 10) were as high as 12.6 mg/L (Parsons ES, in preparation). It therefore might be expected that the background DO concentration at this site would be much higher. The low observed upgradient DO concentration suggests that other known or unknown sources of contamination are consuming DO upgradient of the Hangar 10 site. However, the maximum DO concentration measured at the site (0.8 mg/L) will be assumed to be the background DO concentration for modeling purposes.

The following equations describe the overall stoichiometry of aromatic hydrocarbon mineralization caused by aerobic microbial biodegradation. In the absence of microbial

**GROUND WATER GEOCHEMICAL DATA
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

Sample Location	Sample Date	Temperature (C)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Total Alkalinity (mg/L)	Conductivity (µmhos)	pH	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	NO ₃ +NO ₃ Nitrogen (mg/L)	Methane (mg/L)	TOC (mg/L)
ESMW-1A	6/13/94	6.70	0.20	152	310	632	6.4	0.13	5.14	0.7	15.7	2.373	2.3
ESMW-1B	6/13/94	6.70	0.10	-20	460	876	6.9	0.07	5.49	9.0	<0.5	8.5	4.1
ESMW-2	6/22/94	7.00	0.61	188	365	865	NA ^{a/}	3.14	21.3	<0.05	9.1	<0.001	NA
ESMW-3A	6/22/94	6.40	0.60	240.1	386	817	NA	8.04	2.12	<0.05	7.64	0.063	NA
ESMW-3B	6/22/94	6.50	0.67	209	385	793	NA	5.64	8.14	<0.05	1.13	0.192	NA
ESMW-4A	6/22/94	5.90	1.6 ^{b/}	131.7	115	388	NA	3.09	26.7	<0.05	9.98	<0.001	NA
ESMW-4B	6/22/94	5.90	0.44	71.9	93.9	272	NA	2.74	27.7	<0.05	0.24	0.063	NA
ESMW-5A	6/23/94	5.70	*	249.9	230	558	NA	4.26	15	<0.05	4.58	<0.001	NA
ESMW-5B	6/23/94	NA	*	208.8	114	312	NA	1.72	22.5	<0.05	0.68	0.133	NA
ESMW-6A	6/23/94	5.70	1.16 ^{b/}	255.8	368	1140	NA	5.36	17.3	<0.05	49.2	<0.001	NA
ESMW-6B	6/23/94	5.50	0.85	257.1	380	780	NA	6.89	4.32	<0.05	0.6	0.344	NA
ESMW-7A	6/23/94	6.40	1.36 ^{b/}	241.3	393	799	NA	4.69	4.47	<0.05	3.08	0.002	NA
ESMW-7B	6/23/94	5.50	*	229.7	406	827	NA	4.82	8.78	<0.05	0.23	0.008	NA
W-09	6/9/94	6.40	0.40	123	345	812	7	15.5	3.58	<0.05	15.5	0.002	1.6
W-18	6/8/94	7.90	0.10	-120	347	876	7	7.4	10.3	4.3	0.29	6.02	1.6
W-19	6/8/94	6.30	0.00	165	467	902	7	13.7	21.6	<0.05	7.44	0.004	1.3
OU4W-1	6/9/94	7.60	0.10	-39	456	908	6.9	8.87	3.39	2.9	9.04	4.079	4.6
OU4W-2	6/3/94	6.90	0.20	33	326	683	7.2	13.3	13	<0.05	3.23	0.008	1.1
OU4W-3	6/9/94	8.20	0.00	-20	428	834	7	3.48	5.02	0.4	15.4	0.136	1.3
OU4W-4	6/9/94	7.90	0.30	-80	353	733	7.1	7.71	8.41	4.6	1.71	0.993	2
OU4W-5	6/9/94	7.90	0.00	60	274	662	7.1	19.5	13.6	<0.05	8.88	0.001	1.6
OU4W-10	6/9/94	7.80	0.10	20	265	544	6.9	3.04	4.49	0.3	8.27	<0.001	1.8
SP/710-02	6/9/94	6.80	0.80	40	269	790	6.9	25.6	18.6	<0.05	15.1	0.001	1.2

^{a/} NA = Data not available.

^{b/} Data suspect due to instrument malfunction.

* = Dissolved oxygen meter malfunctioned.

Note: Analytical methods as follows:

Temperature, dissolved oxygen, redox potential, conductivity, pH - direct reading meter (field)

Alkalinity - EPA Method E150.1, titrimetric

Chloride - EPA Method E300

Sulfate - Hach method 8051 (field)

Ferrous Iron - Hach method 8146 (field)

NO₃ + NO₃ (as Nitrogen) - EPA Method E353.1

Methane - RSKSOP-147 (FID)

TOC - RSKSOP-102

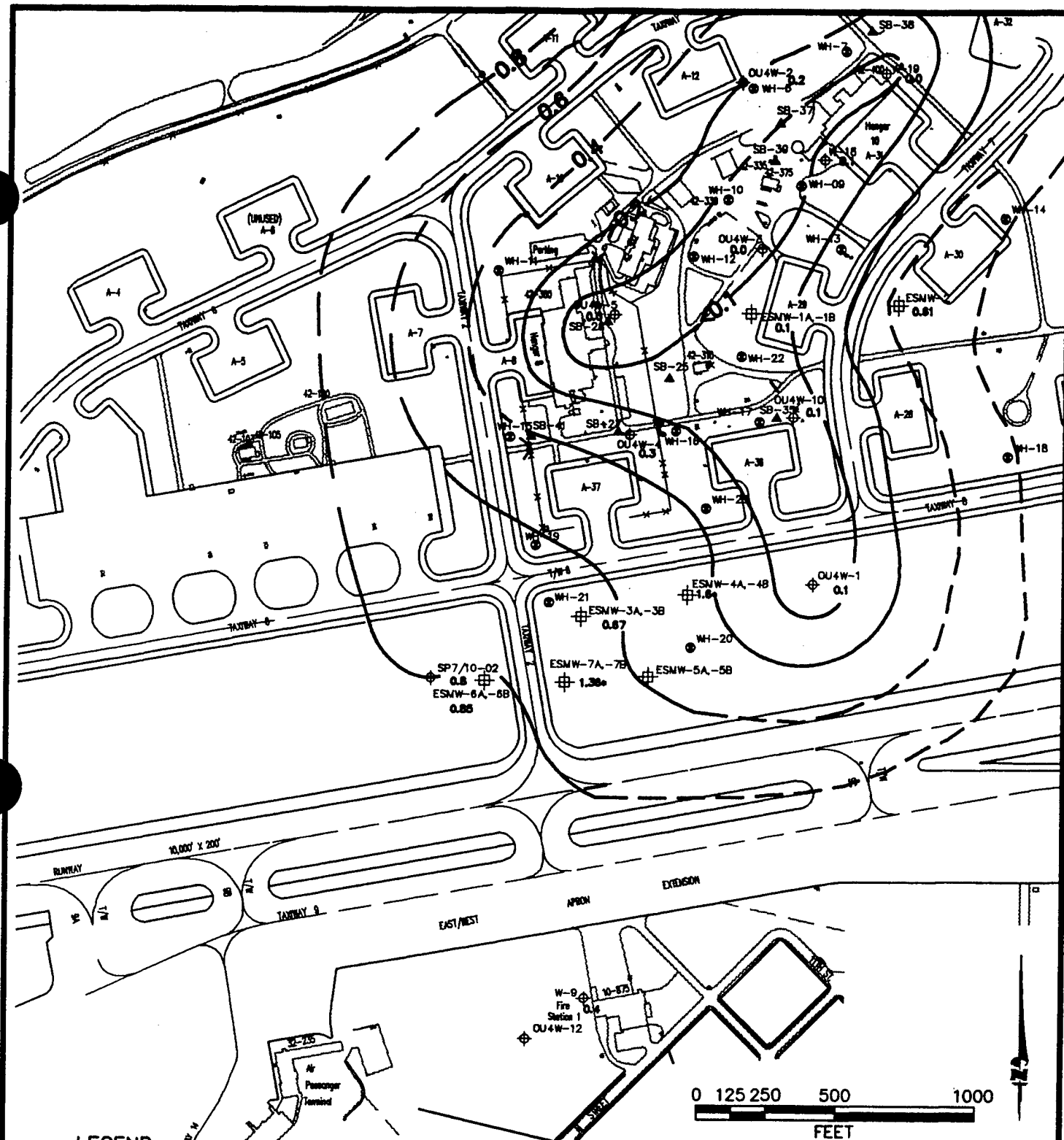


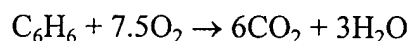
FIGURE 4.3
DISSOLVED OXYGEN
ISOPLETH MAP
FOR GROUND WATER
JUNE 1994

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

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cell production, the oxidation (mineralization) of benzene to carbon dioxide and water is given by:



Therefore, 7.5 moles of oxygen are required to metabolize 1 mole of benzene. On a mass basis, the ratio of oxygen to benzene is given by:

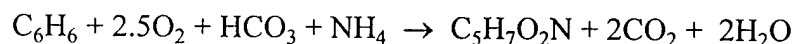
Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Oxygen	$7.5(32) = 240 \text{ gm}$

$$\text{Mass Ratio of Oxygen to Benzene} = 240/78 = 3.08:1$$

Therefore, in the absence of microbial cell production, 3.08 mg of oxygen are required to completely metabolize 1 mg of benzene.

Similar calculations can be completed for toluene (3.13 oxygen to 1 toluene), ethylbenzene (3.17 oxygen to 1 ethylbenzene), and the xylenes (3.17 oxygen to 1 xylene). The average mass ratio of oxygen to total BTEX is thus 3.14:1. This means that approximately 0.32 mg of BTEX is mineralized for every 1.0 mg of DO consumed. With a maximum probable background DO concentration of approximately 0.8 mg/L, the shallow ground water at this site has the capacity to assimilate 0.26 mg/L (260 $\mu\text{g/L}$) 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 shown above.

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



From this it can be seen that only 2.5 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:

Benzene	$6(12) + 1(6) = 78 \text{ gm}$
Oxygen	$2.5(32) = 80 \text{ gm}$

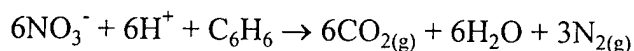
$$\text{Mass Ratio of Oxygen to Benzene} = 80/78 = 1.03:1$$

Based on 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. Based on these calculations, approximately 0.97 mg of BTEX is mineralized to carbon dioxide and water for every 1.0 mg of DO consumed. With a background DO concentration of approximately 0.8 mg/L, the shallow ground water at this site has the capacity to assimilate 0.8 mg/L (800 µg/L) of total BTEX 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 ground water monitoring wells in June 1994. Nitrate concentrations at the site range from <0.5 mg/L to 15.1 mg/L. Table 4.4 summarizes measured nitrate and nitrite (as N) concentrations. Figure 4.4 is an isopleth map showing the distribution of nitrate + nitrite (as N) in ground water in June 1994. Comparison of this figure with Figure 4.2 shows graphically that areas with elevated total BTEX concentrations have depleted nitrate + nitrite concentrations. Comparison of Figures 4.3 and 4.4 shows graphically that areas with depleted DO concentrations also have depleted nitrate + nitrite concentrations. These relationships provide strong evidence that anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of denitrification.

In the absence of microbial cell production, the biodegradation of benzene via denitrification to carbon dioxide and water is given by:

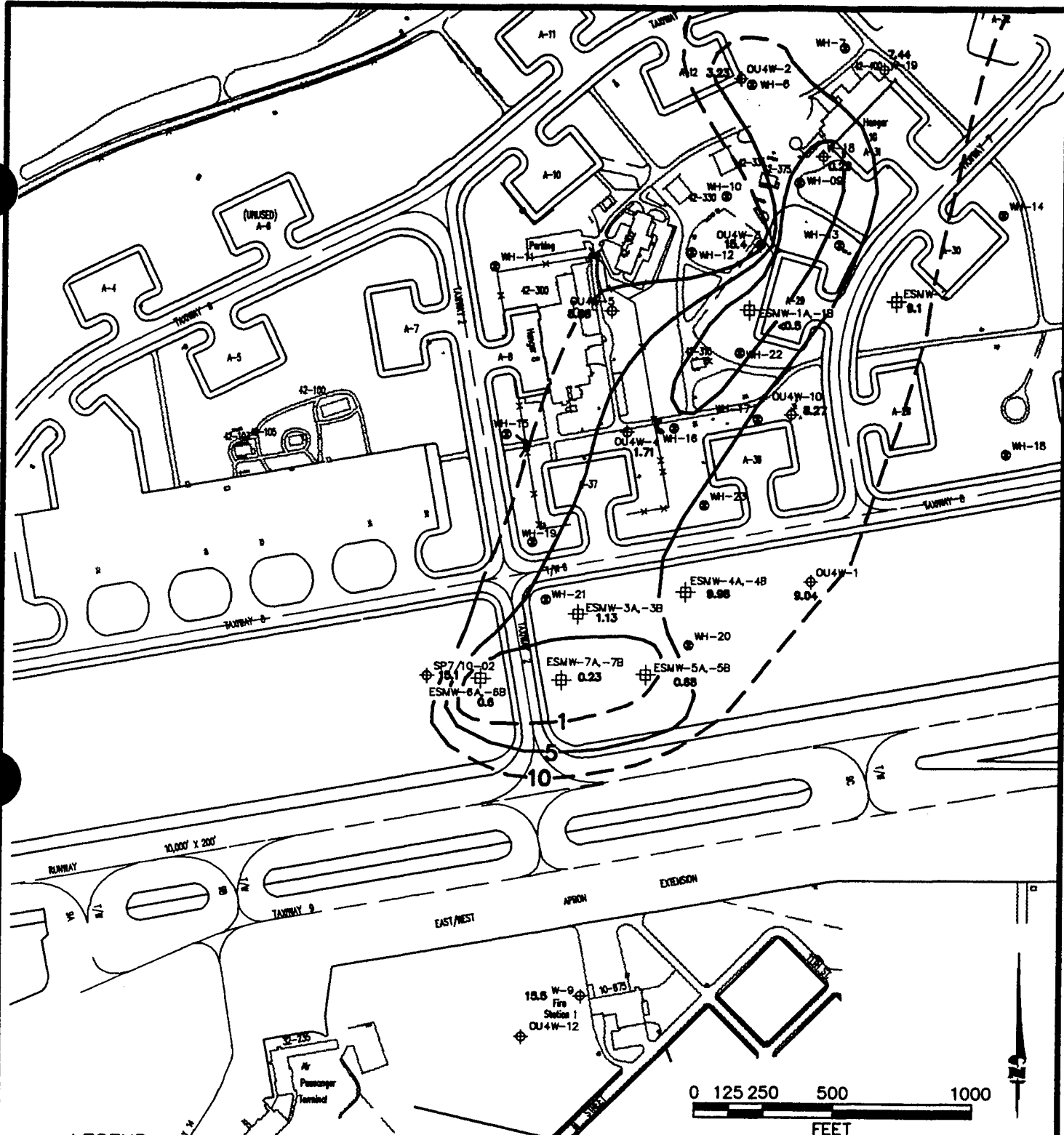


Based on this relationship, 6 moles of nitrate are required to mineralize 1 mole of benzene. On a mass basis, the ratio of nitrate to benzene is given by:

Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Nitrate	$6(62) = 372 \text{ gm}$

$$\text{Mass ratio of nitrate to benzene} = 372/78 = 4.77:1$$

In the absence of microbial cell production, 4.77 mg of nitrate are required to completely mineralize 1 mg of benzene. Similar calculations can be completed for toluene (4.85 mg nitrate to 1 mg toluene), ethylbenzene (4.92 mg nitrate to 1 mg ethylbenzene), and the xylenes (4.92 mg nitrate to 1 mg xylene). The average mass ratio



LEGEND

OU4W-1
18.1

WH-20

ESMW-5A, -5B
18.1

MONITORING WELL LOCATION (JUNE 1993)
WITH NITRATE CONCENTRATION (mg/L)(JUNE 1994)
HYDROPUNCH LOCATION (JUNE 1993)

MONITORING WELL LOCATION (JUNE 1994)
WITH NITRATE CONCENTRATION (mg/L)(JUNE 1994)

1.0

LINE OF EQUAL NITRATE CONCENTRATION (mg/L)
(DASHED WHERE INFERRED)

CONTOUR INTERVAL = VARIABLE

0 125 250 500 1000
FEET

FIGURE 4.4 **NITRATE + NITRITE (AS N)** **ISOPLETH MAP** **FOR GROUND WATER** **JUNE 1994**

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

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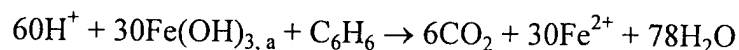
NOTE:
AT NESTED WELLS, THE CONCENTRATION FROM THE DEPTH CORRESPONDING
TO THE HIGHEST BTEX CONCENTRATION WAS USED TO GENERATE ISOPLETHS

of nitrate consumed to total BTEX degraded is 4.9:1. This means that approximately 0.20 mg of BTEX is mineralized for every 1.0 mg of nitrate consumed. With a maximum observed nitrate concentration of approximately 15 mg/L, the shallow ground water at this site has the capacity to assimilate 3.0 mg/L (3,000 µg/L) of total BTEX during denitrification. This is a conservative estimate of the assimilative capacity of nitrate because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1).

4.3.2.3 Ferrous Iron

Ferrous iron (Fe^{2+}) concentrations were measured at ground water monitoring wells in June 1994. Table 4.4 summarizes ferrous iron concentrations. Figure 4.5 is an isopleth map showing the distribution of ferrous iron in ground water. Comparison of Figures 4.5 and 4.2 shows graphically that most of the area with elevated total BTEX concentrations has elevated ferrous iron concentrations. This suggests that ferric iron hydroxide (Fe^{3+}) is being reduced to ferrous iron during biodegradation of BTEX compounds. The highest measured ferrous iron concentration, 9.0 mg/L, was observed at ESMW-1B. Ferrous iron concentrations of 4.3 and 4.6 mg/L were observed at W-18 and OU4W-4. Well OU4W-4 is also the location with the highest total BTEX concentration. Background levels of ferrous iron are generally at or below 0.4 mg/L, as measured at wells with little or no known BTEX contamination.

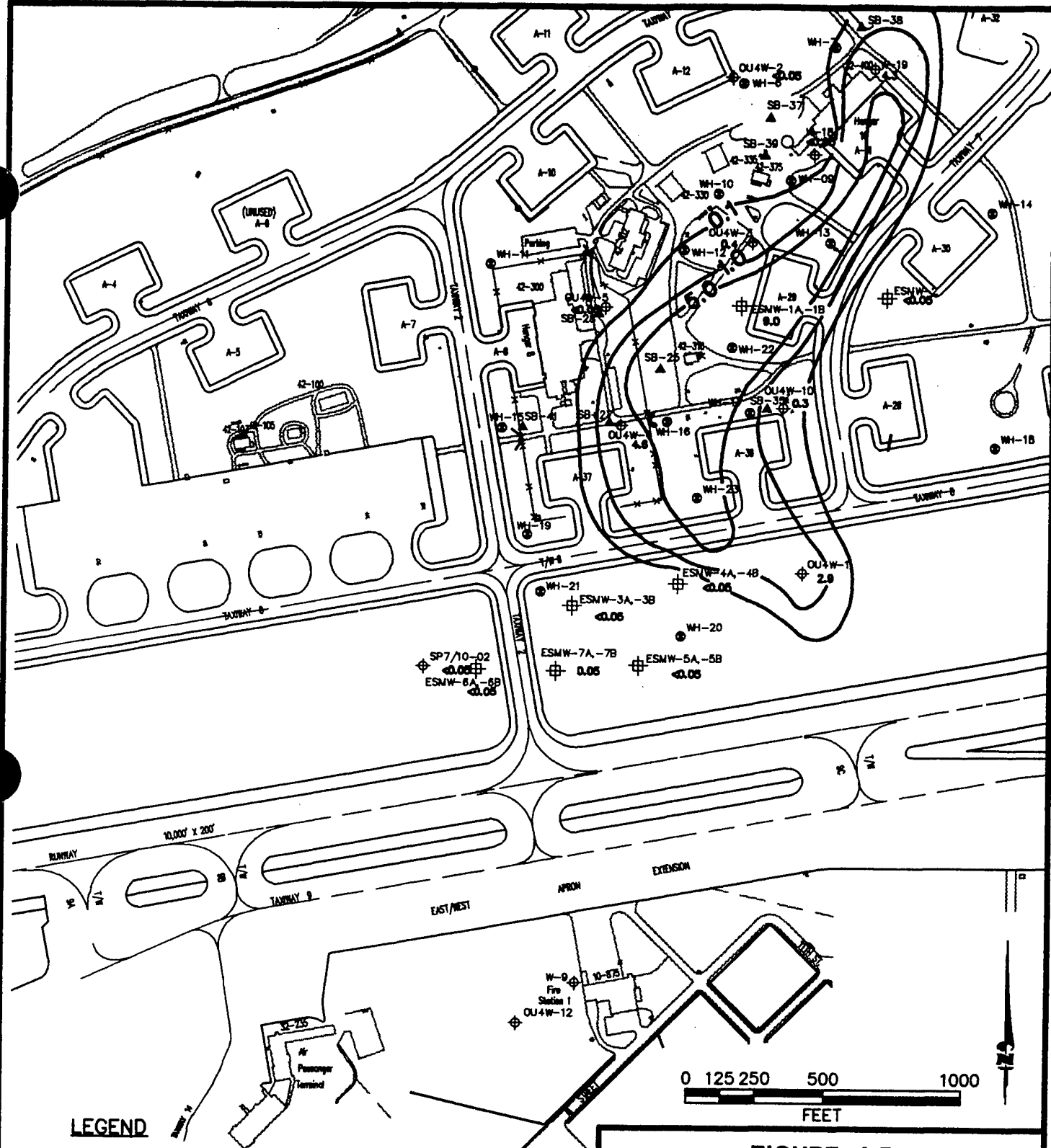
The following equations describe the overall stoichiometry of benzene oxidation by iron reduction caused by anaerobic microbial biodegradation. In the absence of microbial cell production, the mineralization of benzene is given by:



Therefore, 30 moles of ferric iron are required to metabolize 1 mole of benzene. On a mass basis, the ratio of ferric iron to benzene is given by:

Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Ferric Iron	$30(106.85) = 3205.41 \text{ gm}$

$$\text{Mass ratio of ferric iron to benzene} = 3205.41/78 = 41.1:1$$



LEGEND

- MONITORING WELL LOCATION (JUNE 1993)
 WITH FERROUS IRON CONCENTRATION (mg/L) (JUNE 1994)
- HYDOPUNCH LOCATION (JUNE - JULY 1993)
- MONITORING WELL LOCATION (JUNE 1994)
 WITH FERROUS IRON CONCENTRATION (mg/L) (JUNE 1994)
- SOIL BORING (JUNE 1993)
- LINE OF EQUAL FERROUS IRON CONCENTRATION (mg/L)
- CONTOUR INTERVAL = VARIABLE

NOTE:
 AT NESTED WELLS, THE CONCENTRATION FROM THE DEPTH CORRESPONDING
 TO THE HIGHEST BTEX CONCENTRATION WAS USED TO GENERATE ISOPLETHS

FIGURE 4.5
FERROUS IRON
ISOPLETH MAP
FOR GROUND WATER
JUNE 1994

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

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Therefore, in the absence of microbial cell production, 41.1 mg of ferric iron are required to completely metabolize 1 mg of benzene. Alternatively, the mass ratio of ferrous iron produced during respiration to benzene degraded can be calculated and is given by:

Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Ferrous Iron	$30(55.85) = 1675.5 \text{ gm}$

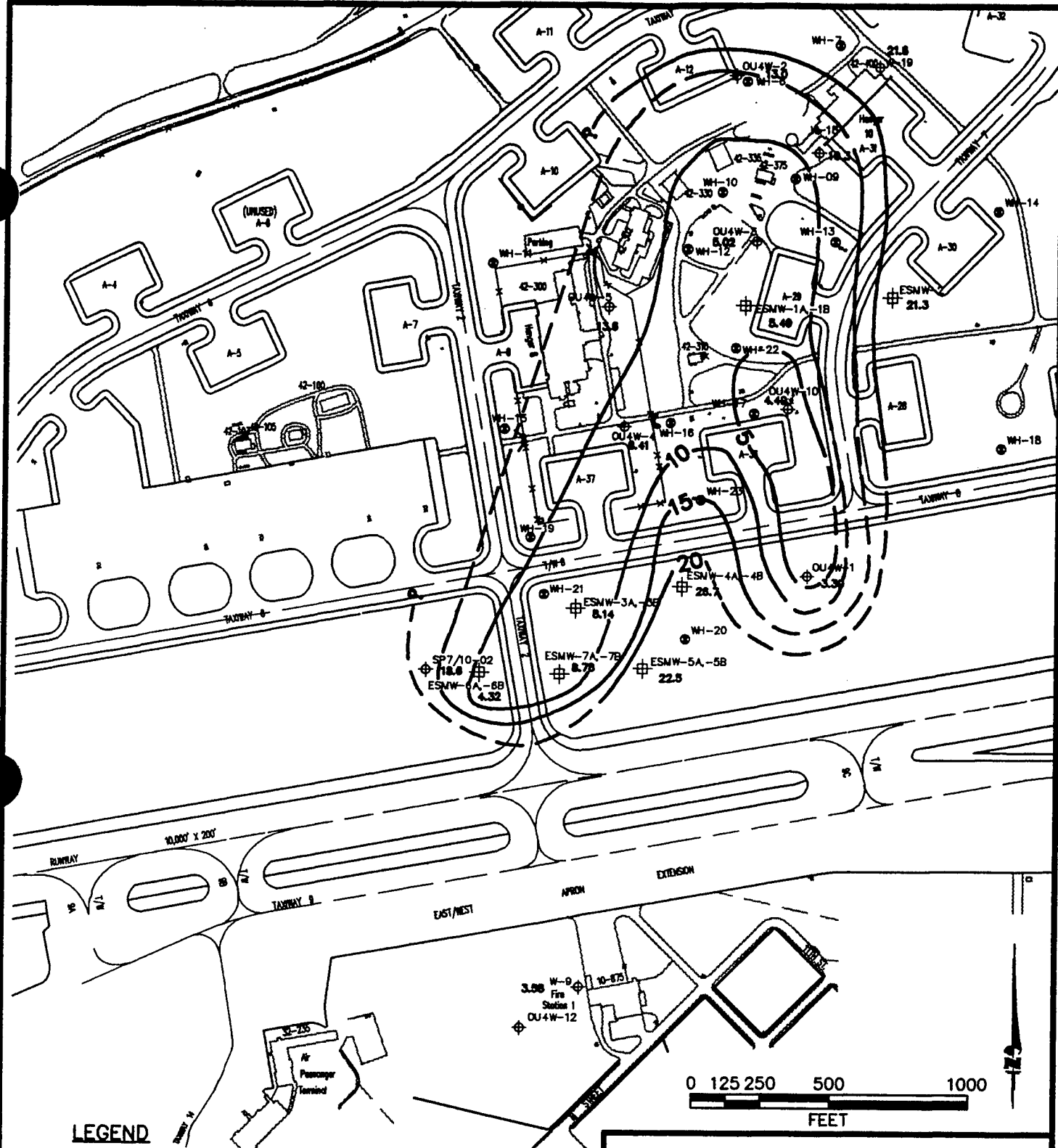
$$\text{Mass ratio of ferrous iron to benzene} = 1675.5/78 = 21.5:1$$

Therefore, 21.5 mg of ferrous iron are produced during mineralization of 1 mg of benzene.

Similar calculations can be completed for toluene (21.86 mg of Fe^{2+} produced during mineralization of 1 mg of toluene), ethylbenzene (22 mg of Fe^{2+} produced during mineralization of 1 mg of ethylbenzene), and the xylenes (22 mg of Fe^{2+} produced during mineralization of 1 mg of xylene). The average mass ratio of Fe^{2+} produced during total BTEX mineralization is thus 21.8:1. This means that approximately 1 mg of BTEX is mineralized for every 21.8 mg of Fe^{2+} produced. The highest measured Fe^{2+} concentration was 9.0 mg/L. This suggests that the shallow ground water at this site has the capacity to assimilate 0.41 mg/L (410 $\mu\text{g/L}$) of total BTEX during iron reduction. This is a conservative estimate of the assimilative capacity of iron because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1). 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.

4.3.2.4 Sulfate

Sulfate concentrations were measured at ground water monitoring wells in June 1994. Sulfate concentrations at the Hangar 10 site range from 3.39 mg/L to 26.7 mg/L. Table 4.4 summarizes measured sulfate concentrations. Figure 4.6 is an isopleth map showing the distribution of sulfate in ground water in June 1994. Comparison of Figures 4.6 and 4.2 shows graphically that areas with elevated total BTEX concentrations have depleted sulfate concentrations. This is a strong indication that anaerobic biodegradation of BTEX compounds is occurring at the site through the microbially mediated process of sulfate reduction.



LEGEND

OU4W-1
 4.32

WH-20

ESMW-5A-5B
 4.32

MONITORING WELL LOCATION (JUNE 1993)
 WITH SULFATE CONCENTRATION (mg/L) (JUNE 1994)
 HYDOPUNCH LOCATION (JUNE - JULY 1993)
 MONITORING WELL LOCATION (JUNE 1994)
 WITH SULFATE CONCENTRATION (mg/L) (JUNE 1994)

5.0

LINE OF EQUAL SULFATE CONCENTRATION (mg/L)
 (DASHED WHERE INFERRED)
 CONTOUR INTERVAL = 5 mg/L

NOTE:
 AT NESTED WELLS, THE CONCENTRATION FROM THE DEPTH CORRESPONDING
 TO THE HIGHEST BTEX CONCENTRATION WAS USED TO GENERATE ISOPLETHS

FIGURE 4.6

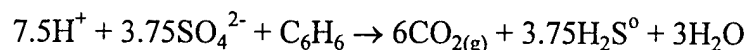
SULFATE ISOPLETH MAP FOR GROUND WATER JUNE 1994

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

The following equations describe the overall stoichiometry of BTEX oxidation by sulfate reduction caused by anaerobic microbial biodegradation. In the absence of microbial cell production, the biodegradation of benzene is given by:



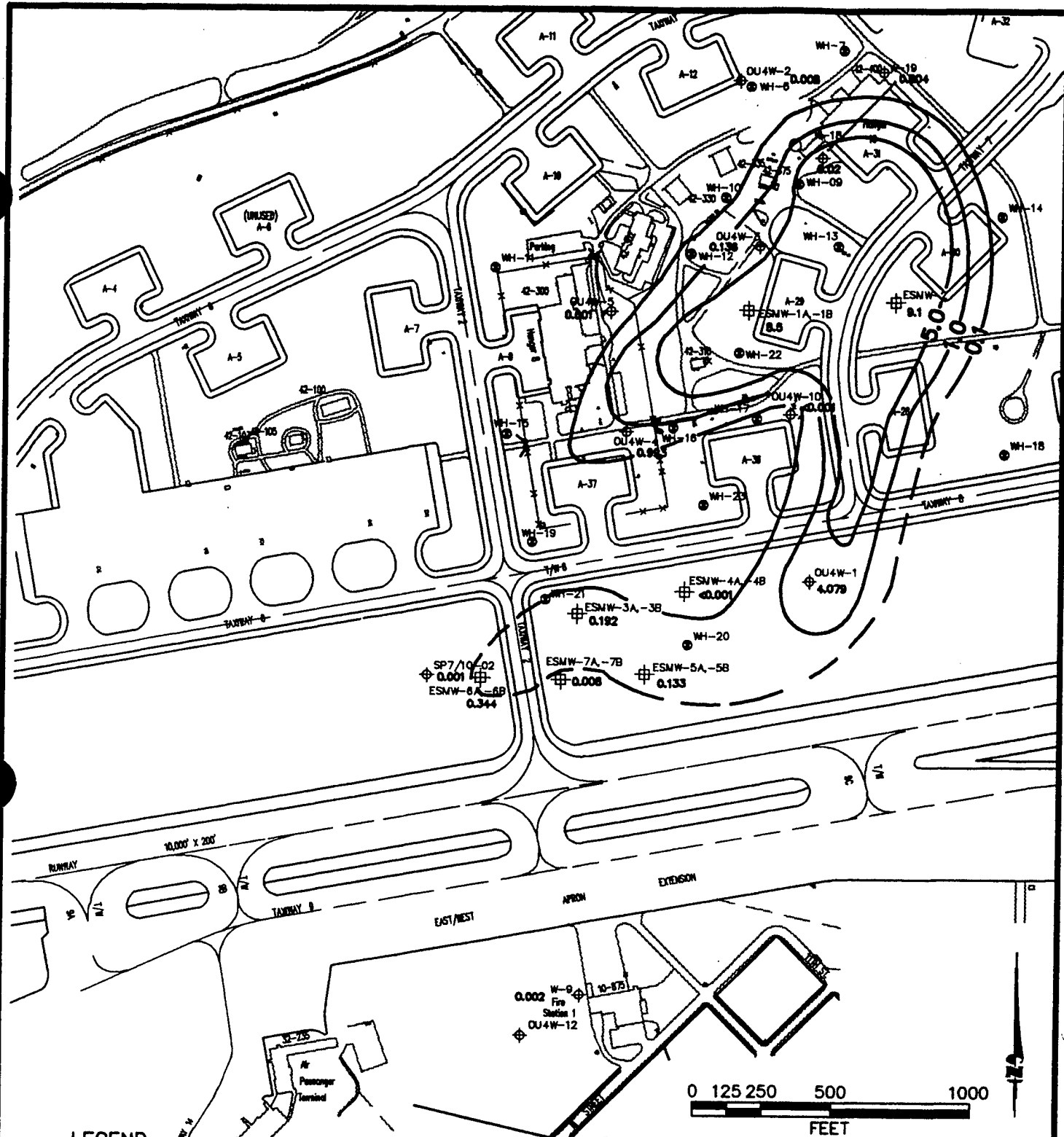
Therefore, 3.75 moles of sulfate are required to mineralize 1 mole of benzene. On a mass basis, the ratio of sulfate to benzene is given by:

Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Sulfate	$3.75(96) = 360 \text{ gm}$
Mass ratio of sulfate to benzene = $360/78 = 4.6:1$	

Therefore, in the absence of microbial cell production, 4.6 mg of sulfate are required to completely mineralize 1 mg of benzene. Similar calculations can be completed for toluene (4.7 mg sulfate to 1 mg toluene), ethylbenzene (4.75 mg sulfate to 1 mg ethylbenzene), and the xylenes (4.75 mg sulfate to 1 mg xylene). The average mass ratio of sulfate to total BTEX is thus 4.7:1. This means that approximately 0.21 mg of BTEX is mineralized for every 1.0 mg of sulfate consumed. Assuming a background sulfate concentration of 26 mg/L, the shallow ground water at this site has the capacity to assimilate 5.46 mg/L (5,460 $\mu\text{g/L}$) of total BTEX during sulfate reduction. Again, this is a very conservative estimate of the assimilative capacity of sulfate because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1).

4.3.2.5 Methane in Ground Water

Methane concentrations were measured at ground water monitoring wells in June 1994. Table 4.4 summarizes methane concentrations. Figure 4.7 is an isopleth map showing the distribution of methane in ground water. Comparison of Figures 4.2 and 4.7 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. This is consistent with other electron acceptor data for this site, with the area having elevated methane concentrations corresponding with the areas with depleted DO, nitrate, and sulfate concentrations and elevated ferrous iron concentrations.



LEGEND

OU4W-1
0.192
WH-20

MONITORING WELL LOCATION (JUNE 1993)
WITH METHANE CONCENTRATION (JUNE 1994)
HYDROPUNCH LOCATION (JUNE - JULY 1993)

ESNW-5A-5B
0.192

MONITORING WELL LOCATION (JUNE 1994)
WITH METHANE CONCENTRATION (JUNE 1994)

1.0

LINE OF EQUAL METHANE CONCENTRATION (mg/L)
(DASHED WHERE INFERRED)

CONTOUR INTERVAL = VARIABLE

NOTE:

AT NESTED WELLS, THE CONCENTRATION FROM THE DEPTH CORRESPONDING TO THE HIGHEST BTX CONCENTRATION WAS USED TO GENERATE ISOPLETHS

FIGURE 4.7

METHANE ISOPLETH MAP FOR GROUND WATER JUNE 1994

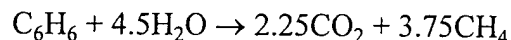
Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Methane concentrations ranged from <0.001 mg/L to 9.1 mg/L. Background levels of methane at wells outside areas with known BTEX contamination are below 0.01 mg/L. Samples collected from monitoring wells located near the area with the highest BTEX concentrations contain the highest methane concentrations. In these locations, methane concentrations range from about 0.133 to 9.1 mg/L. The highest methane concentration observed at the site was in ESMW-2, with significantly elevated concentrations also present in wells W-18, ESMW-1B, OU4W-1, and OU4W-4.

The following equations describe the overall stoichiometry of benzene oxidation by methanogenesis. In the absence of microbial cell production, the mineralization of benzene is given by:



The mass ratio of methane produced during respiration to benzene degraded can be calculated and is given by:

Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Methane	$3.75(16) = 60 \text{ gm}$

$$\text{Mass ratio of methane to benzene} = 60/78 = 0.77:1$$

Therefore, 0.77 mg of methane is produced during mineralization of 1 mg of benzene.

Similar calculations can be completed for toluene (0.78 mg of methane produced during mineralization of 1 mg of toluene), ethylbenzene (0.79 mg of methane are produced during mineralization of 1 mg of ethylbenzene), and the xylenes (0.79 mg of methane are produced during mineralization of 1 mg of xylene). The average mass ratio of methane produced during total BTEX mineralization is thus 0.78:1. This means that approximately 1 mg of BTEX is mineralized for every 0.78 mg of methane produced. The highest measured methane concentration was 9.1 mg/L. This suggests that the shallow ground water at this site has the capacity to assimilate up to 11.6 mg/L (11,600 µg/L) of total BTEX during methanogenesis. Again, this is a conservative estimate of the assimilative capacity of methanogenesis because microbial cell mass production is not taken into account by the stoichiometry shown above (see Section 4.3.2.1). In addition, these calculations are based on observed methane concentrations and not on the amount of carbon dioxide available in the aquifer. Therefore, methanogenic assimilative capacity could be much higher.

4.3.2.6 Reduction/Oxidation Potential

Redox potentials were measured at ground water monitoring wells in June 1994. Redox potential is a measure of the relative tendency of a solution to accept or transfer electrons. The redox potential of a ground water system depends on which electron acceptor is being reduced by microbes during BTEX oxidation. The redox potential at the Hangar 10 site ranges from 257.1 millivolts (mV) to -120 mV. Table 4.4 summarizes available redox potential data. Figure 4.8 is a map that graphically illustrates the distribution of redox potentials. Redox is decreased to values below -80 mV in the vicinity of OU4W-4 and W-18. As expected, areas at the site with low redox potentials appear to coincide with areas of high BTEX contamination, low DO, nitrate, and sulfate concentrations, and elevated ferrous iron and methane concentrations (compare Figure 4.8 with Figures 4.2, 4.3, 4.4, 4.5, 4.6, and 4.7).

4.3.2.7 Alkalinity

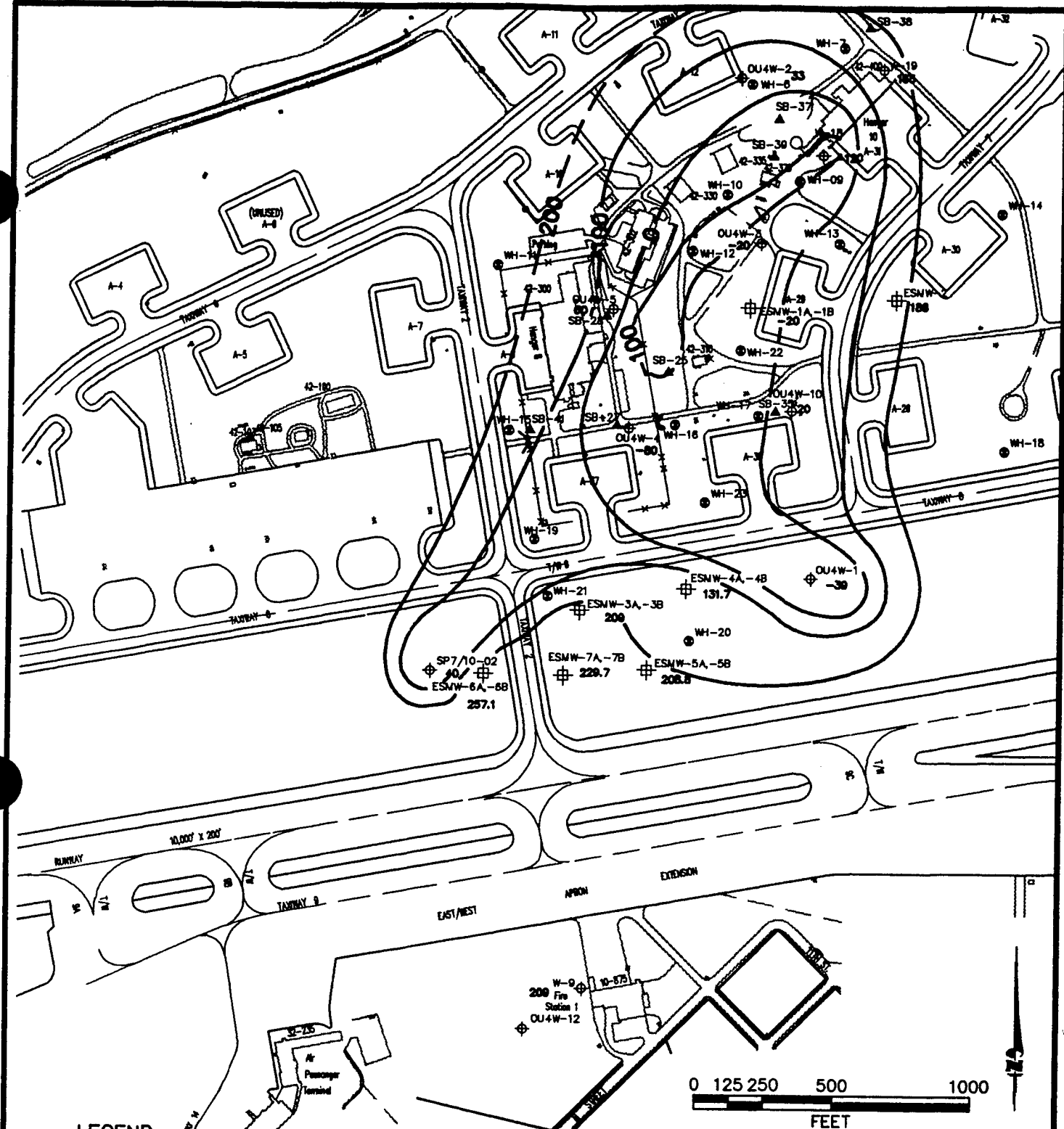
Total alkalinity (as calcium carbonate) was measured at ground water monitoring wells in June 1994. These measurements are summarized in Table 4.4. Alkalinity is a measure of a ground water's ability to buffer changes in pH caused by the addition of biologically generated acids. Total alkalinity at the site is in the low to moderate range for ground water, varying from 93.9 mg/L at ESMW-4B to 467 mg/L at W-19. 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 ground water monitoring points and existing monitoring wells in June 1994. These measurements are summarized in Table 4.4. The pH of a solution is the negative logarithm of the hydrogen ion concentration $[H^+]$. Ground water pH at the Hangar 10 site ranges from 6.4 to 7.2. The majority of ground water samples had a pH of 6.9 to 7.2. This range of pH is within the optimal range for BTEX-degrading microbes.

4.3.2.9 Temperature

Ground water temperature was measured at ground water monitoring points and existing monitoring wells in June 1994. Table 4.4 summarizes ground water temperature



LEGEND

OU4W-1
200
WH-20

MONITORING WELL LOCATION (JUNE 1993)
WITH REDUCTION-OXIDATION POTENTIAL (mV)(JUNE 1994)
HYDROPUNCH LOCATION (JUNE - JULY 1993)

ESNW-5A-5B
200
SB-39

MONITORING WELL LOCATION (JUNE 1994)
WITH REDUCTION-OXIDATION POTENTIAL (mV)(JUNE 1994)
SOIL BORING (JUNE 1993)

100

LINE OF EQUAL REDUCTION-OXIDATION POTENTIAL (mV)
(DASHED WHERE INFERRED)

CONTOUR INTERVAL = 100 mV

NOTE:
AT NESTED WELLS, THE POTENTIAL FROM THE DEPTH CORRESPONDING
TO THE HIGHEST BTEX CONCENTRATION WAS USED TO GENERATE ISOPLETHS

FIGURE 4.8

REDUCTION-OXIDATION POTENTIAL ISOPLETH MAP FOR GROUND WATER JUNE 1994

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

readings. Temperature affects the types and growth rates of bacteria that can be supported in the ground water environment, with higher temperatures generally resulting in higher growth rates. Temperatures in the shallow aquifer varied from 5.5 degrees Celsius (°C) to 8.2°C. These are relatively low temperatures for shallow ground water, suggesting that bacterial growth rates could be lower than those seen in warmer ground water.

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, denitrification, iron and sulfate reduction, and methanogenesis. Based on the stoichiometry presented in these sections, the expressed BTEX assimilative capacity of ground water at the Hangar 10 Site is at least 20,730 µg/L (Table 4.5). The calculations presented in the earlier sections are conservative because they do not account for microbial cell mass production. In addition, the measured concentrations of ferrous iron and methane may not be the maximum achievable. The highest plausible dissolved-phase total BTEX concentration observed at the site was 22,200 µg/L, at HydroPunch® location WH-10 in June 1993. In 1994, the highest dissolved-phase BTEX concentrations observed at the site was 477.6 µg/L at monitoring well OU4W-4, suggesting that concentrations have decreased.

Based on the calculations presented in the preceding sections, and on site observations, ground water at the Hangar 10 site has more than sufficient assimilative capacity to degrade the observed dissolved-phase BTEX and limit plume migration to less than 300 feet per year. As noted in Section 4.3.2.1, the upgradient DO concentrations at the site appear uncharacteristically low and may not reflect background concentrations. As a result, the assimilative capacity of the ground water presented in Table 4.5 may be underestimated because the assumed background DO concentration does not reflect the actual background concentration.

TABLE 4.5
EXPRESSED ASSIMILATIVE CAPACITY OF SITE GROUND WATER
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

Electron Acceptor or Process	Expressed BTEX Assimilative Capacity ($\mu\text{g/L}$)
Dissolved Oxygen	260
Nitrate	3,000
Iron Reduction	410
Sulfate	5,460
Methanogenesis	11,600
Expressed Assimilative Capacity	20,730
Highest observed Total BTEX Concentration, June 1993 ^{a/}	22,200
Highest observed Total BTEX Concentration, June 1994 ^{b/}	477

^{a/} Analyzed by modified EPA Method SW8015

^{b/} Analyzed by RSKSOP-124

SECTION 5

GROUND WATER MODEL

5.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

In order to help estimate degradation rates for dissolved-phase BTEX compounds at the Hangar 10 site and to help predict the future migration of these compounds, Parsons ES modeled the fate and transport of the dissolved-phase BTEX plume. The modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase 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 natural attenuation remedial option at post-modeling regulatory negotiations. The model was developed using site-specific data and conservative assumptions about governing physical and chemical processes. Because of the conservative nature of model input, 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 Bioplume II code was used to estimate the potential for dissolved-phase BTEX migration and degradation by naturally occurring mechanisms operating at the Hangar 10 site. The Bioplume II model incorporates advection, dispersion, sorption, and biodegradation to simulate contaminant plume migration and degradation. The model is based upon the USGS Method of Characteristics (MOC) two-dimensional (2-D) solute transport model of Konikow and Bredehoeft (1978). The model was modified by researchers at Rice University to include a biodegradation component that is activated by a superimposed DO plume. Based on the work of Borden and Bedient (1986), the model assumes a reaction between DO and BTEX that is instantaneous relative to the advective ground water velocity. Bioplume II solves the USGS 2-D solute transport equation twice, once for hydrocarbon concentrations in the aquifer and once for a DO plume. The two plumes are combined using superposition at every particle move to simulate the instantaneous, biologically-mediated, reaction between hydrocarbons and oxygen.

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 there is evidence that anaerobic biodegradation processes are occurring at the Hangar 10 site, these processes were accounted for during Bioplume II modeling using a first order anaerobic decay coefficient. 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 ground water model, it is important to determine if sufficient data are available to provide a reasonable estimate of aquifer conditions. In addition, it is important to ensure that any limiting assumptions can be justified. The most important assumption made when using the Bioplume II model is that oxygen-limited biodegradation is occurring at the site. The Bioplume II model assumes that the limiting factors for biodegradation are: 1) the presence of an indigenous hydrocarbon degrading microbial population, and 2) sufficient background electron acceptor concentrations. Data and information presented in Sections 3 and 4 suggest that oxygen, nitrate, ferric hydroxide, sulfate, and carbon dioxide (methanogenesis) are being used as electron acceptors for aerobic and anaerobic biodegradation. To be conservative, only oxygen was used as an electron acceptor in the Bioplume II model presented herein. To model biodegradation of BTEX with DO as the primary electron acceptor, the isopleth map for oxygen was superimposed on the model grid. Data from this map were then used for model input.

Based on the data presented in Section 3, the shallow saturated zone was conceptualized and modeled as a shallow unconfined aquifer comprised of gravelly sand to sandy gravel (Figures 3.3 and 3.4). The use of a 2-D model is appropriate at the Hangar 10 site because the saturated interval is relatively homogenous, and water level data indicate that the local flow system as defined by horizontal and vertical gradients will likely prevent significant downward vertical migration of dissolved-phase contamination. Existing evidence suggests that mobile LNAPL is not present at the site. Contaminated soils at the site have not been remediated, but because soil contaminant data did not delineate a significant source area with high total BTEX concentrations,

initial model simulations did not include continuing sources of dissolved-phase BTEX contamination. This approach is justified because of the observed decrease in contaminant concentrations between 1993 and 1994, and because the plume core appeared to separate and move away from the postulated source area. This data suggests that this plume may be the result of a single spill event rather than a continuing discharge of fuel.

5.3 INITIAL MODEL SETUP

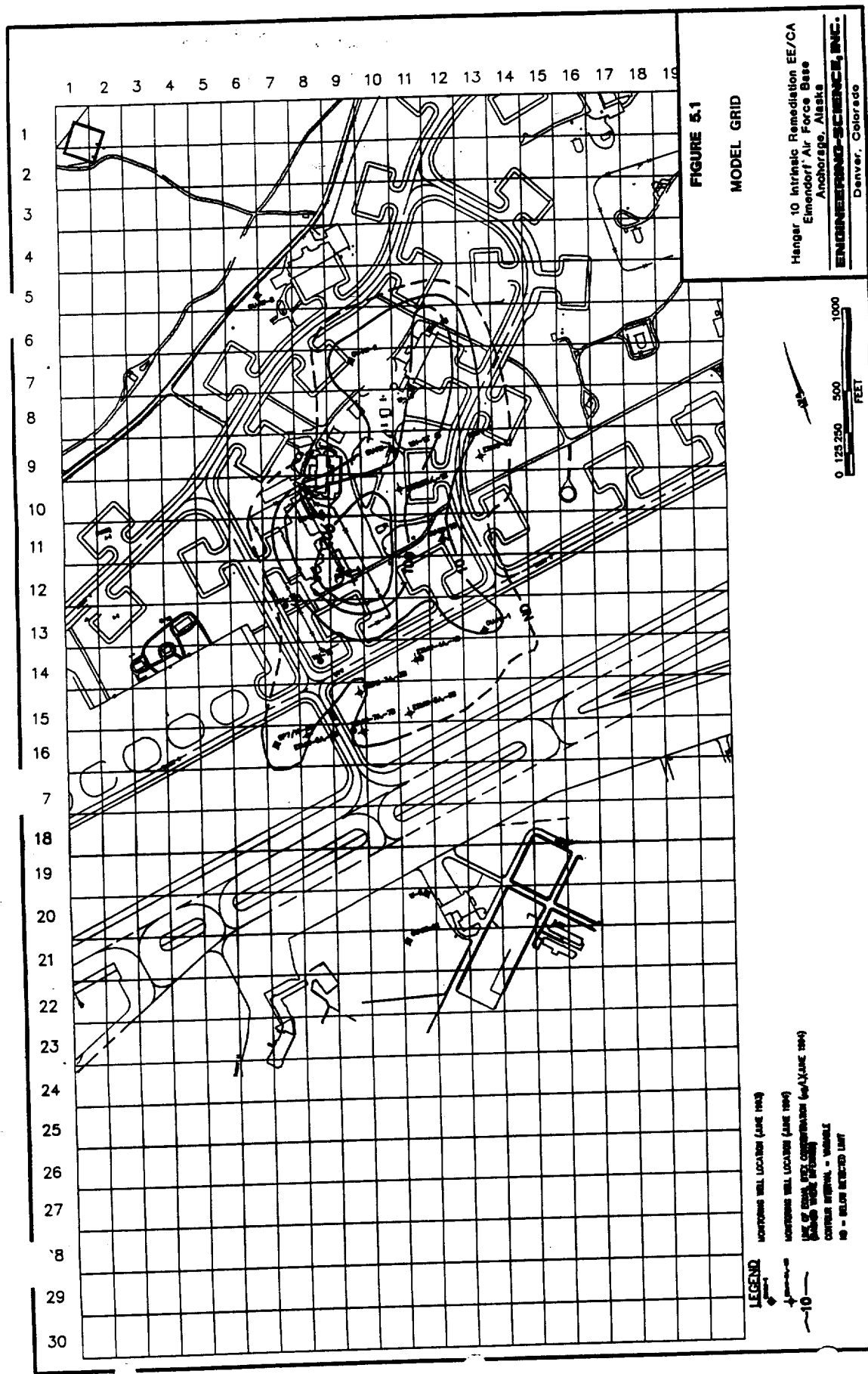
Where possible, the initial setup for this model was based on existing site data. Where site-specific data were not available (e.g., effective porosity), reasonable assumptions for the types of materials comprising the shallow aquifer were made based on widely accepted literature values. The following sections describe the basic model setup. Those Bioplume II model parameters that were varied during model calibration are discussed in Section 5.4.

5.3.1 Grid Design and Boundary Conditions

The maximum grid size for the Bioplume II model is limited to 20 columns by 30 rows. The dimension of each column and row can range from 0.1 to 999.9 feet. A 20- by 30-cell grid was used to model the Hangar 10 site. Each grid cell was 250 feet long by 200 feet wide. The grid was oriented so that the longest dimension was parallel to the overall direction of ground water flow. The model grid covers an area of 30 million square feet, or approximately 689 acres. The full extent of the model grid is indicated on Figure 5.1.

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



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

- 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 ground water divides and impermeable hydrostratigraphic units. Specified-flux boundaries are expressed mathematically as:

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

- 3) 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)
- H₀ = Head in external zone (separated from plume by semipermeable layer)
- K' = Hydraulic conductivity of semipermeable layer
- B' = Thickness of semipermeable layer.

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

Specified-head boundaries for the model were set on the northeastern and southwestern perimeter of the model grid to simulate the south-southwest ground water flow observed at the site. Both boundaries were set in the approximate location of the water table indicated by water level data. The head of the northeastern boundary was estimated to be from 160.3 to 160.7 feet above msl. The southwestern model boundary was defined by the assumed downgradient position of the 149.5-foot water table contour. The location of this contour was estimated from available water table elevation and flow gradient data. These constant-head cells were placed far enough away from the BTEX plume to avoid potential boundary interferences.

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

5.3.2 Ground Water Elevation and Gradient

The water table elevation map presented in Figure 3.5 was used to define the starting heads input into the Bioplume II model. Ground water flow in the vicinity of the Hangar 10 site is to the south-southwest with an average gradient of approximately 0.002 ft/ft between monitoring wells OU4W-3 and ESMW-3A. Data quantifying seasonal variations in ground water flow direction and gradient at the site are presented by Jacobs Engineering Group (1994a). These data suggest that there are no significant seasonal variations in ground water flow direction, and that seasonal gradients consistently vary around the average of approximately 0.002 ft/ft. 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 Concentrations

The total dissolved BTEX concentrations obtained from laboratory analytical results for each well location were used for model development. At well nests, the highest BTEX concentration observed at that location was used. Table 4.3 presents dissolved

BTEX concentration data. Figures 4.1 and 4.2 show the spatial distribution of dissolved-phase BTEX compounds in June 1993 and June 1994, respectively.

The BTEX plume observed in June 1993 covers an area of at least 1,700,000 square feet (39 acres). The BTEX plume observed in June 1994 covers an area of approximately 3,400,000 square feet (78 acres). However, while the plume spread laterally during this 1-year period, it did not migrate more than 300 feet downgradient. The shape and distribution of the total BTEX plume is the result of advective-dispersive transport and biodegradation of dissolved-phase BTEX contamination. As described in Section 5.4.2, the simulated BTEX plume was calibrated to match the observed BTEX plume.

5.3.4 Dissolved Oxygen

As discussed previously, the Bioplume II model assumes an instantaneous reaction between the BTEX plume and the DO plume. The discussion presented in Section 4 suggests that DO, nitrate, ferric iron, sulfate, and carbon dioxide (methanogenesis) are being used as electron acceptors for biodegradation of BTEX compounds at the Hangar 10 site. To be conservative, the total BTEX plume at the site was modeled assuming that DO was the only electron acceptor being utilized at a rate that is instantaneous relative to the advective ground water flow velocity for the biodegradation of the BTEX compounds.

Ground water samples collected in uncontaminated portions of the aquifer suggest that background DO concentrations at the site are approximately 0.8 mg/L. Therefore, background oxygen levels were assumed to be 0.8 mg/L for Bioplume II model development. Table 4.4 contains DO data for the site. Figure 4.3 is a DO isopleth map. Oxygen input data are included in Appendix C.

The upgradient constant-head cells in the Bioplume II model require background DO concentrations to be input as constant concentrations to simulate incoming electron acceptors. The background DO concentration of 0.8 mg/L was used for these cells.

5.3.5 Anaerobic Degradation Rates

Available data strongly suggest that anaerobic degradation is occurring at the Hangar 10 site. Because DO concentrations at this site are relatively low, anaerobic degradation

must be simulated with Bioplume II so that predictions are meaningful. To account for anaerobic degradation of BTEX compounds, the Bioplume II model simulates anaerobic biodegradation by assuming that such degradation follows first-order kinetics. As with a large number of biological processes, anaerobic biodegradation can generally be described using a first order rate constant and the equation:

$$\frac{C}{C_0} = e^{-kt}$$

Where: C = Contaminant Concentration at Time t
 C_0 = Initial Contaminant Concentration
 k = Coefficient of Anaerobic Decay (anaerobic rate constant)
 t = time

In order to calculate anaerobic rate constants, the apparent degradation rate must be normalized for the effects of dilution caused by advective-dispersive processes. This is accomplished by normalizing the concentration of each contaminant to the concentration of a component of jet fuel (a tracer) that has similar sorptive properties but that is fairly recalcitrant. Observed concentration data can be normalized to 1,3,5-TMB, 1,2,4-TMB, and 1,2,3-TMB or another tracer with similar physiochemical properties. The TMB suite serves as a good tracer because it is known to be recalcitrant under anaerobic conditions, and has sorptive properties similar to the BTEX compounds (Cozzarelli *et al.*, 1990, and Cozzarelli *et al.*, 1994).

Anaerobic rate constants were calculated based on BTEX and TMB data from June 1994 (presented in Table 4.3). Rate constant calculations are included in Appendix C. Calculated constants for the Hangar 10 site range from 0.009 day⁻¹ to 0.019 day⁻¹. A review of recent literature indicates that similar rate constants have been observed at other sites. For example, Chapelle (1994) reported that at two different sites with anaerobic conditions, the anaerobic rate constants were both approximately 0.01 day⁻¹. Wilson *et al.* (1994), report first-order anaerobic biodegradation rates of 0.05 to 1.3 week⁻¹ (0.007 to 0.185 day⁻¹). Stauffer *et al.* (1994) reports rate constants of 0.01 and 0.018 for benzene and p-xylene, respectively.

Based on the site-specific calculations and the literature values, an anaerobic rate constant of 0.01 day⁻¹ was used in the Bioplume II model. This value was selected

because it is in the lower range of the site-specific values and is within the range of the values reported in the literature.

5.4 MODEL CALIBRATION

Model calibration is an important component in the development of any numerical ground water 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 transmissivity 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 hydraulic parameters and transport parameters in a trial-and-error fashion until the simulated BTEX plume approximated observed field values. Table 5.1 lists input parameters used for the modeling effort. Model input and output is included in Appendix D.

5.4.1 Water Table Calibration

The shallow water table at the Hangar 10 site was assumed to be influenced only by continuous recharge and discharge at the constant-head cells established at the upgradient and downgradient model boundaries. To be conservative, recharge of the aquifer through rainfall (which would add water, thereby increasing dilution of the plume) was not included in the model. Potential recharge by other sources was omitted because of a lack of reliable data. Only the initial water levels at the constant-head cells and the transmissivity values were varied to calibrate the water table surface. The model was calibrated under steady-state conditions.

Hydraulic conductivity is an important aquifer characteristic that determines the ability of the water-bearing strata to transmit ground water. Transmissivity is the product of the hydraulic conductivity and the thickness of the aquifer. An accurate estimate of hydraulic conductivity is important to help quantify advective ground water flow velocities and to define the flushing potential of the aquifer and the quantity of electron-acceptor-charged ground water that is entering the site from upgradient locations. Based on the work of Rifai *et al.* (1988), the Bioplume II model is particularly sensitive to variations in

TABLE 5.1
BIOPLUME II MODEL INPUT PARAMETERS
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

Parameter	Description	Calibrated Model Setup	Model Runs			
			ELMA	ELMB	ELMC	ELMF
NTIM	Maximum number of time steps in a pumping period	6	66	36	16	36
NPMP	Number of Pumping Periods	1	1	1	1	1
NX	Number of nodes in the X direction	20	20	20	20	20
NY	Number of nodes in the Y direction	30	30	30	30	30
NPMAX	Maximum number of Particles $NP_{MAX} = (NX-2)(NY-2)(NPTPND) + (N_s^w)(NPTPND) + 250$	5200	5200	5200	5200	5200
NPNT	Time step interval for printing data	1	1	1	1	1
NITP	Number of iteration parameters	7	7	7	7	7
NUMOBS	Number of observation points	0	0	0	0	0
ITMAX	Maximum allowable number of iterations in ADIP ^b	200	200	200	200	200
NREC	Number of pumping or injection wells	0	0	0	4	0
NPTPND	Initial number of particles per node	9	9	9	9	9
NCODES	Number of node identification codes	2	2	2	2	2
NPNTMV	Particle movement interval (IMOV)	0	0	0	0	0
NPNTVL	Option for printing computed velocities	2	2	2	2	2
NPNTD	Option to print computed dispersion equation coefficients	0	0	0	0	0
NPDELC	Option to print computed changes in concentration	0	0	0	0	0
NPNTCHV	Option to punch velocity data	0	0	0	0	0
NREACT	Option for biodegradation, retardation and decay	1	1	1	1	1
PINT	Pumping period (years)	1	11	6	16	6
TOL	Convergence criteria in ADIP	0.001	0.001	0.001	0.001	0.001
POROS	Effective porosity	0.35	0.35	0.35	0.35	0.35
BETA	Characteristic length (long. dispersivity; feet)	60	60	60	60	60
S	Storage Coefficient	0 (Steady-State)	0	0	0	0
TIMX	Time increment multiplier for transient flow	-	-	-	-	-
TINIT	Size of initial time step (seconds)	-	-	-	-	-
XDEL	Width of finite difference cell in the x direction (feet)	200	200	200	200	200
YDEL	Width of finite difference cell in the y direction (feet)	250	250	250	250	250
DLTRAT	Ratio of transverse to longitudinal dispersivity	0.3	0.3	0.3	0.3	0.3
CELDIS	Maximum cell distance per particle move	0.5	0.5	0.5	0.5	0.5
ANFCTR	Ratio of Tyy to Txx (1 = isotropic)	1	1	1	1	1
DK	Distribution coefficient	0.14	0.14	0.14	0.14	0.14
RHOB	Bulk density of the solid (grams/cubic centimeter)	1.6	1.6	1.6	1.6	1.6
THALF	Half-life of the solute	-	-	-	-	-
DEC1	Anaerobic decay coefficient (day ⁻¹)	0.01	0.01	0.005	0.001	0
DEC2	Reaeration coefficient (day ⁻¹)	0	0	0	0	0
F	Stoichiometric Ratio of Hydrocarbons to Oxygen	3.1	3.1	3.1	3.1	3.1

^a Ns = Number of nodes yhat represent fluid sources (wells or constant head cells)

^b ADIP = Alternating-direction implicit procedure (subroutine for solving ground water flow equation)

hydraulic conductivity. Lower values of hydraulic conductivity result in a slower-moving plume that degrades at a slower rate because less oxygen, nitrate, iron, sulfate, and carbon dioxide is available for biodegradation. Higher values of hydraulic conductivity result in a faster-moving plume that degrades faster because more electron acceptors are available for biodegradation.

Saturated thickness data from previous reports, geologic logs, and water level measurements were used in conjunction with the average hydraulic conductivity as determined from a previous pumping test (0.4 ft/min; Radian, 1994) to estimate an initial uniform transmissivity for the entire model domain. To better match heads in the model to observed values, the transmissivities were progressively varied in blocks and rows until the simulated water levels for cells corresponding to the selected well locations matched the observed water levels as closely as possible. Figure 5.2 shows the calibrated water table. Calibrated model hydraulic conductivities ranged from 0.01 feet per second (ft/sec) to 0.4 ft/sec (0.2 ft/min to 2.6 ft/min).

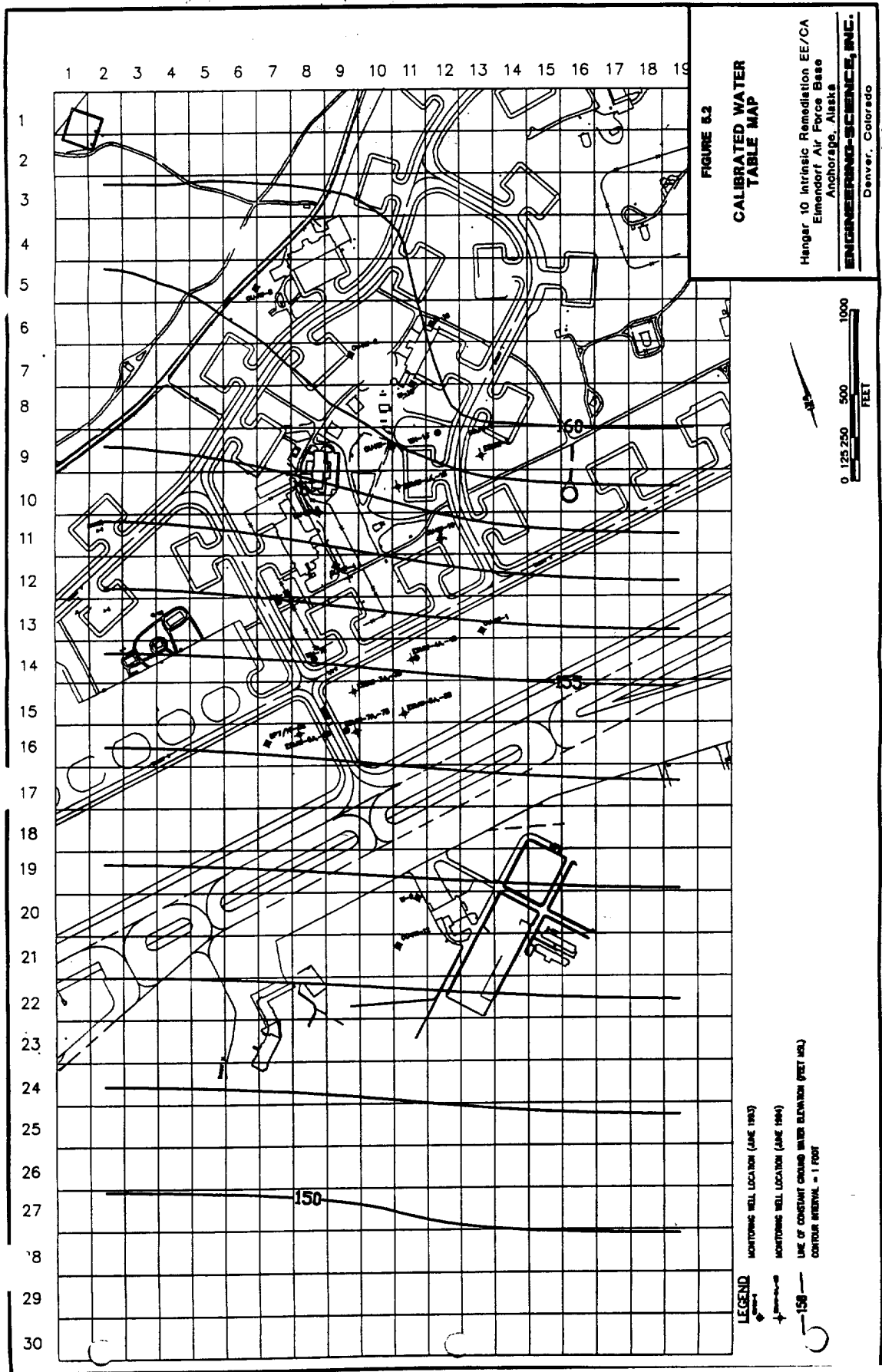
Water level elevation data from 13 monitoring well locations were used to compare measured and simulated heads for calibration. The 13 selected locations were W-18, W-19, OU4W-1, OU4W-2, OU4W-3, OU4W-10, ESMW-1A, ESMW-2, ESMW-3A, ESMW-4A, ESMW-5A, ESMW-6A, and ESMW-7A.

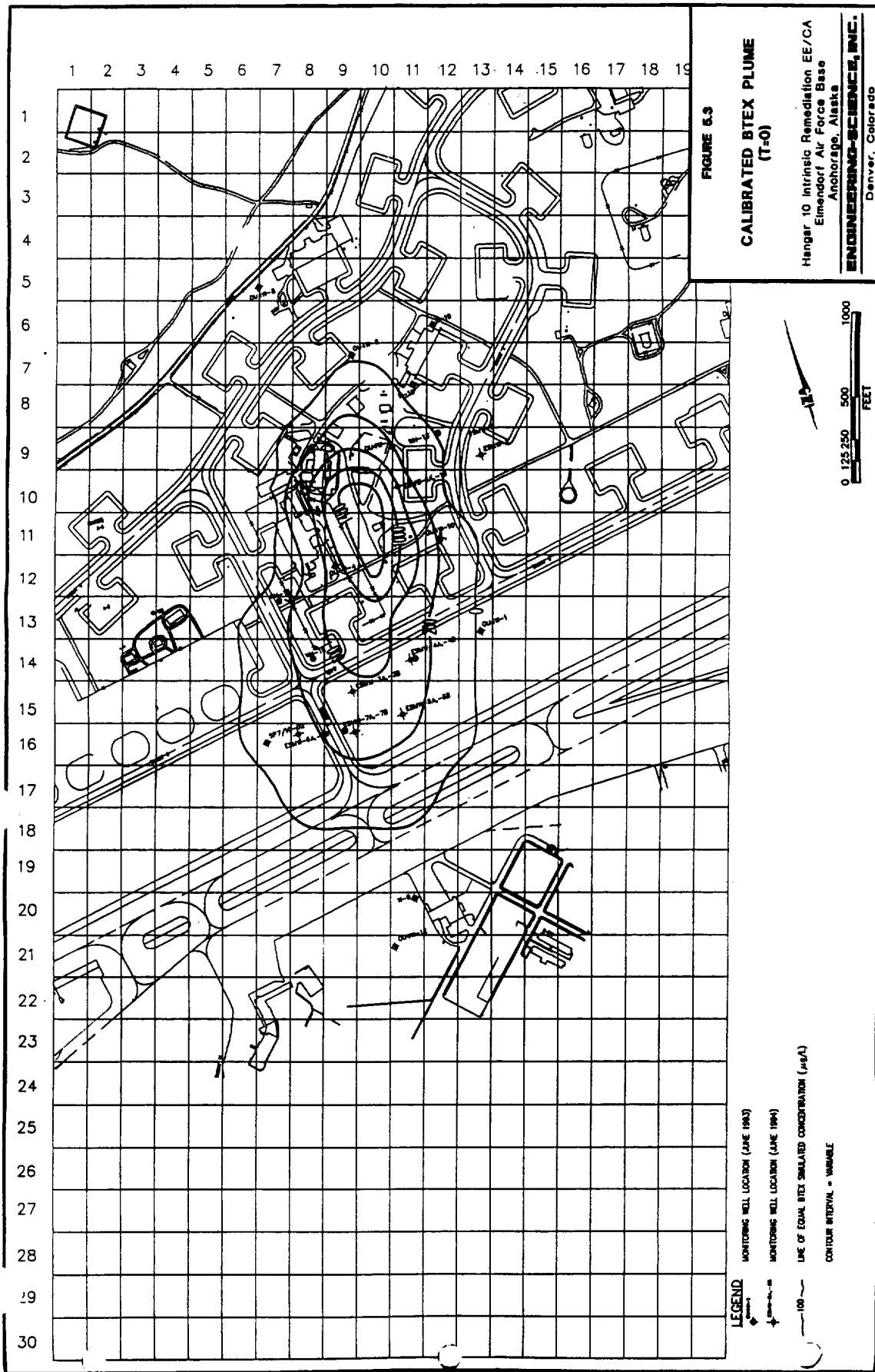
The root mean squared (RMS) error is commonly used to express the average difference between simulated and measured heads. RMS error is the average of the squared differences between measured and simulated heads, and can be expressed as:

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

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 13 comparison points was 0.49 foot, which corresponds to a calibration error of 4.19 percent (water levels dropped 11.7 feet over the length of the model grid). RMS error calculations are summarized in Appendix C.





The maximum simulated total BTEX concentration was 1,622 µg/L for the cell 10,11 (in the vicinity of well nest ESMW-1). The computed distribution represents a greater total mass of BTEX, because the concentrations are higher than those observed, and because the model assumes that contamination extends throughout the total depth of the aquifer. In reality, the plume is only present in a portion of the total aquifer thickness. Because of this, and because the calibrated model concentrations are higher than observed, 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 dispersivity, the coefficient of retardation, and the anaerobic decay coefficient. Those parameters were generally varied with intent of limiting plume migration to the observed extents, because the original estimates for the parameters resulted in a calculated BTEX plume that extended almost twice as far as the observed plume. While these parameters were varied with this common intent, each had a slightly different impact on the size and shape of the simulated plume.

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). Longitudinal dispersivity was originally estimated as 42 feet, using one-tenth (0.1) of the distance between the upgradient margin of the 10,000 µg/L isopleth and the longitudinal centroid of the June 1993 plume (see Figure 4.1). Dispersivity estimation calculations are included in Appendix C. Transverse dispersivity values generally are estimated as one-tenth (0.1) of the longitudinal dispersivity values (Domenico and Schwartz, 1990). However, because the 1994 data indicated the plume was wider than in 1993, the initial model input assumed a ratio of 0.3.

During plume calibration, longitudinal dispersivity was raised to 60 feet from the original estimate of 42 feet. This was done to prevent the computed plume from extending too far downgradient (by dispersing BTEX at the margins of the plume so that it degraded more rapidly) and also to help increase the lateral extent of the plume to better match the observed extents.

5.4.2.1.2 Anaerobic Decay Coefficient

As discussed in Section 5.3.5, the anaerobic decay coefficient was originally estimated to be 0.01 day^{-1} . This value was varied during plume calibration, but the calibrated model used the original estimate. This prevented the plume from migrating too far in the calibration run, and at the same time prevented contaminant concentrations in the center portion of the plume from being excessively high.

5.4.2.1.3 Coefficient of Retardation

Retardation of the BTEX compounds relative to the advective velocity of the ground water occurs when BTEX molecules are sorbed to the aquifer matrix. Based on measured TOC concentrations in the saturated zone at ESMW-1B, and assuming a bulk density of 1.6 grams/cubic centimeter (Freeze and Cherry, 1979), and published values of the soil sorption coefficient (K_{oc}) for the BTEX compounds (as listed in Wiedemeier *et al.*, 1994), the coefficients of retardation for the BTEX compounds were calculated. The results of these calculations are summarized in Table 5.2. Average coefficients of retardation were also computed for data from Site ST41 at Elmendorf AFB to provide an additional set of data for comparison. To be conservative, the minimum range of retardation coefficients calculated for the BTEX compounds (1.45 to 3.67) was used as a constraint for model input. The coefficient of retardation originally used as model input was 1.7. The lower the assumed coefficient of retardation, the farther the BTEX plume will migrate downgradient.

During plume calibration, the coefficient of retardation was gradually raised from the initial value of 1.7 to a value of 1.9. As with the dispersivity and porosity, this variable was altered in response to model predictions of BTEX concentrations extending beyond the observed limits. In addition, increasing the value of this parameter was also necessary to limit the contaminants' rate of travel.

5.5 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to determine the effect of varying model input parameters on model output. Based on the work of Rifai *et al.* (1988), the Bioplume II model is most sensitive to changes in the coefficient of reaeration, the coefficient of anaerobic decay, and the hydraulic conductivity of the media, and is less sensitive to changes in the retardation factor, porosity, and dispersivity. Because the

TABLE 5.2

**CALCULATION OF RETARDATION COEFFICIENTS
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

Compound	K_{oc} (L/kg ^{a/})	Maximum Fraction Organic Carbon ^{b/}	Minimum Fraction Organic Carbon ^{b/}	Average Fraction Organic Carbon ^{c/}	Distribution Coefficient K_d (L/kg)			Bulk Density (kg/L) ^{d/}	Effective Porosity	Coefficient of Retardation	
					Maximum ^{d1/}	Minimum ^{d2/}	Average ^{d3/}			Maximum	Average
Benzene	79	0.03255	0.00125	0.00252	2.571	0.099	0.199	1.60	0.35	12.76	1.45
Toluene	190	0.03255	0.00125	0.00252	6.185	0.238	0.479	1.60	0.35	29.27	2.09
Ethylbenzene	468	0.03255	0.00125	0.00252	15.233	0.585	1.179	1.60	0.35	70.64	3.67
m-xylene	405	0.03255	0.00125	0.00252	13.183	0.506	1.021	1.60	0.35	61.26	3.31
o-xylene	422	0.03255	0.00125	0.00252	13.736	0.528	1.063	1.60	0.35	63.79	3.41
p-xylene	357	0.03255	0.00125	0.00252	11.620	0.446	0.900	1.60	0.35	54.12	3.04
											5.11

NOTES:

^{a/} From technical protocol (Wiedemeier *et al.*, 1994)^{b/} From Hangar 10 site data^{c/} From Site ST41 data (Hangar 10 data insufficient to calculate an average)^{d1/} K_d = Maximum Fraction Organic Carbon x K_{oc} ^{d2/} K_d = Minimum Fraction Organic Carbon x K_{oc} ^{d3/} K_d = Average Fraction Organic Carbon x K_{oc} ^{e/} Literature values

coefficient of reaeration was set to zero, the sensitivity analysis was conducted by varying transmissivity, dispersivity, the coefficient of retardation, and the coefficient of anaerobic decay.

To perform the sensitivity analyses, an individual run of the plume calibration model was made with the same input as the calibrated model, except that one of the aforementioned parameters was varied. The models were run for a 1-year period, just as the original was, so that the independent effect of each variable could be assessed. As a result, eight sensitivity runs of the calibrated model were made, with the following variations:

- 1) Transmissivity uniformly increased by a factor of 5;
- 2) Transmissivity uniformly decreased by a factor of 5;
- 3) Longitudinal dispersivity increased by a factor of 5;
- 4) Longitudinal dispersivity decreased by a factor of 5;
- 5) Coefficient of anaerobic decay increased by a factor of 5;
- 6) Coefficient of anaerobic decay decreased by a factor of 5;
- 7) Coefficient of retardation increased by a factor of 2; and
- 8) Coefficient of retardation decreased by a factor of 2.

The results of the sensitivity analyses are shown graphically in Figures 5.4, 5.5, 5.6, and 5.7. These figures display the modeled BTEX concentrations versus distance along the centerline of the plume (in the eleventh model column). This manner of displaying data is useful because BTEX concentrations are highest in the eleventh column, the plume is relatively symmetrical, and the plume migrates in a direction parallel to the model grid. Furthermore, the figures allow easy visualization of the changes in BTEX concentration caused by varying model input parameters.

The effects of varying transmissivity are shown by Figure 5.4. Uniformly increasing the transmissivity by a factor of five increased the biodegradation rate of the plume such that the maximum observed concentrations in the source cell area were only about 150 $\mu\text{g/L}$, compared to the calibrated maximum of 1,622 $\mu\text{g/L}$. In addition, the leading edge of the BTEX plume was approximately 3,000 feet farther downgradient than in the calibrated model. This results from the greater flux of water through the model area bringing a greater mass of DO and other electron acceptors into contact with the plume.

Concentration Distribution for Various Values of Transmissivity (T)

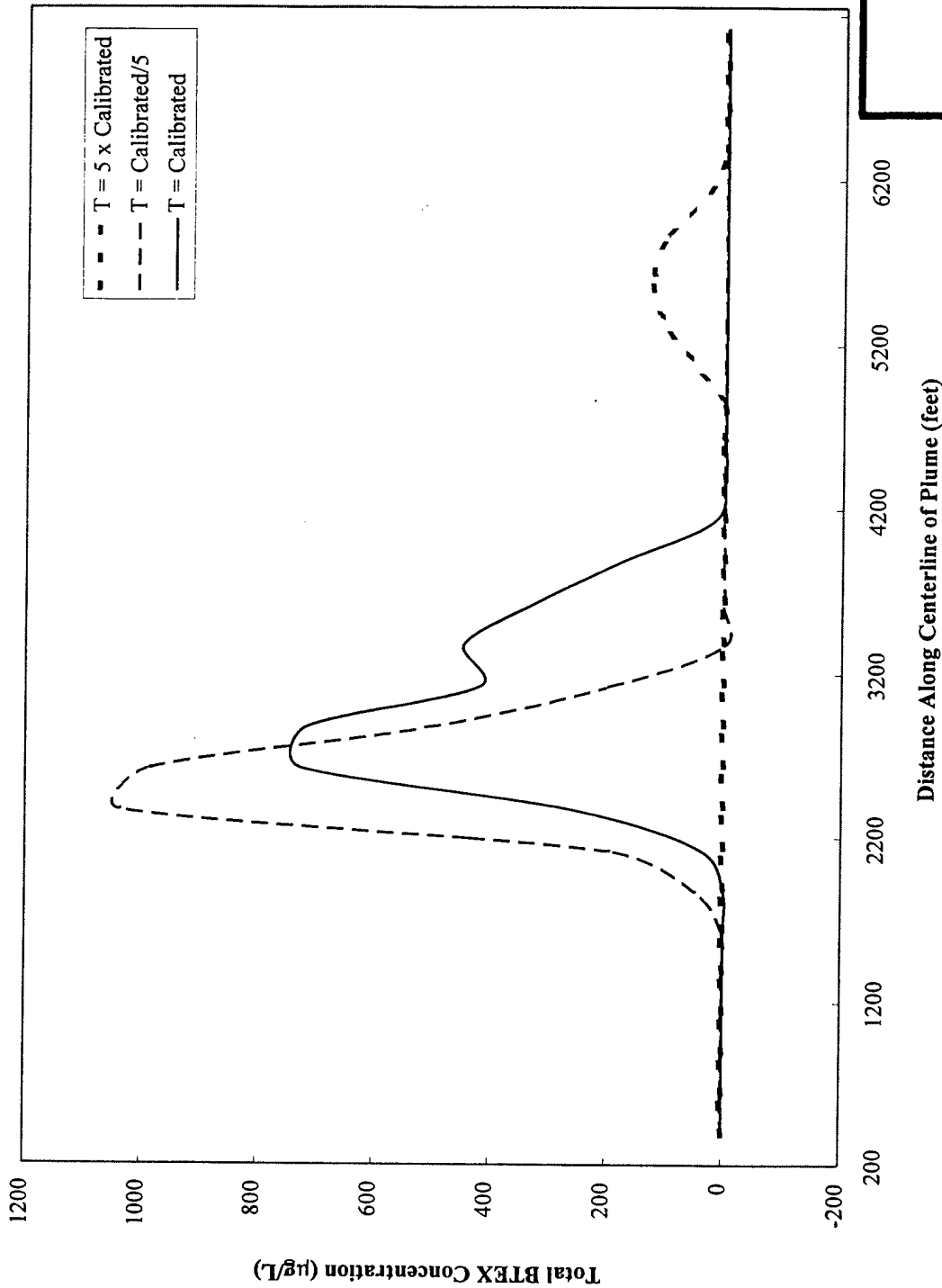


FIGURE 5.4

MODEL SENSITIVITY TO VARIATIONS IN TRANSMISSIVITY

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Concentration Distribution for Various Values of Longitudinal Dispersivity (BETA)

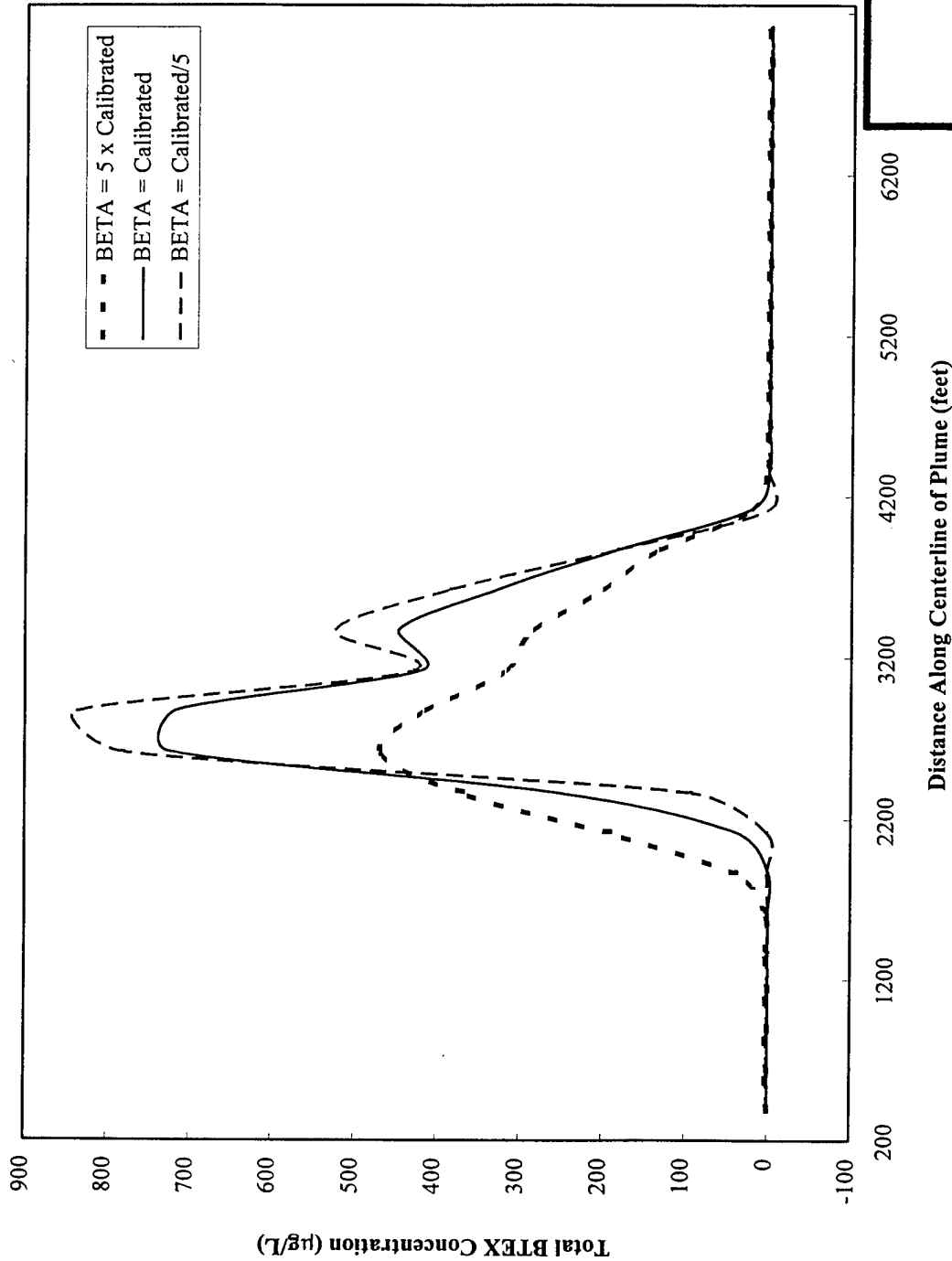


FIGURE 5.5

MODEL SENSITIVITY TO VARIATIONS IN DISPERSIVITY

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Concentration Distribution for Various Values of the Anaerobic Decay Coefficient (DEC1)

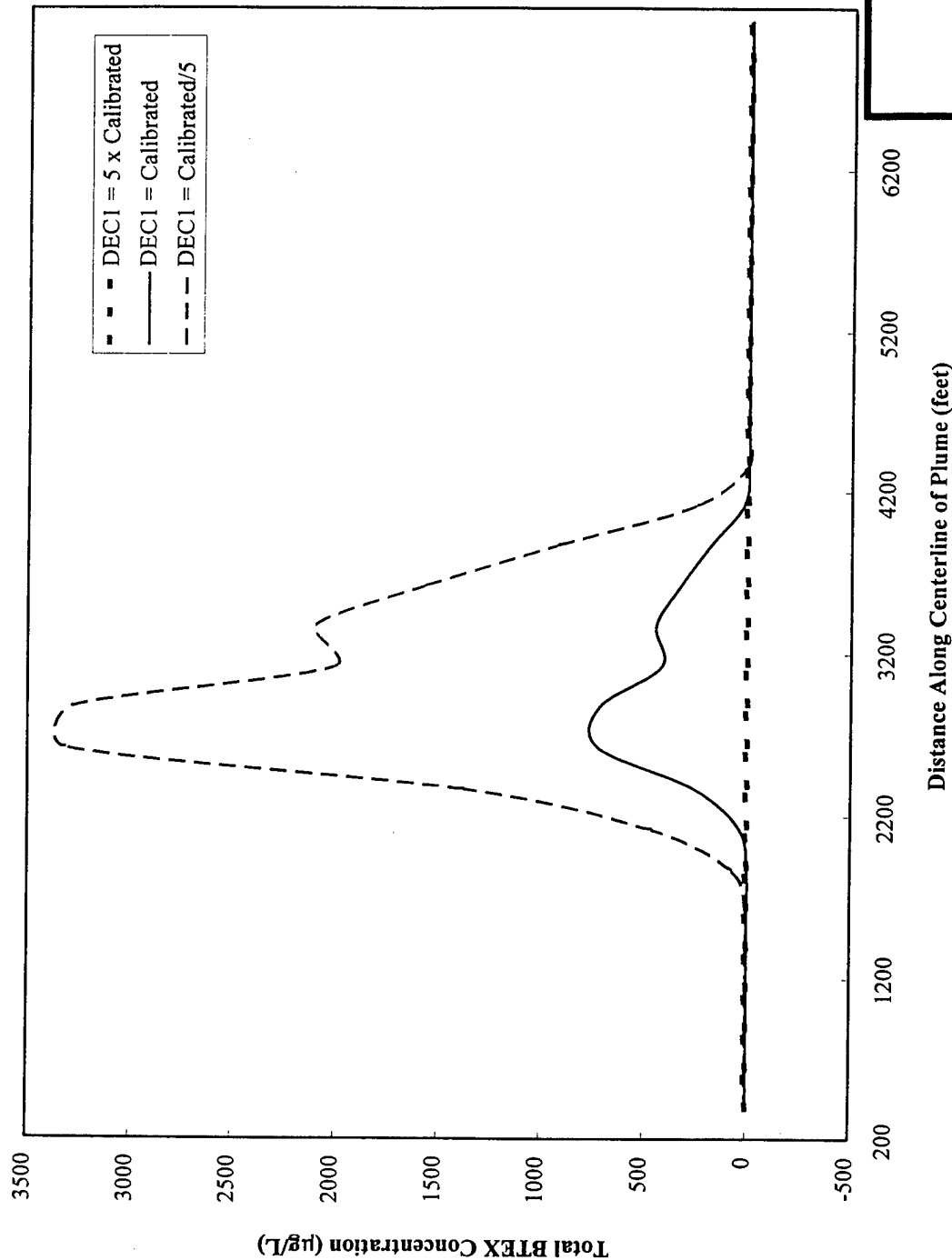


FIGURE 5.6

MODEL SENSITIVITY TO VARIATIONS IN THE ANAEROBIC DECAY COEFFICIENT

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Concentration Distribution for Various Values of the Coefficient of Retardation (R)

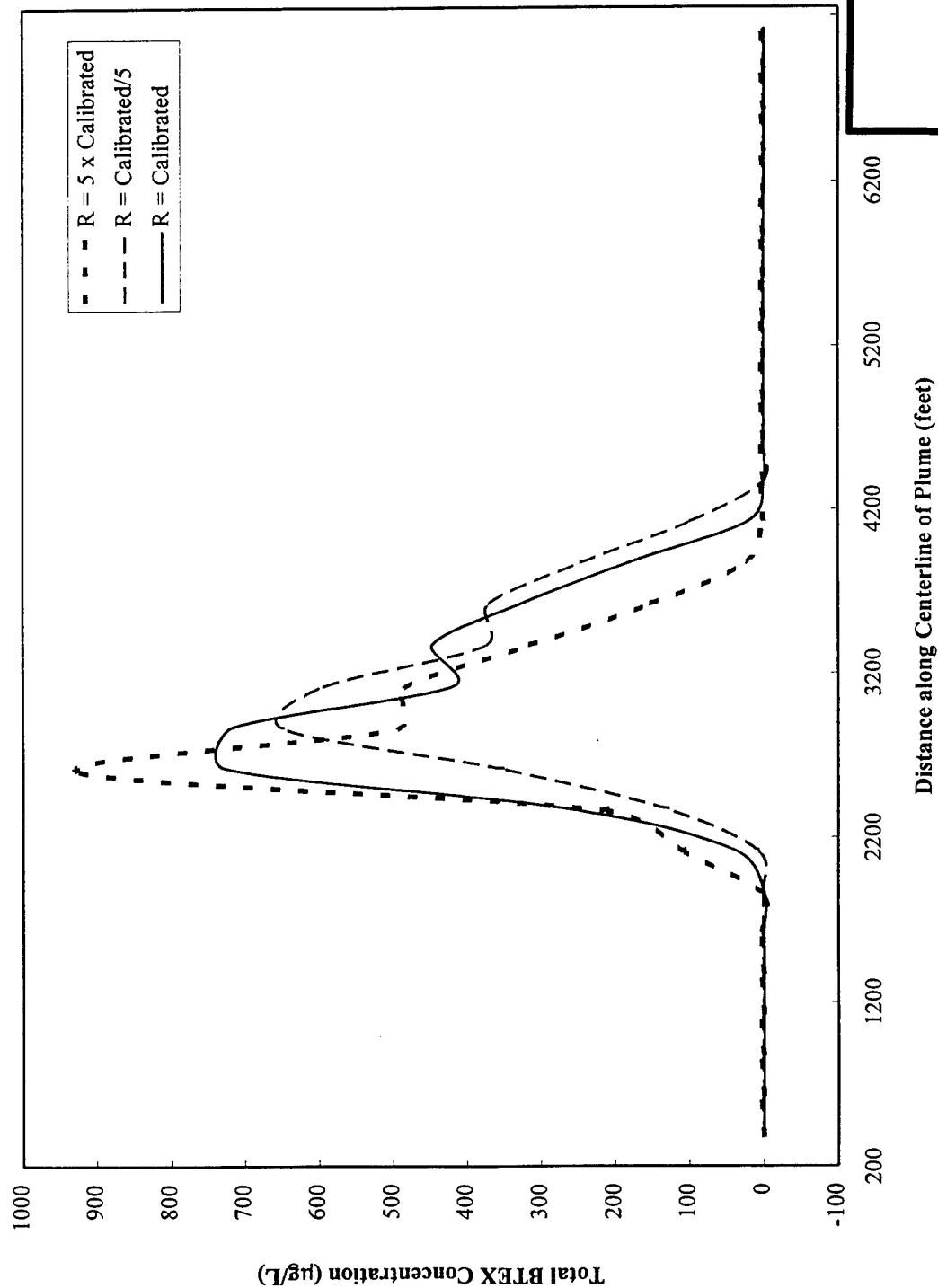


FIGURE 5.7

**MODEL SENSITIVITY TO
VARIATION IN THE
COEFFICIENT OF RETARDATION**
 Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Because more electron acceptors are available, biodegradation occurs more rapidly. Also, the faster ground water velocity produced by the higher transmissivity initially results in greater plume travel rates and distances, further exposing the BTEX to oxygenated water. In contrast, decreasing the transmissivity 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 plume area are caused by a reduction in the plume travel rate and the amount of oxygen being brought into contact with the contaminants from upgradient locations.

The effects of varying dispersivity are illustrated by Figure 5.5. Both longitudinal and transverse dispersivity were varied for this analysis, as the ratio of the two values was kept constant at 0.3. Increasing the dispersivity by a factor of five resulted in lower maximum BTEX concentrations although the plume was spread out over a similar area. Decreasing dispersivity by a factor of five produced a plume with an extent similar to the calibrated plume, but with slightly higher concentrations.

Figure 5.6 shows the effects of varying the anaerobic decay coefficient. Increasing this parameter by a factor of five results in rapid degradation of dissolved-phase BTEX. This dramatic reduction in contaminant mass is the result of the large increase in the decay rate caused by increasing the coefficient, because the anaerobic decay coefficient is exponentiated in the equation expressing the decay rate (see Section 5.3.5). Conversely, decreasing the anaerobic decay coefficient by a factor of five greatly decreases the rate of degradation, resulting in a large increase of the computed maximum BTEX concentration to approximately 3,400 $\mu\text{g/L}$ and an increase in plume length.

The effects of varying the coefficient of retardation (R) are shown on Figure 5.7. Increasing R by a factor of 2 has a slight effect on the contaminant distribution. The maximum BTEX concentration is approximately 200 $\mu\text{g/L}$ greater, and the plume is approximately 400 feet shorter than in the calibrated model. On the other hand, decreasing R by a factor of two produces a plume that extends about 200 feet further downgradient than the original model plume and has a slightly lower maximum concentration. These results suggest that the R used for the calibrated simulation is acceptable, because the model is relatively insensitive to higher values of R , while a value of R that is too low will result in a simulated plume that travels beyond the limits of the observed plume.

The results of the sensitivity analysis suggest that the calibrated model used for this report is reasonable. The calibrated model is most sensitive to transmissivity and the anaerobic decay coefficient, although the coefficient of retardation is also an important parameter. Increasing the anaerobic decay coefficient or the transmissivity greatly diminishes the predicted BTEX concentrations. Lowering the values of the anaerobic decay coefficient and the coefficient of retardation lengthens the plume beyond reasonable distances based on recent observations at the site. While the model appears relatively insensitive to dispersivity, adjustment of that parameter contributed toward producing an appropriate plume configuration.

5.6 MODEL RESULTS

To predict fate and transport of dissolved-phase BTEX compounds at the Hangar 10 site, four Bioplume II simulations (ELMA, ELMB, ELMC, and ELMF) were run under steady-state conditions. The first simulation assumed that conditions which produced the calibrated model continue, and that no additional contamination is introduced. The second simulation reduced the anaerobic decay coefficient by one-half to demonstrate the effectiveness of intrinsic remediation with reduced anaerobic degradation. The third simulation assumed that a continuous source of dissolved-phase BTEX would be present in the vicinity of the highest contaminant concentrations observed in June 1993. The fourth and final simulation assumed that original conditions continue, except that no anaerobic decay would occur. Complete input and output files are presented in Appendix D. Model results are described in the following sections.

Model time for the predictive simulations described in the following sections is described using the term "prediction time", which refers to model time after the initial 1 - year calibration period (i.e., simulation time after 1994). In other words, prediction time for the simulations starts in 1994. In the figures showing model output, the prediction time is referred to using the nomenclature " $T = X$ years", where X represents the number of years elapsed since 1994. For example, the phrases " $T = 1$ year" or "after 1 year of prediction time" refer to the model results projected 1 year beyond the calibrated model, or to mid-1995. The term " $T = 0$ " is used for model results that are to be compared to the 1994 plume.

5.6.1 Continuation of Calibrated Conditions (Model ELMA)

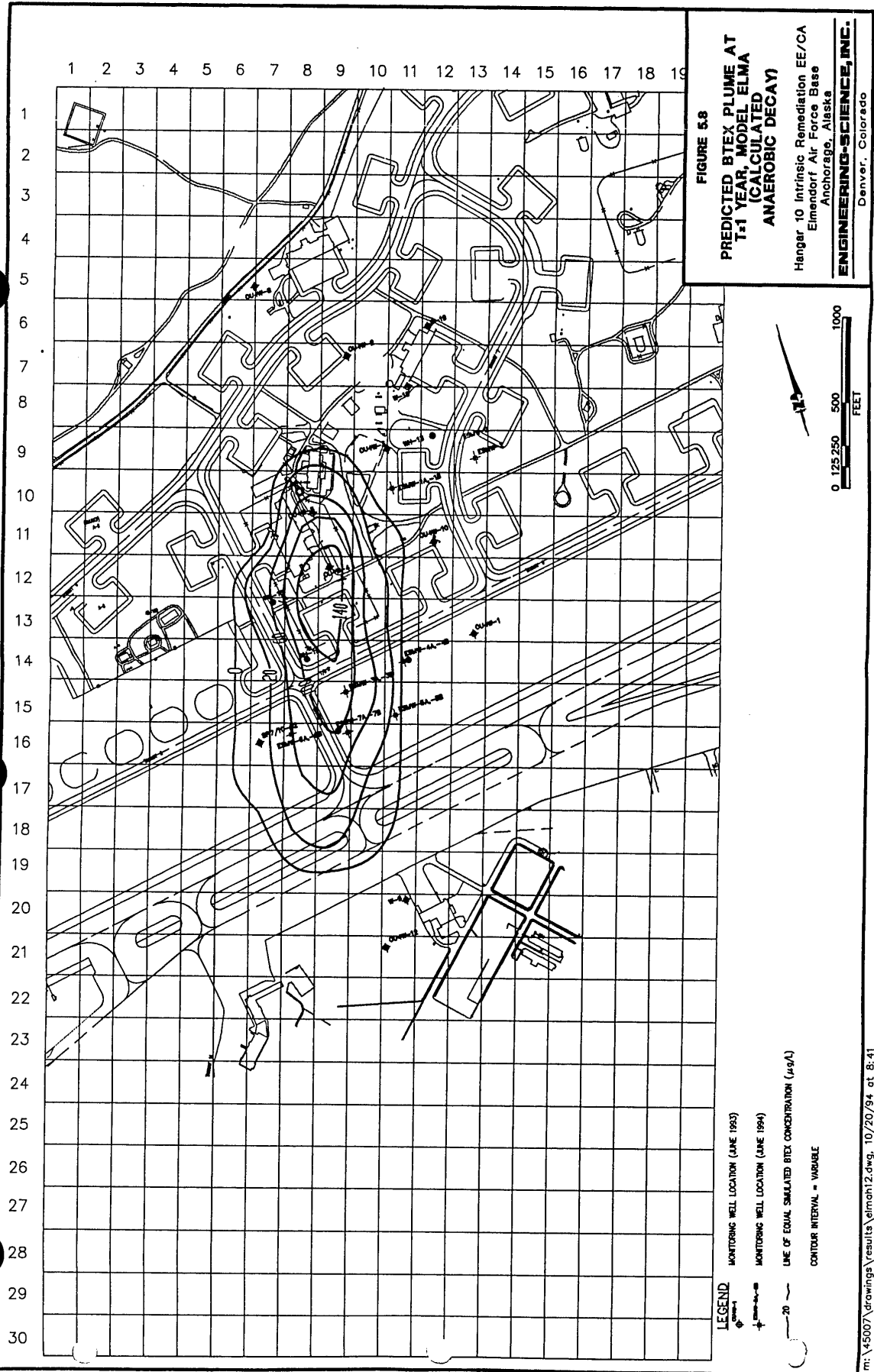
Model ELMA was used to simulate the migration and biodegradation of the BTEX plume assuming that the conditions that produced the calibrated model continue, including the absence of a continuing source of dissolved-phase BTEX compounds. The calibrated simulation was run to predict conditions up to 5 years beyond the original calibrated model ending time, for a total simulation time of 6 years. Figure 5.8 shows the extent of the main body of the BTEX plume after 1 year of prediction time. Modeled BTEX concentrations decrease significantly, to a maximum of 143 $\mu\text{g/L}$, while the plume front extends approximately 750 feet beyond the extent observed in June 1994. After a total of 1.5 years of prediction time, the plume completely degrades and/or sorbs onto the aquifer matrix.

5.6.2 Reduced Anaerobic Decay (Model ELMB)

To illustrate the time frame for reduction in BTEX concentrations with less anaerobic decay than the original simulation, model ELMB was run with the anaerobic decay coefficient reduced by one-half. Figure 5.9 shows the configuration of the simulated BTEX plume indicated for 1994 (i.e., at $T = 0$). The plume in Figure 5.9 is longer than the calibrated plume, and BTEX concentrations are much higher. After 1 year of prediction time, the plume front migrates approximately 1,250 feet beyond the June 1994 plume front to the vicinity of wells OU4W-12 and W-9, as shown on Figure 5.10. The plume detaches from the probable source area and continues to migrate downgradient, but shrinks in overall length as indicated on Figure 5.11, which shows the plume configuration after 2 years of prediction time. The maximum simulated concentration at this time is 313 $\mu\text{g/L}$, and the plume front is 1,750 feet downgradient from the June 1994 front. After 3 years of prediction time (Figure 5.12), the plume front is at the same location as after 2 years, but the plume is much smaller, and maximum concentration decreases to approximately 34 $\mu\text{g/L}$. After a total of 3 years and 2 months of prediction time, the BTEX plume completely degrades and/or sorbs onto the aquifer matrix.

5.6.3 Continuous BTEX Source (Model ELMC)

Model ELMC assumed that a continuing source of contamination (such as residual-phase or mobile LNAPL) is present and introducing dissolved-phase BTEX into the



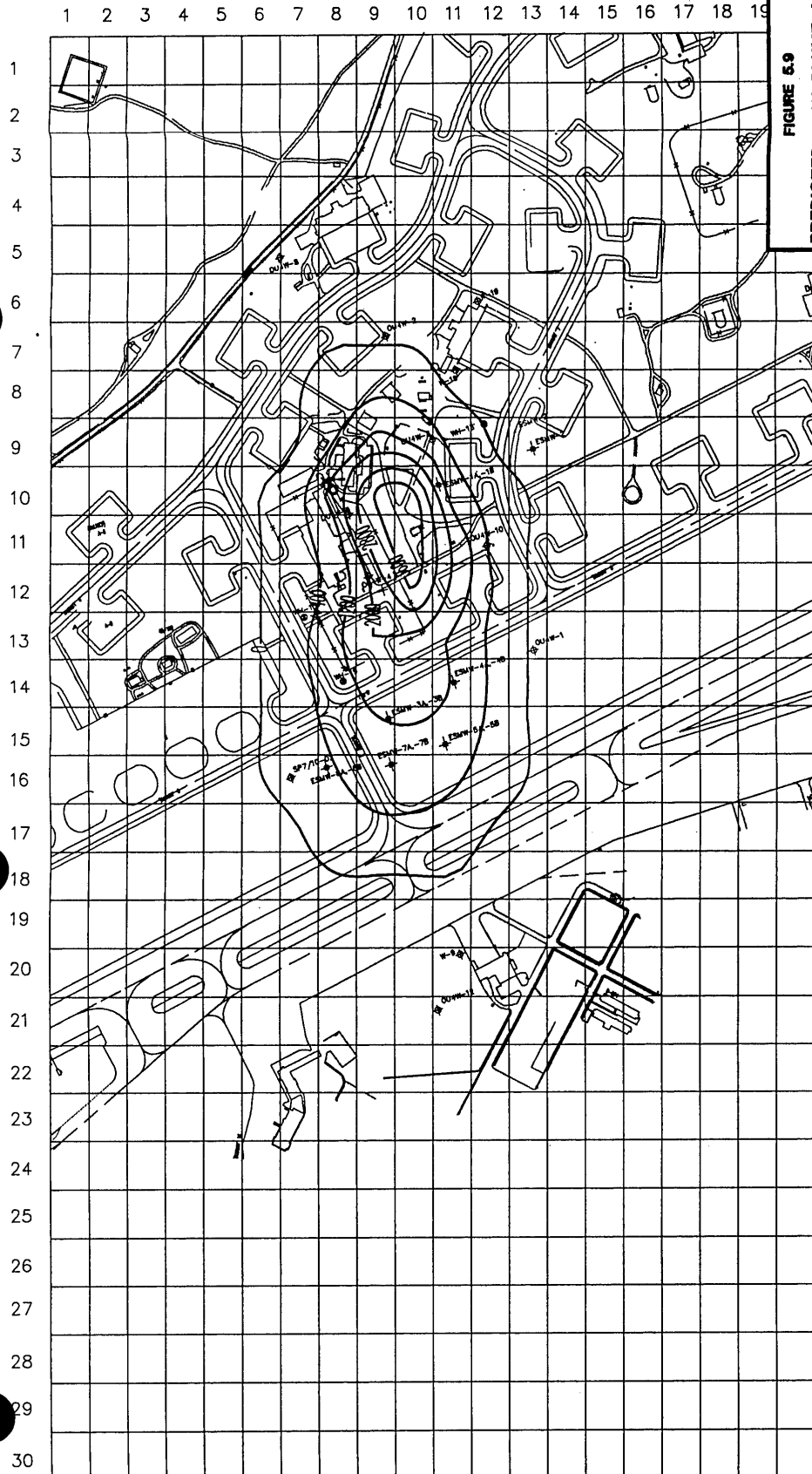


FIGURE 5.9
PREDICTED BTEX PLUME AT T=0,
MODEL ELMB
(REDUCED ANAEROBIC DECAY)

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
 Denver, Colorado

5-27

LEGEND
 MONITORING WELL LOCATION (JUNE 1993)
 MONITORING WELL LOCATION (JUNE 1994)
 LINE OF EQUAL BTEX SIMULATED CONCENTRATION (µg/L)
 CONTOUR INTERVAL = VARIABLE

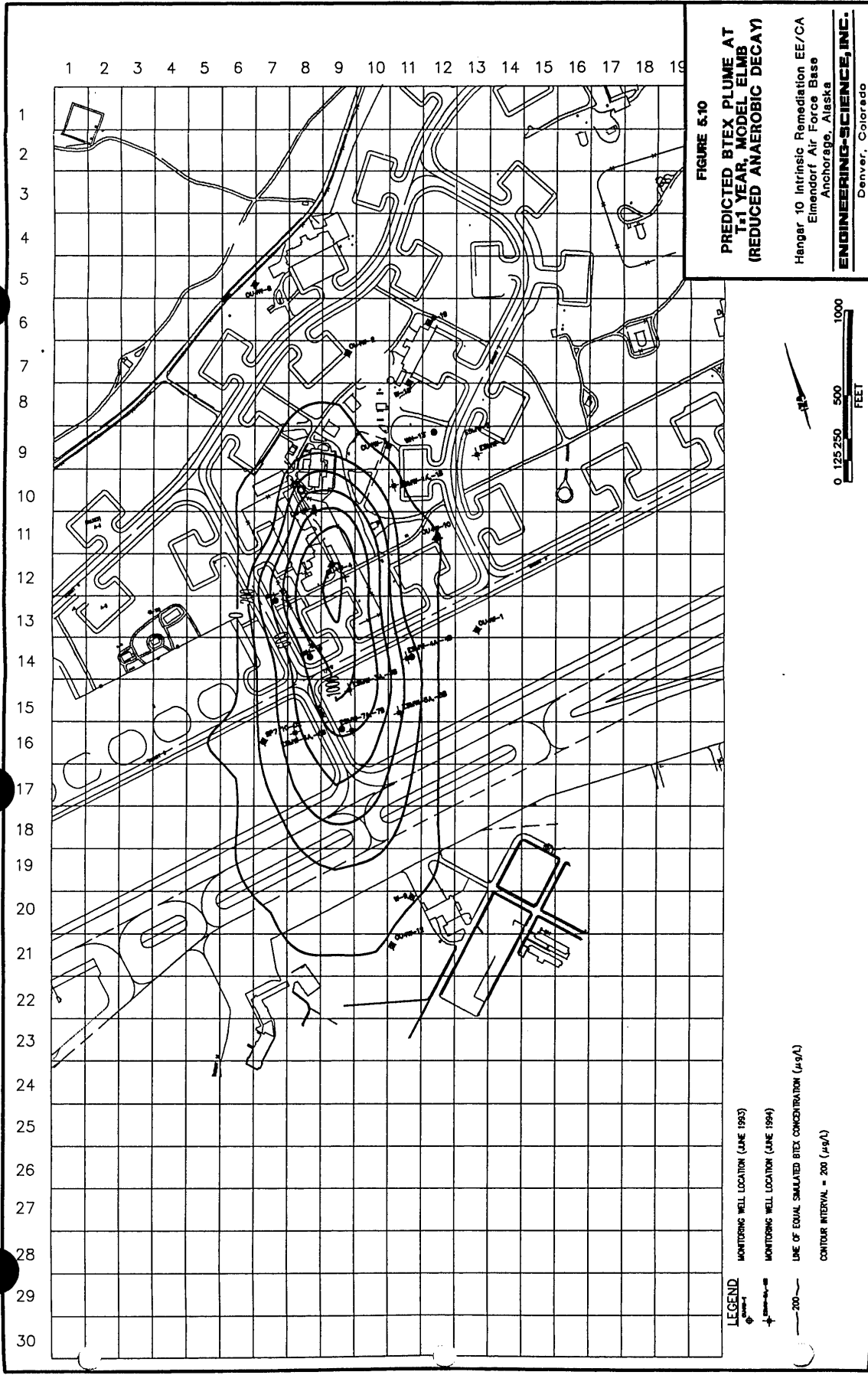
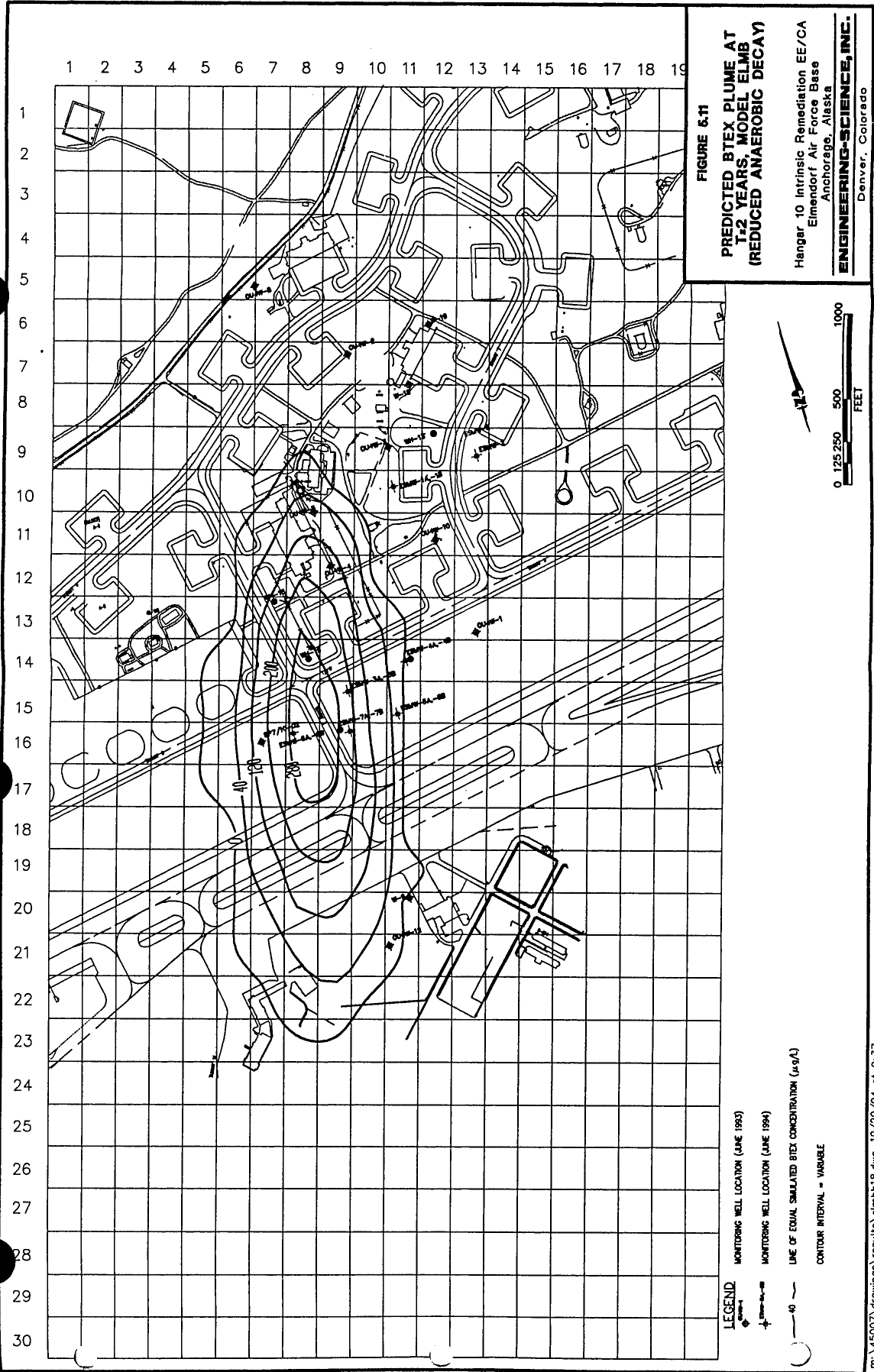


FIGURE 5.10
PREDICTED BTX PLUME AT
T+1 YEAR, MODEL ELMB
(REDUCED ANAEROBIC DECAY)

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
 Denver, Colorado



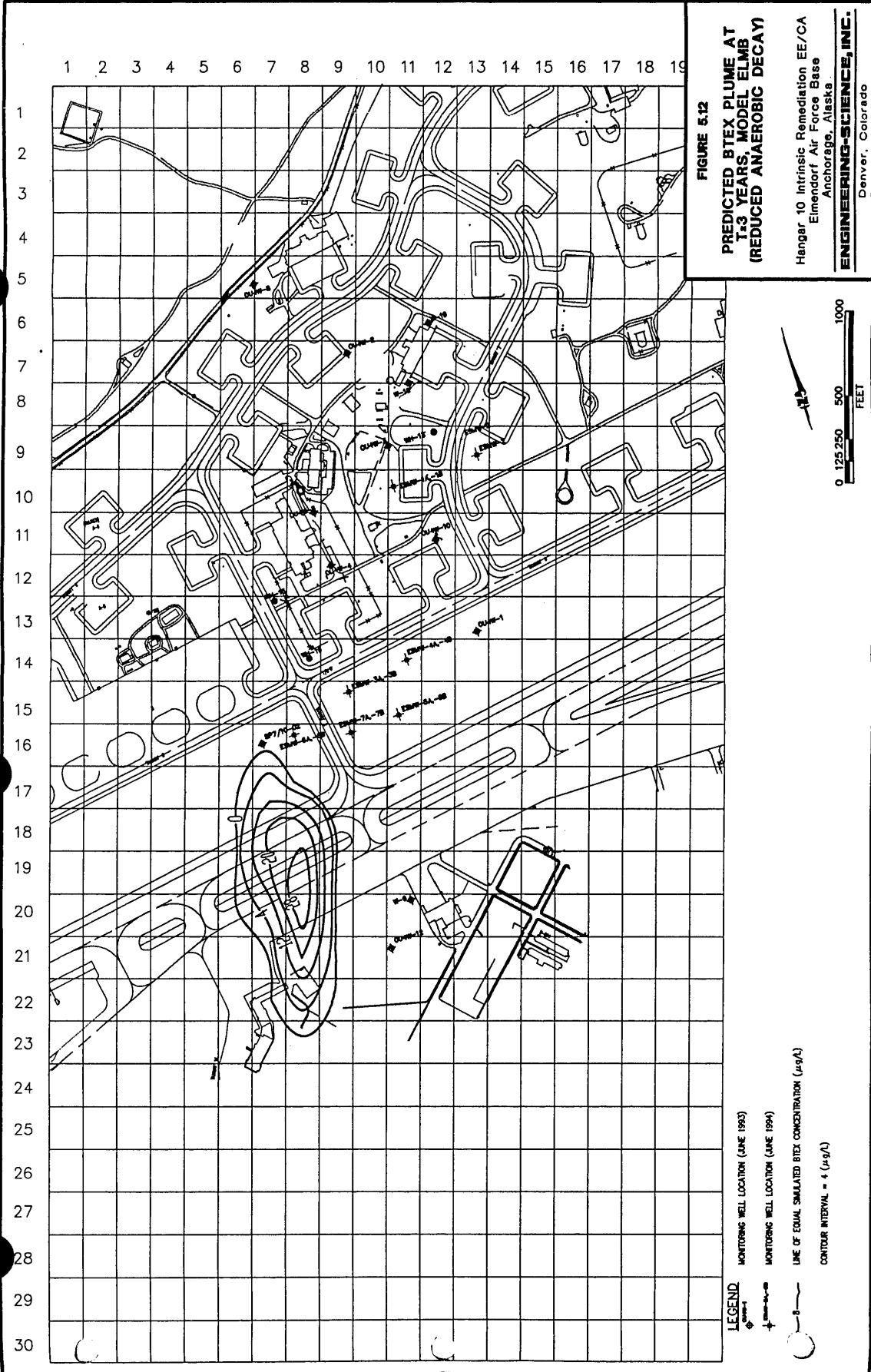
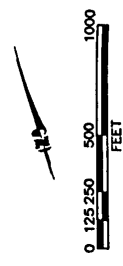


FIGURE 5.12
PREDICTED BTEX PLUME AT
T+3 YEARS, MODEL ELMB
(REDUCED ANAEROBIC DECAY)

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
 Denver, Colorado

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- LEGEND**
- MONITORING WELL LOCATION (JUNE 1993)
 - MONITORING WELL LOCATION (JUNE 1994)
 - LINE OF EQUAL SIMULATED BTEX CONCENTRATION ($\mu\text{g/L}$)
 - CONTOUR INTERVAL = 4 ($\mu\text{g/L}$)

ground water. It was assumed that this source area is present in the vicinity of Pump House 2 and the nearby valve pit. Contaminants were introduced to the aquifer using simulated injection wells located in cells 9,8; 9,9; 10,8; and 10,9, as indicated on Figure 5.13. This scenario was run to assess the effects of a continuing source of contamination, although firm evidence of such a source does not exist. As with model ELMA, model ELMC assumed that all other calibrated model conditions continued throughout the entire simulation.

While the term "injection well" suggests contaminants are being introduced at a point, Bioplume II assumes that contamination introduced at a well instantly equilibrates throughout the entire cell in which the well is located. The injection rate for the cells was set at $1 \times 10^{-3} \text{ ft}^3/\text{sec}$, a value low enough so that the flow calibration and water balance was not affected. Relatively high BTEX concentrations were injected through the wells because of the low pumping rate. The total BTEX injection concentration was set at 100 mg/L. After the mass is dispersed throughout the entire cell volume, this results in the total BTEX concentration in the source area being maintained at approximately 450 $\mu\text{g/L}$. Therefore, this simulations illustrates the effects of a source that would continuously introduce enough BTEX to produce a total BTEX concentration of 450 $\mu\text{g/L}$.

Although the loading rate indicated above results in a total of 245 kg of BTEX per day being introduced at each well (a total of 1 metric ton of BTEX per day), this does not imply that an equivalent loading would be necessary to actually produce such concentrations within the aquifer. This is because the model assumes the mass of BTEX that enters each cell from the wells is instantly dispersed throughout a volume of water equivalent to the area of the cell times its saturated thickness. Because the aquifer is assumed to be 60 feet thick in the vicinity of the injection wells, the injected BTEX equilibrates with a very large volume of water. In most situations, BTEX is actually introduced near the water table and generally is most concentrated in the vicinity of the water table, where monitoring wells water table then intercept the contamination. As a result, it would require only a fraction of the simulated mass loading rate to produce BTEX concentrations of 450 $\mu\text{g/L}$ within the aquifer.

This simulation indicates that BTEX contamination will degrade rapidly despite the continued source loading. At $T = 0$ years, the plume configuration in Figure 5.14 is very similar to the original calibrated plume. After 1 year of prediction time the plume reaches

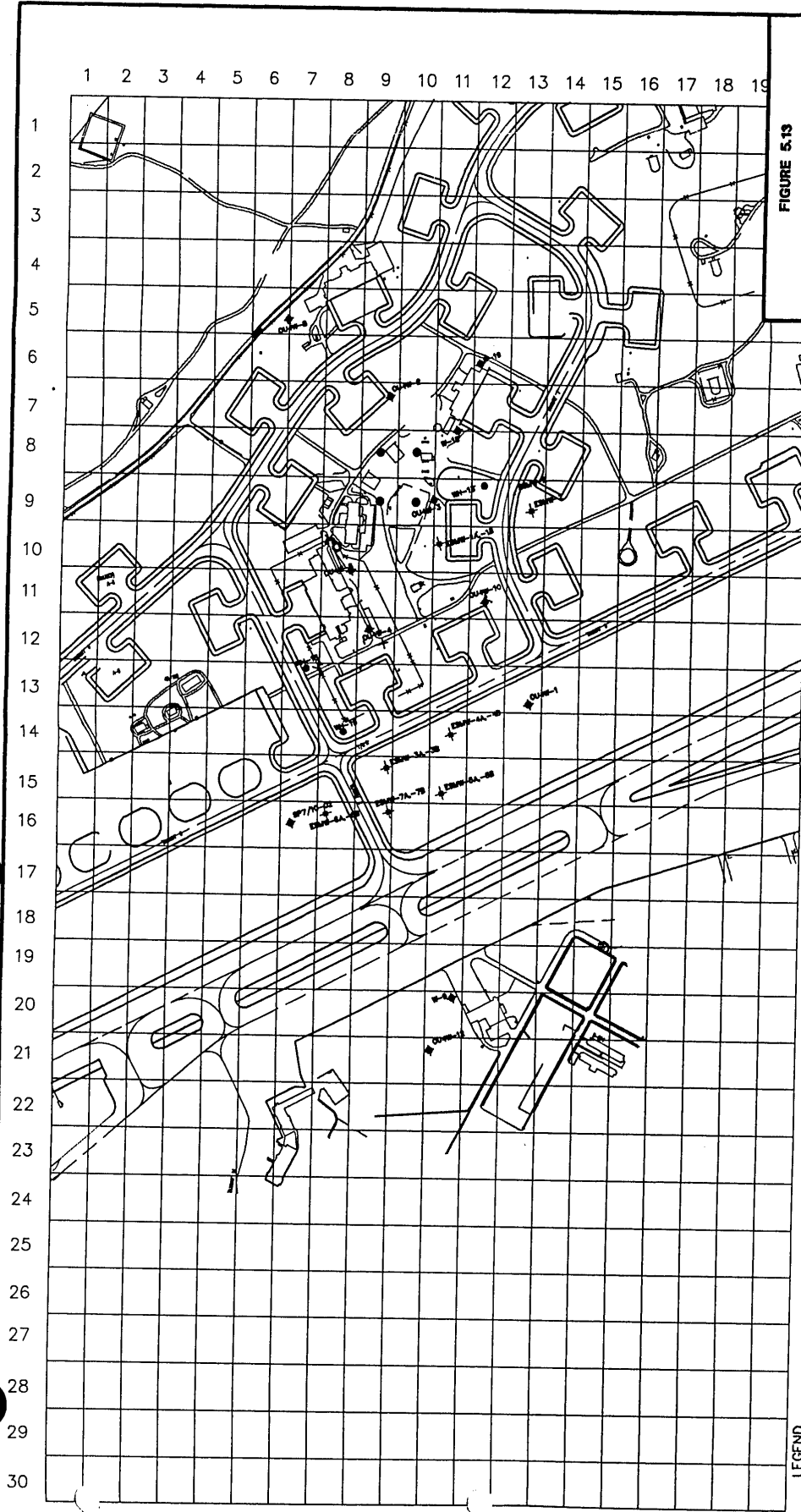
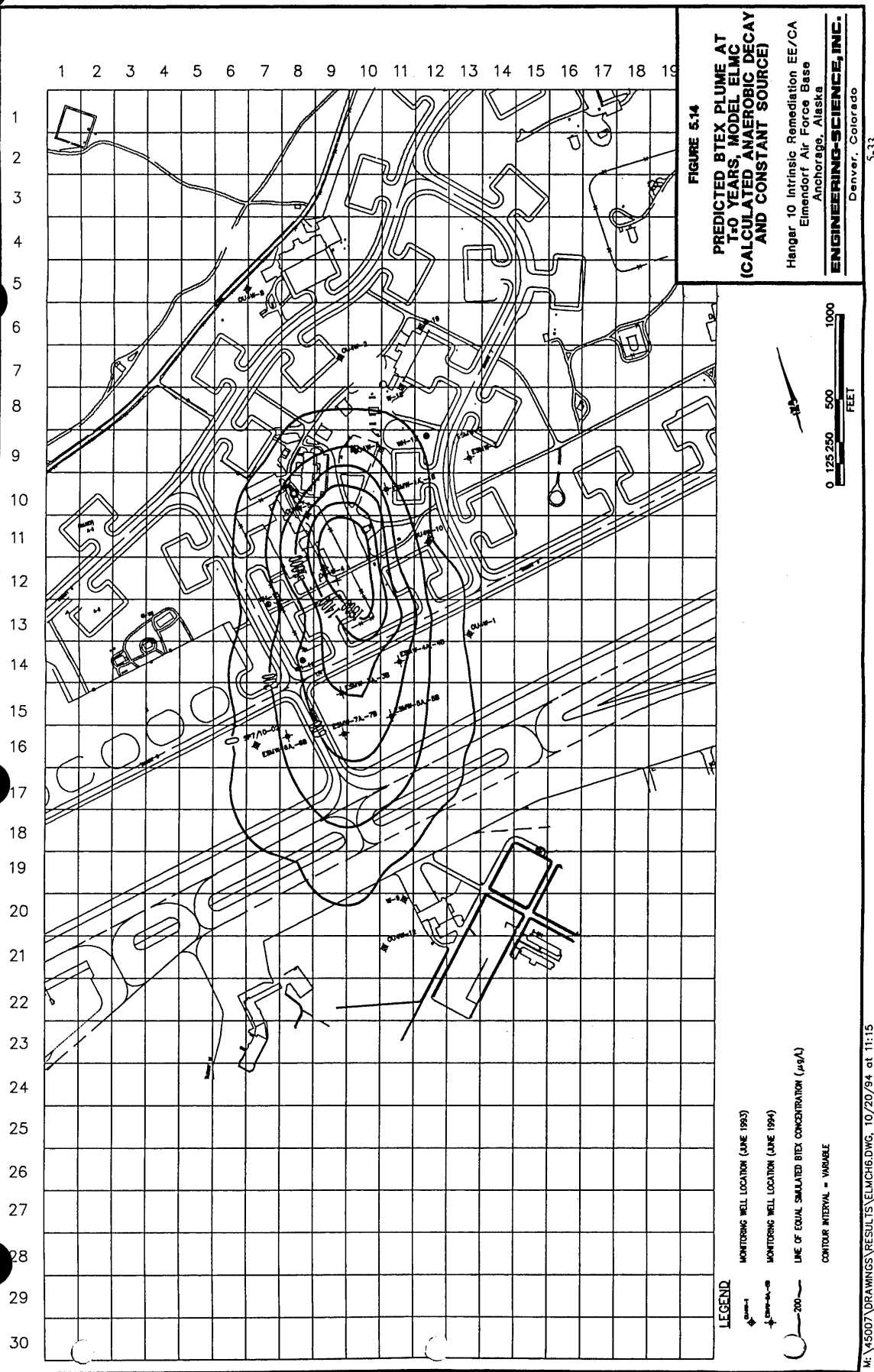


FIGURE 5.13
LOCATIONS OF SIMULATED
INJECTION WELLS FOR
MODEL ELMC

Hanger 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
 Denver, Colorado

LEGEND
 ◆ MONITORING WELL LOCATION (JUNE 1993)
 + MONITORING WELL LOCATION (JUNE 1994)
 • LOCATION OF SIMULATED INJECTION WELL



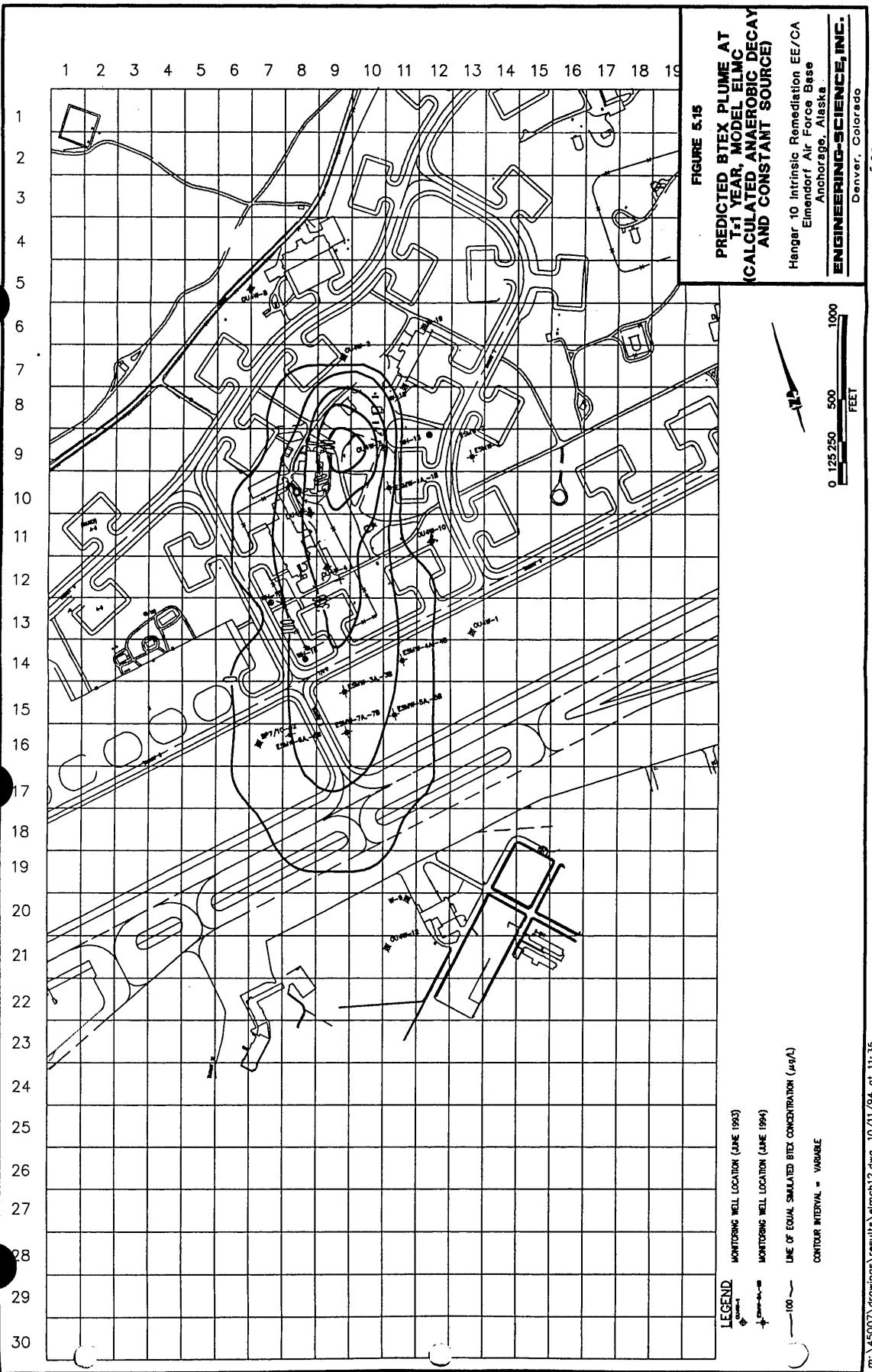
its maximum extent, approximately 750 feet beyond the June 1994 plume (Figure 5.15). After 1 year of prediction time, the plume begins to shrink back toward the source area, so that after 3 years of prediction time the plume is only about 750 feet long with a maximum simulated concentration of approximately 560 $\mu\text{g/L}$. After 5 years of prediction time, BTEX is present only in the vicinity of the source cells, as shown by Figure 5.16. The plume remains in this configuration for the remainder of the simulation (15 years of prediction time), suggesting that the plume stabilizes so that BTEX is present only within the source area. Maximum source area BTEX concentrations fluctuated around an average of 450 $\mu\text{g/L}$ throughout the remainder of the simulation.

5.6.4 No Anaerobic Degradation (Model ELMF)

Model ELMF was run to illustrate the effects of ignoring anaerobic degradation of BTEX compounds. The anaerobic decay coefficient was set to 0 for this simulation, so that only aerobic biodegradation was simulated. The plume computed by this model after 1 year (at $T = 0$ years) was compared to the calibrated and observed BTEX plumes. As indicated on Figure 5.17, elimination of anaerobic decay results in a plume configuration that does not reflect June 1994 conditions. The plume simulated by ELMF extends much farther than the calibrated plume, and concentrations are approximately five times greater than those in the calibrated model. Under these conditions, the leading edge of the plume migrates to the downgradient model boundary (a total distance of over 3,000 feet) within 5 years. Given that the plume was observed to migrate less than 300 feet between 1993 and 1994, this model is unrealistic. However, this model is important in that it further demonstrates that anaerobic biodegradation of BTEX compounds is occurring in the vicinity of Hangar 10 and is an important factor in controlling the migration of contaminants because aerobic biodegradation alone is insufficient to reproduce observed site conditions.

5.7 CONCLUSIONS AND DISCUSSION

The results of four different Bioplume II model scenarios for the Hangar 10 site suggest that the dissolved-phase BTEX plume front is not likely to migrate more than 1,750 feet downgradient of its June 1994 position. The first scenario, model ELMA, assumed that conditions which produced the calibrated model would remain constant for the full duration of the simulation. The second scenario, model ELMB, assumed that the



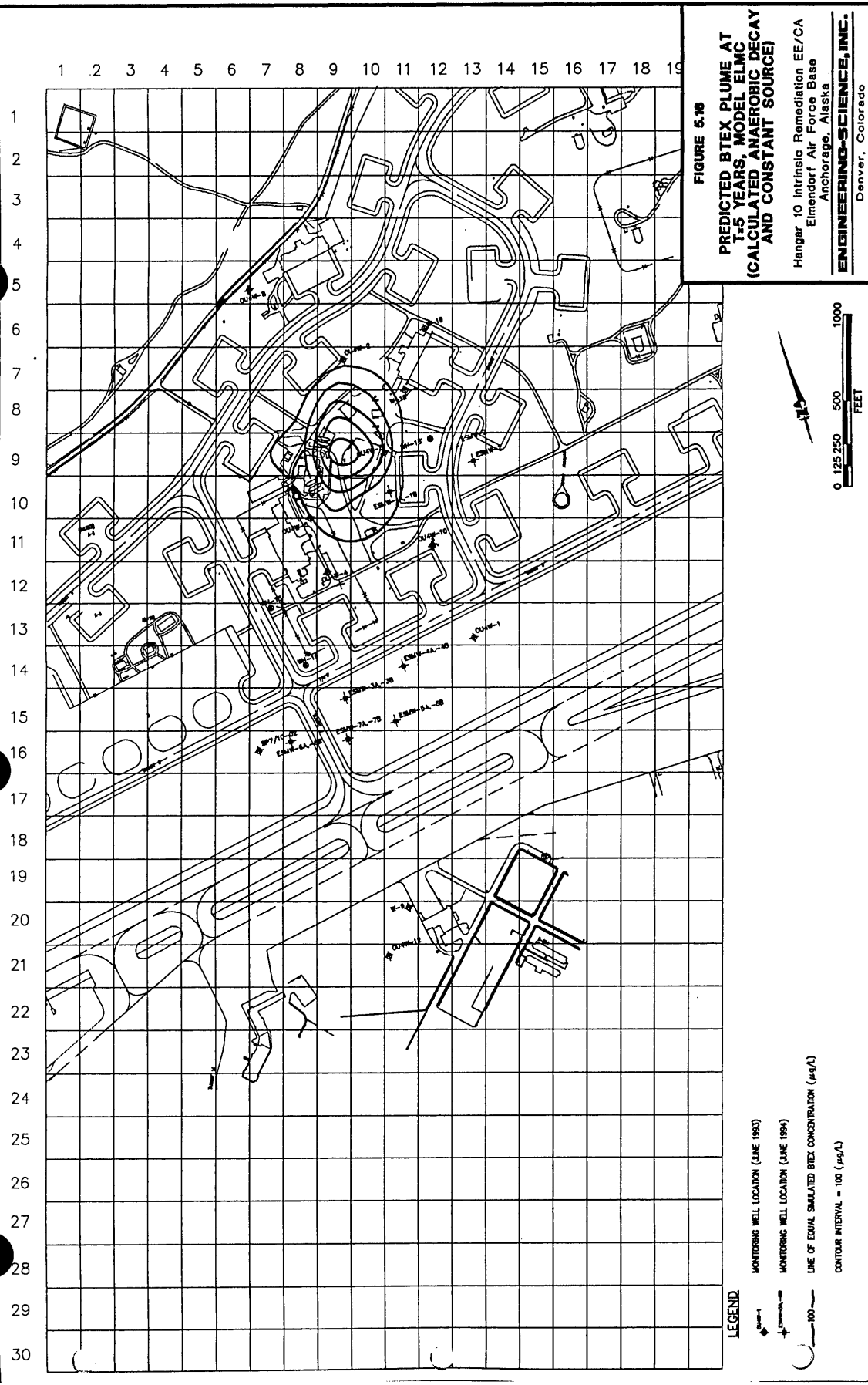


FIGURE 5.16
PREDICTED BTEX PLUME AT
T=5 YEARS, MODEL ELMC
(CALCULATED ANAEROBIC DECAY
AND CONSTANT SOURCE)
 Hanger 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska
ENGINEERING-SCIENCE, INC.
 Denver, Colorado

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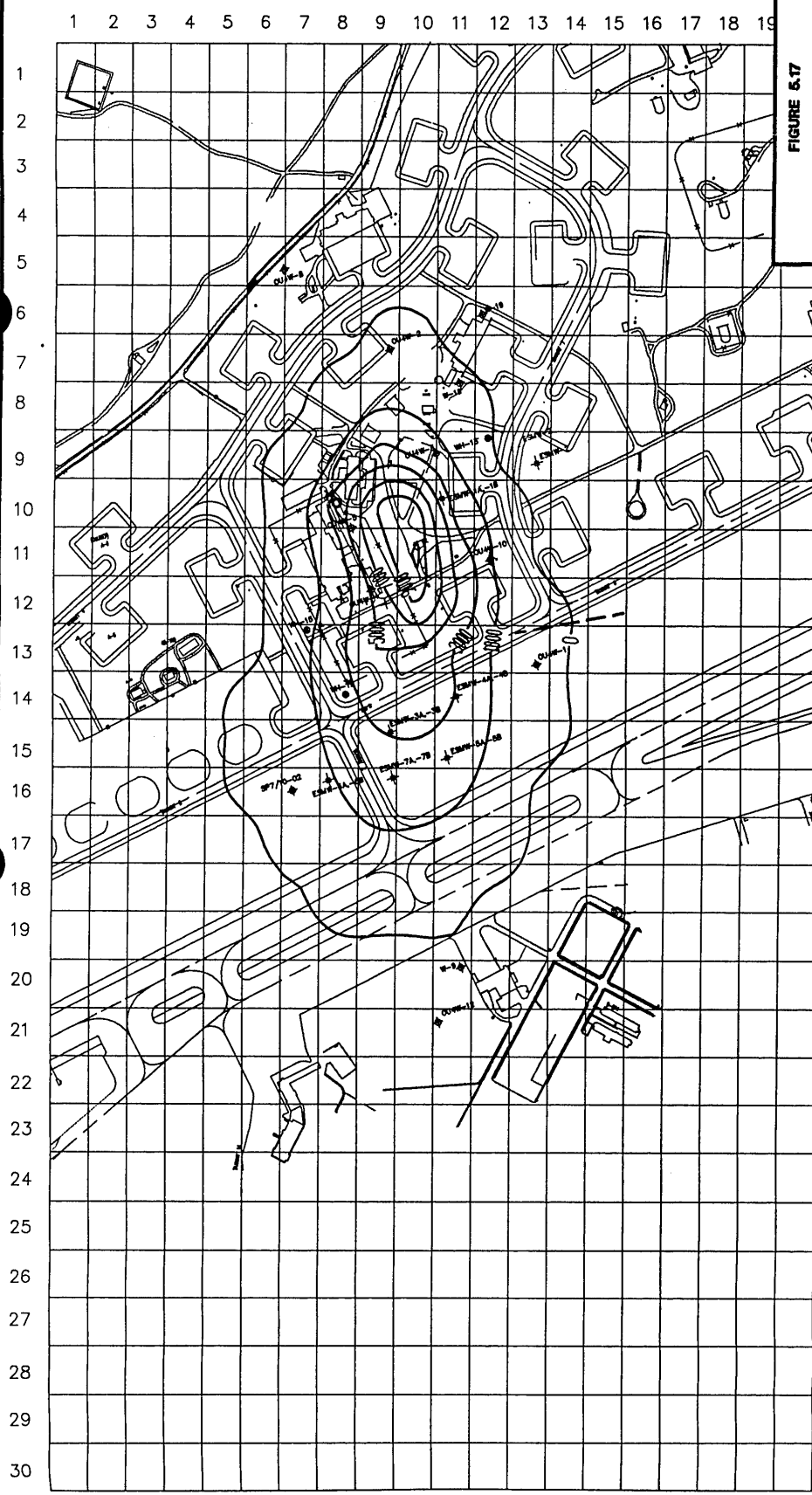


FIGURE 5.17
PREDICTED BTEX PLUME AT
T=0 YEARS, MODEL ELMF
(NO ANAEROBIC DECAY)

Hangar 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska
ENGINEERING-SCIENCE, INC.
 Denver, Colorado

LEGEND
 MONITORING WELL LOCATION (JUNE 1993)
 MONITORING WELL LOCATION (JUNE 1994)
 LINE OF EQUAL SIMULATED BTEX CONCENTRATION ($\mu\text{g/L}$)
 CONTOUR INTERVAL = 1000 ($\mu\text{g/L}$)

anaerobic decay constant was reduced by one-half, thus simulating reduced anaerobic biodegradation of BTEX compounds. The third scenario, ELMC, was identical to ELMA except that a continuous source of BTEX was simulated in the vicinity of Pump House 2. Finally, the fourth scenario (ELMF) illustrated the effects of not including an anaerobic biodegradation term.

These simulations were run to provide constraints on BTEX migration and degradation for a range of conditions, allowing a more thorough evaluation of the effects of advective-dispersive transport and biodegradation on dissolved-phase BTEX plume migration. This was done largely because the source(s) of petroleum hydrocarbon contamination in the Hangar 10 area have not been well-defined, and also because Bioplume II is only capable of simulating anaerobic biodegradation using first-order kinetics.

ELMA results suggest that after 1.5 years of prediction time, the BTEX plume will be completely degraded and/or sorbed onto the aquifer matrix. ELMB results suggest that even with reduced anaerobic decay, BTEX compounds will migrate no more than 1,750 feet downgradient from the June 1994 plume front and will be degraded in just over 3 years. ELMC predicts that even with continued loading of BTEX compounds, the plume will reach no more than 500 feet beyond its observed downgradient limit, and that within 5 years contamination will be present only within the source area. The results of model ELMF illustrate the effects of ignoring anaerobic biodegradation of BTEX compounds. In that simulation, reducing the anaerobic decay coefficient to zero resulted in unrealistic plume migration and spreading.

The rapid removal of BTEX compounds predicted by the simulations is largely a function of anaerobic biodegradation. However, the high hydraulic conductivity of the outwash sand and gravel plays an important role by flushing water containing DO and other electron acceptors through the BTEX plume, which is retarded with respect to the advective ground water velocity. As a result, aerobic and anaerobic biodegradation is increased due to the continuous influx of electron acceptors.

The results of models ELMA, ELMB, and ELMC suggest that rapid removal of BTEX compounds is occurring. In the worst-case scenario, the plume front is not likely to reach more than 1,750 feet downgradient of the position observed in June 1994, before diminishing in size and degrading in slightly more than 3 years. Even if significant concentrations of BTEX are added from a continuous source, the plume should migrate

no further. Actual plume migration will likely be less, as this estimate is based on model ELMB, which simulated transport with reduced anaerobic degradation. Taking into account the model cell size and the resolution of concentrations at the margin of the plume, it appears unlikely that detectable concentrations of BTEX will migrate more than 500 feet beyond wells OU4W-12 and W-9 (near the fire station). While ELMA results are based on calibrated model conditions, ELMB results are likely to be more realistic, particularly with respect to the time required for complete plume degradation. This is partly because there may be a continuing source of BTEX contamination, and partly because the BTEX that sorbs onto the aquifer matrix will eventually desorb and re-enter solution as aqueous concentrations decrease.

Model results also suggest that it would take a considerable source of hydrocarbon contamination to cause the plume to grow or to migrate a significant distance. This is important to consider, because the source of the dissolved-phase BTEX contamination in the Hangar 10 area is poorly defined and may or may not be continuing to release BTEX into the outwash aquifer.

Bioplume II does not account for desorption of contaminants from the aquifer matrix. However, a review of mass-balance computations for model ELMA, ELMB, and ELMC indicates that the mass of BTEX sorbed onto the aquifer solids is at most 1.1 percent of the total dissolved mass that is removed by aerobic and anaerobic biodegradation. As a result, the concentrations of BTEX that will desorb after the aqueous plume diminishes will be very minor compared to observed concentrations. In addition, as the compounds enter the aqueous phase, they will be diluted and will be available for biodegradation.

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

- 1) Aerobic respiration, denitrification, iron reduction, sulfate reduction, and methanogenesis are all occurring at this site; however, only DO is considered as an electron acceptor during model simulations, and the anaerobic decay coefficient used in the calibrated model is based on site-specific calculations which compare favorably to literature values;
- 2) The stoichiometry used to determine the ratio between DO and total BTEX assumed that no microbial cell mass was produced during the reaction. As discussed in Section 4.3.2.1, this approach may be too conservative by a factor of three.

- 3) A midrange coefficient of retardation for benzene (1.9) was used for model simulations. Minimum coefficient of retardation values for the other BTEX compounds range from 1.45 to 3.67. The use of the 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.

The rapid degradation of BTEX observed in simulations ELMA, ELMB, and ELMC is feasible, given the observed BTEX concentrations, the conservative assumptions made in constructing the simulation, and the strong geochemical evidence of anaerobic biodegradation. Further confirmation of the rapid pace of biodegradation is provided by comparing the plumes observed in June 1993 and June 1994 (Figures 4.1 and 4.2, respectively). The data collected for this study indicate that the plume front advanced less than 300 feet in a year and that total BTEX concentrations were reduced between 1993 and 1994, largely because of anaerobic biodegradation. As indicated by model ELMF, aerobic biodegradation alone is insufficient to account for the conditions observed at the site.

SECTION 6

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the development and comparative analysis of two ground water remedial alternatives for the Hangar 10 site at Elmendorf AFB. The intent of this evaluation is to determine if intrinsic remediation is an appropriate and cost-effective remedial technology to consider when developing final remedial strategies for the Hangar 10 site, especially when combined with other innovative and conventional remedial technologies

Section 6.1 presents the evaluation criteria used to evaluate ground water 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 the appropriate remedial alternative for shallow ground water contamination at Hangar 10 were adapted from those recommended by the USEPA (1988) for selecting remedies for Superfund sites (OSWER Directive 9355.3-01). These criteria included (1) long-term effectiveness and permanence, (2) technical and administrative implementability, and (3) relative cost. The following sections briefly describe the scope and purpose of each evaluation criterion. This report does not include a complete discussion of applicable or relevant and appropriate requirements (ARARs) for the site. Rather, this report focuses on the potential use of intrinsic remediation and source reduction technologies to reduce BTEX concentrations within the shallow ground water to levels which pose no risk to human health or the environment.

6.1.1 Long-Term Effectiveness and Permanence

Each remedial technology or remedial alternative (which can be a combination of remedial technologies such as intrinsic remediation and institutional controls) was analyzed to determine how effectively it will minimize ground water plume expansion so that ground water 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 ground water is qualitatively assessed by conservatively estimating if a potential exposure pathway involving ground water could be completed, either now or in the future. This evaluation criterion also included 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, is also 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 inflation 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 ground water contamination at Hangar 10. Factors considered included the objectives of the natural attenuation demonstration program; contaminant, ground water, and soil properties; present and future land use; and potential exposure pathways. The following section briefly describes each of these factors and how they were used to narrow the list of potentially applicable remedial technologies to the final remedial alternatives considered for the Hangar 10 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 Hangar 10 study is to provide solid evidence of intrinsic remediation of dissolved-phase fuel hydrocarbons so that this information can be used to develop an effective ground water remediation strategy. A secondary goal of this multi-site initiative is to provide a series of regional case studies that demonstrate that natural processes of contaminant degradation can often reduce contaminant concentrations in ground water to below acceptable cleanup standards before completion of potential exposure pathways.

Because the objective of this program is to study natural processes in the saturated zone rather than all contaminated media (soil, soil gas, etc.), technologies have been evaluated based primarily on their potential impact on shallow ground water and phreatic soils. Technologies that can reduce vadose zone contamination and partitioning of contaminants into ground water have also been evaluated. Many of the source removal technologies evaluated in this section will also reduce soil and soil gas contamination, but it is important to emphasize that the remedial alternatives developed in this document are not intended to remediate all contaminated 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, ground water pump and treat, and intrinsic remediation. Soil excavation, slurry walls, sheet piling, carbon adsorption, *ex situ* biological or chemical treatment, and onsite/offsite disposal are not attractive technology candidates for this site.

6.2.2 Contaminant Properties

The site-related contaminants considered as part of this demonstration at the Hangar 10 site are the BTEX compounds. The source of this contamination is weathered petroleum (i.e., JP-4 fuel) present as residual contamination in capillary fringe and saturated soil in the vicinity of Hangar 10. The physiochemical characteristics of JP-4 and the individual BTEX compounds will greatly influence the effectiveness and selection of a remedial technology.

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

The BTEX compounds are generally volatile, highly soluble in water, and adsorb less strongly to soil than other hydrocarbons in a petroleum mixture. These characteristics allow the BTEX compounds to leach more rapidly from contaminated soil into ground water, and to migrate as dissolved-phase 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 ground water (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).

Based on these physiochemical characteristics, intrinsic remediation, soil vapor extraction, bioventing, biosparging, ground water extraction, and air stripping technologies could all be effective at collecting, destroying, and/or treating BTEX contaminants at the Hangar 10 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 ground water 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 Ground Water and Soil Characteristics

Site geology and hydrogeology will have a profound effect on the transport of contaminants and the effectiveness and scope of required remedial technologies at a given site. Hydraulic conductivity is perhaps the most important aquifer parameter governing ground water flow and

contaminant transport in the subsurface. The velocity of the ground water and dissolved-phase contamination is directly related to the hydraulic conductivity of the saturated zone. Previous pumping tests conducted downgradient of the Hangar 10 site indicate a high conductivity within the outwash sand and gravel present in the vicinity of the source area and dissolved-phase plume. Estimated values ranged from 0.2 to 0.6 ft/min. These high values are characteristic of sandy and gravelly materials (see Sections 4 and 5 of this report). The high hydraulic conductivity at this site directly influences the fate and transport of contaminants. The shallow ground water plume 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 increased biodegradation.

Although high hydraulic conductivity can result in plume expansion and migration, this same characteristic will also enhance the effectiveness of other remedial technologies, such as ground water 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 may also 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 also increases the amount of contaminant mass traveling through the biosparging network. The DO introduced through biosparging can also enhance aerobic degradation of the dissolved contaminant mass.

The rapid movement of contaminants within the subsurface away from the source will also increase the effectiveness of natural biodegradation processes by distributing the contaminant mass into areas enriched with electron acceptors. To satisfy the requirements of indigenous microbial activity and intrinsic remediation, the aquifer must also 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 demonstration project and described in Sections 3 and 4 of this document indicate that the Hangar 10 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, nitrate, ferric iron, sulfate, 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 ground water and phreatic soil at the Hangar 10 site are not likely to inhibit microorganism growth, although growth might be slowed by the relatively low temperatures.

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 the Hangar 10 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 potential mechanism(s) of release, a pathway of transport to an exposure point, an exposure point, and a receptor. If any of these elements do not exist, the exposure pathway is considered incomplete, and receptors will not come into contact with site-related contamination. Evaluation of the potential long-term effectiveness of any remedial technology or remedial alternative as part of this demonstration project includes determining if the approach will be sufficient and adequate to minimize plume expansion so that potential exposure pathways involving shallow ground water are incomplete.

Assumptions about current and future land uses at a site form the basis for identifying potential receptors, potential exposure pathways, reasonable exposure scenarios, and appropriate remediation goals. USEPA (1991) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be used to guide the identification of potential exposure pathways and to determine the level to which the site must be remediated. The probable source area consists of POL facilities, including distribution lines, pump houses, and valve pits, and possibly a 1,000-gallon UST near Hangar 10. Hangars and other maintenance buildings, aircraft pads, taxiways, and runway infields are located to the north, west, and east of Hangar 10. The area south of the site is occupied by aircraft runways and their associated infields. The ground water plume originating from the Hangar 10 site is migrating to the south-southwest, and has impacted ground water in an

area extending from the vicinity of Hangar 10 to an area just south of the taxiway south of Hangar 8 (Figures 4.1 and 4.2). Thus, the current land use within and downgradient of the contaminant plume is entirely industrial. Other base facilities, including a fire station and the base operations buildings, are located approximately 1,500 feet beyond the downgradient margin of the BTEX plume. Some base housing is present, but is over 2,000 feet downgradient from the plume margin. Ultimately, ground water from the shallow aquifer discharges into Ship Creek, which is approximately 1.5 miles south of the site.

Under reasonable current land use assumptions, potential receptors only include worker populations. It is unlikely that workers could be exposed to site-related contamination in phreatic soils or shallow ground water unless this material is removed during future construction excavations or remedial activities. Previous soil data did not indicate any widespread areas of soil contamination, and because the water table is at least 15 feet bgs in the plume area, exposure to the ground water is also unlikely. Ground water from the outwash aquifer is not currently used to meet any demands at Elmendorf AFB. On-base water demands are met by supply wells screened in the deep confined aquifer. 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. Migration to and discharge of contaminated shallow ground water into Ship Creek could complete an exposure pathway to human or ecological receptors via dermal contact or possible ingestion, but it is very unlikely that detectable BTEX concentrations from the Hangar 10 site could reach the creek.

Assumptions about hypothetical future land uses must also be made to ensure that the remedial technology or alternative considered for shallow ground water at the site is adequate and sufficient to provide long-term protection. No changes in land use are anticipated in the foreseeable future, so an industrial land use assumption is most appropriate. Thus, potential future receptors include only worker populations. The potential future exposure pathways involving workers are identical to those under current conditions provided shallow ground water 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 ground water use be enforced in areas downgradient of the Hangar 10 site until natural attenuation reduces contaminants to levels that pose no risk. If source removal technologies such as soil vapor extraction, bioventing, biosparging, or ground water 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.

6.2.3.3 Remediation Goals for Shallow Ground Water

Model results suggest that BTEX compounds are not likely to move more than 1,750 feet downgradient of the observed plume front. Therefore, an area approximately 1,750 feet beyond the plume boundary observed in June 1994 has been identified as the POC for ground water remedial activities because this appears to be the maximum extent of future contaminant migration. This is a suitable location for monitoring and for demonstrating compliance with protective ground water quality standards, such as promulgated ground water maximum contaminant levels (MCLs).

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 ground water within and downgradient of Hangar 10 is limited plume expansion to prevent exposure of downgradient receptors to concentrations of BTEX in ground water at levels that pose a risk. This means that viable remedial alternatives must be able to achieve concentrations that minimize plume migration and/or expansion. The RAO for shallow ground water at the POC is attainment of federal drinking water MCLs for each of the BTEX compounds listed in Table 6.1. Although it is unlikely that ground water would be ingested by humans, this level of long-term protection is appropriate.

TABLE 6.1

**POINT-OF-COMPLIANCE REMEDIATION GOALS
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

Compound	Federal MCLs (µg/L)
Benzene	5
Toluene	1,000
Ethylbenzene	700
Total Xylenes	10,000

In summary, available data suggest that there is no complete potential exposure pathway involving shallow ground water under current conditions. Moreover, it is likely that no potential exposure pathways involving shallow ground water would be complete under future land use assumptions, provided use of shallow ground water as a potable or industrial source of water is prohibited by institutional controls within the plume area and within an area approximately 1,750 feet downgradient of the 1994 plume front. Thus, institutional controls are likely to be a necessary component of any ground water 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 concentration in the ground water.

6.2.4 Summary of Remedial Technology Screening

Several remedial technologies have been identified and screened for use in treating the shallow ground water at the Hangar 10 site. Table 6.2 identifies the initial remedial technologies considered as part of this demonstration and those retained for detailed comparative analysis. Screening was conducted systematically by considering the program objectives of the AFCEE intrinsic remediation demonstration, 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 ground water underlying and migrating from the site. The remedial technologies retained for development of remedial alternatives and comparative analysis include institutional controls, intrinsic remediation, LTM, and biosparging.

6.3 BRIEF DESCRIPTION OF REMEDIAL ALTERNATIVES

This section describes how remedial technologies retained from the screening process were combined into two remedial alternatives for the Hangar 10 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 ground water.

TABLE 6.2
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Retain
Long-Term Monitoring	Periodic Ground Water Monitoring	Confirmation Wells	Many existing wells are available to confirm the progress of remediation.	Yes
		Point-of-Compliance Wells	Sufficient distance exists between the plume and point-of-compliance to locate several wells.	Yes
Institutional Controls	Ground Water Use Control	Land Use Control/Regulate Well Permits	Plume area is currently within the base boundary and land use and ground water use are under base jurisdiction.	Yes
		Seal/Abandon Existing Wells	No production wells are known to exist in the existing or predicted plume area.	No
		Point-of-Use Treatment	No shallow ground water 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	No likely receptors downgradient of site. Installation could disrupt base operations.	No
		Minimum Pumping/Gradient Control	A line or semicircle of vertical pumping wells could be located along the leading edge of plume to intercept and halt the advance of the plume. No likely receptors downgradient of site.	No
	Physical Controls	Slurry Walls/Grout Curtains	Requires significant disruption of base operating area. Limited effectiveness.	No
		Sheet Piling	Requires significant disruption of base operating area. Limited effectiveness.	No
	Reactive/Semi-Permeable Barriers	Biologically Active Zones	Natural biodegradation of BTEX compounds can be stimulated by allowing contaminated ground water to flow through an aquifer zone which has enhanced oxygen and nutrient conditions.	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

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.	Yes
	Chemical/Physical	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Ground water sampling at Hangar 10 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. Limited radius of influence and short-circuiting are common problems.	No
Aboveground Ground Water Treatment	Ground Water Extraction	Vertical Pumping Wells	Entire groundwater plume is pumped by installing numerous wells with submersible pumps. High cost and major disruption to area.	No
		Downgradient Horizontal Drains	See Passive Drain Collection.	No
	Biological	Bioreactors	High flow rates require excessive retention times and large reactors. BTEX is often volatilized in these systems.	No
	Chemical/Physical	Air Stripping	Cost-effective technology for removing varying concentrations of BTEX at higher flow rates. Potential permitting for air emissions.	No
		Activated Carbon	Cost prohibitive for more concentrated BTEX. Creates a carbon disposal problem.	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

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 and hydraulic loading.	No
Treated Ground Water Disposal	Discharge to IWWTP or Sanitary Sewer	IWWTP	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable. Ground water extraction is unlikely.	No
		Sanitary Sewer	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable.	No
	Treated Ground Water ReInjection	Vertical Injection Wells	Not recommended due to clogging and high maintenance.	No
Source Removal/Soil Remediation	Discharge to Surface Waters	Injection Trenches	Require large trenches and can be subject to injection well permitting.	No
		Storm Drains	Viable option but generally requires NPDES or other discharge permit. Ground water extraction is unlikely.	No
	Free Product Recovery	Dual-Pump Systems	Best suited for sites with > 1 foot free product where aboveground ground water treatment already exists	No
		Skimmer Pumps/Bailers/Wicks	Best suited for sites with < 1 foot free product where ground water pumping is undesirable.	No
	Excavation/Treatment	Total Fluids Pumping	Best suited for sites with thin saturated zones where excessive ground water will not be pumped.	No
		Bioslurping	Combined vapor extraction, bioventing and free product recovery system has been operated at some sites with limited success.	No
		Biological Landfarming	Excavation is not feasible at this site due to surface structures and facility use.	No
				No

TABLE 6.2 (Concluded)
 INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
 TECHNOLOGIES AND PROCESS OPTIONS FOR GROUND WATER REMEDIATION
 HANGAR 10 INTRINSIC REMEDIATION EE/CA
 ELMENDORF AFB, ALASKA

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

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-phase contaminant concentrations below numerical concentration goals, thus protecting human health and the environment. Based on the existing evidence of intrinsic remediation described in Section 4, these processes are occurring at the Hangar 10 site and will continue to reduce contaminant mass in the plume area.

Results of model ELMB suggest that the dissolved-phase plume should reach its maximum extent within 1 year. After approximately 3 years, the Bioplume II model predicts that intrinsic remediation within the BTEX plume will significantly reduce its size and concentration. This plume could extend to a maximum of 1,750 feet downgradient of the plume front indicated by June 1994 data. This does not take into account the full extent of anaerobic biodegradation, or source reduction through weathering of the residual product trapped in the soil pores. Model ELMA assumes that more anaerobic degradation occurs than in other models. This model is based on anaerobic decay coefficients calculated from site specific data and confirmed by literature values. Model ELMA predicted much more limited plume migration than ELMB, with BTEX plume reduction occurring approximately twice as fast. Results of model ELMC suggest that even with a continuing source of contamination, the plume will migrate no more than 500 feet beyond the June 1994 plume front before shrinking to the source area within 5 years. Under this scenario, contamination would persist only as long as the source continues to release BTEX to the shallow ground water.

Implementation of Alternative 1 would require the use of institutional controls such as land use restrictions and LTM. Land use restrictions may include placing long-term restrictions on soil excavation within the source area and long-term restrictions on ground water well installations within and downgradient of the plume area. The intent of these restrictions would be to reduce potential receptor exposure to contaminants by legally restricting activities within areas affected by site-related contamination. The three previously discussed model scenarios delineate the minimum and maximum estimated plume migration distances. Future plume migration and degradation will most likely result in conditions that fall between these limits. To be conservative, the results of model ELMB should be considered in making decisions regarding ground water monitoring and potential land use restrictions.

As a minimum, ground water monitoring would be conducted twice annually as part of this remedial technology to evaluate the progress of natural attenuation processes. Based on the

potential plume migration suggested by model ELMB, it is unlikely that benzene concentrations exceeding the MCL of 5 µg/L would be present more than 1,750 feet downgradient of the 1994 plume front (this would be true even if it were assumed that model contaminant concentrations are all benzene rather than total BTEX). Results of models ELMA and ELMC suggest that, at its maximum extent, the BTEX plume would reach no more than 500 feet beyond the 1994 plume front.

Because there are no apparent downgradient receptors, three POC wells should be placed downgradient of the modeled maximum extent (i.e., slightly more than 1,750 feet downgradient of the source area). In addition, four LTM wells within, upgradient and immediately downgradient of the existing BTEX plume would be used to monitor the effectiveness of intrinsic remediation. LTM wells are further described in Section 7.2.1. Detection of benzene in excess of 5 µg/L at downgradient LTM wells may require additional evaluation and modeling to assess BTEX migration and to determine the probable extent of BTEX migration, or to determine if additional corrective action would be necessary. Land use restrictions would also require reevaluation.

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 ground water monitoring program. The purpose of these periodic reviews would be to evaluate the extent of contamination, assess contaminant migration and attenuation through time, document the effectiveness of source removal and institutional controls at the site, and reevaluate the need for additional remedial actions at the site.

6.3.2 Alternative 2 - Biosparging, Intrinsic Remediation, and Institutional Controls with Long-Term Ground Water Monitoring

This alternative is identical to Alternative 1 except that biosparging would be used to introduce DO to the ground water in the vicinity of the plume front to increase aerobic biodegradation and limit plume expansion. Biosparging would be accomplished at this site by injecting air several feet below the ground water surface and allowing air (oxygen) to move upward through the saturated zone and capillary fringe and into the contaminated vadose zone. Multiple wells would be installed along a line near the plume front to assure injection of air along the full width of the plume. This would increase the DO content of the ground water and

promote more rapid aerobic biodegradation of BTEX compounds as the plume enters the sparged zone. Sparging for plume containment is recommended because the source area is poorly defined, background DO levels are low, and model results suggest that anaerobic biodegradation is reducing BTEX concentrations near the plume core.

Biosparging wells would likely be installed and manifolded along an east-west line through the infield north of the east-west runway (Figure 6.1). In this area, the plume is approximately 1,800 feet wide. Assuming that each sparging well has a radius of influence of 25 feet and the wells would be installed 40 feet apart, approximately 50 wells would be needed to fully intersect the plume. This spacing is reasonable given the highly permeable sand and gravel found in the shallow aquifer. All the biosparging wells would be installed to a depth of approximately 30 feet bgs, so that air (oxygen) would be introduced 10 to 15 feet below the water table. The system would likely consist of two separate lines of wells because the taxiway present near the western plume margin will prevent running a single manifold along the full length of the system.

As with Alternative 1, institutional controls and LTM would be required. POC and LTM wells would be installed in the same locations indicated in the previous section.

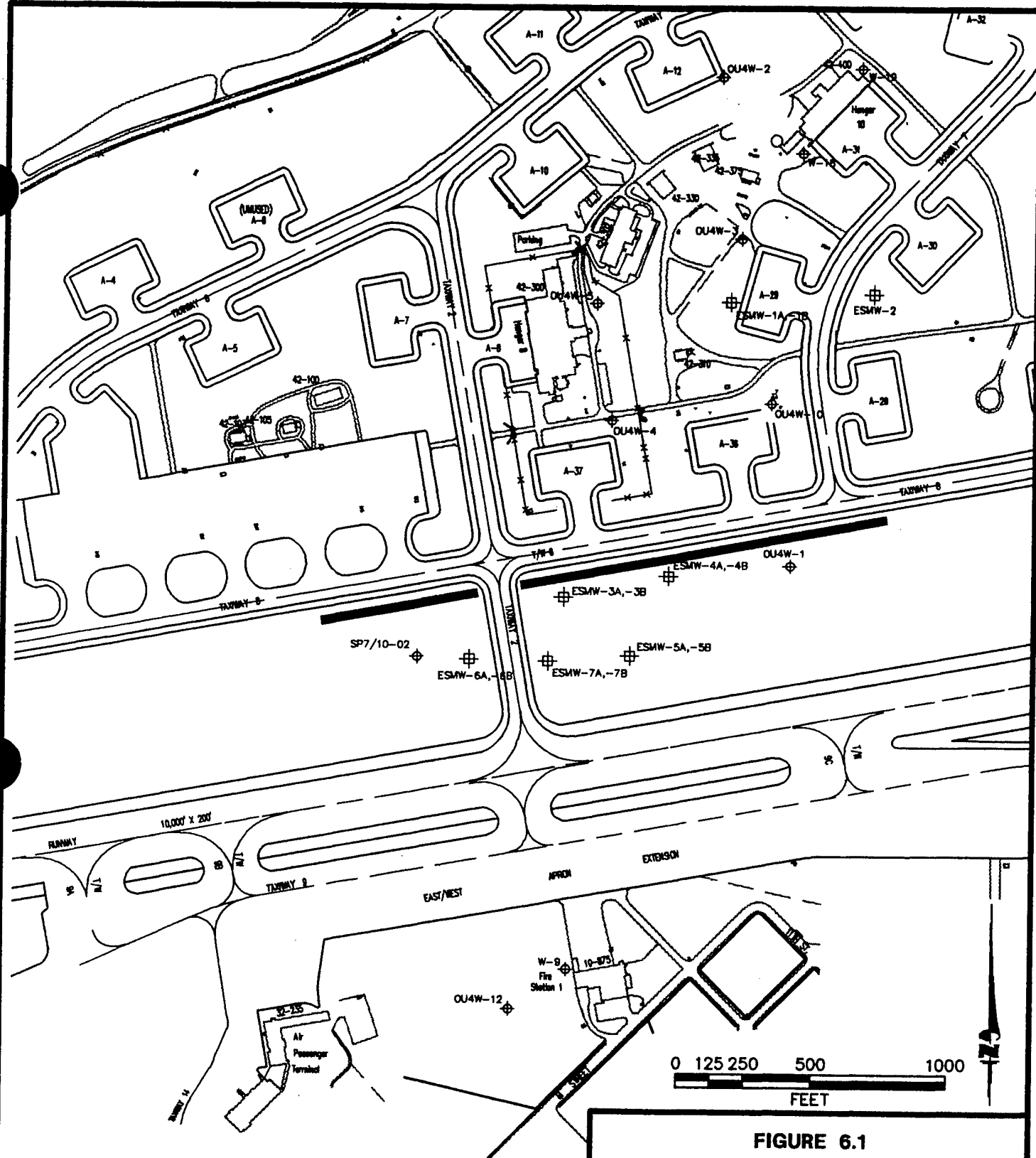
6.4 EVALUATION OF ALTERNATIVES

This section provides a comparative analysis of each of the remedial alternatives based on the effectiveness, implementability, and cost criteria. A summary of this evaluation is presented 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 Bioplume II modeling completed to support the intrinsic remediation alternative at the Hangar 10 site. Three models (ELMA, ELMB, and ELMC) were used to illustrate a range of potential future conditions at the site. Model ELMA predicted BTEX migration and degradation based on conditions that produced the calibrated model. Model ELMB was similar, except that the anaerobic decay coefficient was reduced. ELMC illustrated the effects of a continuous source of BTEX near POL Pump House 2.



LEGEND

OU4W-1

MONITORING WELL LOCATION (JUNE 1993)

ESMW-5A, -5B

MONITORING WELL LOCATION (JUNE 1994)

LOCATION OF BIOSPARING WELLS AND MANIFOLDS

0 125 250 500 1000
FEET

FIGURE 6.1

PROPOSED LOCATION OF BIOSPARGING SYSTEM FOR ALTERNATIVE 2

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

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Denver, Colorado

Model results predicted that natural attenuation mechanisms will significantly limit contaminant migration and reduce contaminant mass and toxicity. Benzene concentrations should not exceed the federal MCL at the POC wells. The Bioplume II model is based upon numerous conservative assumptions. Ground water monitoring at the LTM and POC wells will ensure the protectiveness of this alternative. While this alternative would not cease to be protective if the benzene plume was intercepted by the POC wells, such an instance would indicate that site conditions should be reevaluated.

The effectiveness of this remedial alternative requires that excavations or drilling within the source area be conducted only by properly protected site workers. Reasonable land use assumptions for the plume area indicate that exposure is unlikely unless excavation or drilling activities bring saturated soil to the surface. Long-term land use restrictions will be required to ensure that shallow ground water will not be pumped or removed for potable use within, and approximately 1,750 feet in all directions from, the existing BTEX plume. Existing health and safety plans should be enforced to reduce risks from installing and monitoring additional POC wells.

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

Alternative 1 is based on the effectiveness of enhanced naturally occurring processes that minimize contaminant migration and reduce contaminant mass over time, and the effectiveness of institutional controls. As described earlier, an investigation of the potential effectiveness of naturally occurring processes at the Hangar 10 site using field data and the Bioplume II model 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 Hangar 10 should reduce contaminant migration so that the maximum distance traveled by the plume is unlikely to be beyond the proposed POC wells. The actual maximum migration distance is likely to be much less than the maximum predicted distance of 1,750 feet beyond the June 1994 plume front, due to the significant amount of anaerobic biodegradation at the site and the minimal plume travel observed between June 1993 and June 1994.

Aside from the administrative concerns associated with enforcement of long-term land use restrictions and long-term ground water monitoring programs, this remedial alternative should provide reliable, continued protection. Model results suggest that the plume will degrade in

slightly more than 3 years. However, due to uncertainty about the source of BTEX contamination, it is assumed for cost comparison purposes that dissolved benzene concentrations will exceed federal MCLs throughout the plume for approximately 5 years under Alternative 1. An additional 5 years of semiannual ground water monitoring will be required to ensure that intrinsic remediation has uniformly reduced all BTEX compounds to levels below federal MCLs.

6.4.1.2 Implementability

Alternative 1 is not technically difficult to implement. Installation of LTM and POC wells and semiannual ground water monitoring are standard procedures. Long-term management efforts will be required to ensure proper sampling procedures are followed. Periodic site reviews should be conducted to confirm the adequacy and completeness of LTM data and verify the effectiveness of this remediation approach. There may also be administrative concerns associated with long-term enforcement of ground water use restrictions. Future land use within the source area may be impacted by leaving contaminated soil and ground water in place. Regulators and the public will have to be informed of the benefits and limitations of the intrinsic remediation option. Educational programs are not difficult to implement, and the initial regulatory reaction to this alternative 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 \$147,000 total present worth cost estimate for Alternative 1 are the costs of maintaining institutional controls and long-term ground water monitoring for a total of 10 years.

6.4.2 Alternative 2 - Biosparging, Intrinsic Remediation and Institutional Controls with Long-Term Ground Water Monitoring

6.4.2.1 Effectiveness

Oxygenation of ground water near the plume will mitigate further plume migration by stimulating aerobic biodegradation. In addition, any BTEX compounds present downgradient from the proposed sparging system would be treated as oxygenated ground water travels downgradient at the advective ground water velocity. Given the Bioplume II model results discussed in Section 5, the degradation of BTEX compounds that migrate through the sparged

TABLE 6.3

**ALTERNATIVE 1 - COST ESTIMATE
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

<u>Capital Costs</u>	<u>Cost</u>
Design/Construct Three POC Wells and One LTM Well	\$16,000
<u>Operation, Maintenance and Monitoring Costs (Annual)</u>	<u>Annual Cost</u>
Conduct Semiannual Ground Water Monitoring of 7 wells (10 years)	\$6,000
Maintain Institutional Controls/Public Education (10 years)	\$5,000
Project Management (10 years)	\$6,000
<u>Present Worth of Alternative 1</u> ^{a/}	\$147,000

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

zone should be greatly enhanced as aerobic biodegradation plays a more significant role. However, because the system would not address contamination in the plume core, dissolved-phase BTEX upgradient of the system would continue to be reduced by intrinsic remediation alone. 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 biosparging 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 and other wastes requiring treatment and/or disposal.

As in Alternative 1, it is assumed that dissolved benzene concentrations will exceed federal MCLs throughout the plume for approximately 5 years under Alternative 2. An additional 5 years of semiannual ground water monitoring will be required to ensure that biosparging and

intrinsic remediation has uniformly reduced all BTEX compounds to levels below MCLs. Costs for installation of the biosparging system are based on the conceptual design discussed in Section 6.3.2.

6.4.2.2 Implementability

Installing and operating a biosparging system to limit the migration of BTEX contamination at the Hangar 10 site will present additional implementability concerns. Installation involves standard drilling practices for wells, and limited shallow excavation for piping and manifold connections. Implementation in and around the infield area could be disruptive to flight operations. Biosparging equipment is readily available and the technology used to construct the system is proven and reliable. The technical and administrative implementability concerns associated with the intrinsic remediation and long-term monitoring component of this remedial alternative are identical to those discussed in Alternative 1

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 \$588,000. The cost of Alternative 2 will be increased from the costs of Alternative 1 by the addition of biosparging, but monitoring would be continued for the same length of time to verify that the plume continues to degrade upgradient of the sparging system and that any part of the plume does not reach the POC wells. Semiannual long-term monitoring would continue for 10 years to ensure that intrinsic remediation is reducing BTEX concentrations below MCLs throughout the plume.

6.5 RECOMMENDED REMEDIAL APPROACH

Two remedial alternatives have been evaluated for remediation of the shallow ground water at the Hangar 10 site. Components of the alternatives evaluated include biosparging, intrinsic remediation with LTM, and institutional controls. Table 6.5 summarizes the results of the evaluation based upon effectiveness, implementability, and cost criteria. Based on this evaluation, Parsons ES recommends Alternative 1 as achieving the best combination of risk reduction and cost effectiveness.

TABLE 6.4

**ALTERNATIVE 2 - COST ESTIMATE
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA**

<u>Capital Costs</u>	<u>Cost</u>
Design/Construct Three POC Wells and Two Long-Term Monitoring Wells	\$16,000
Design/Construct Biosparging System, Including Manifolding and Blowers (assuming 50 wells @ 30 feet deep)	\$400,000
<u>Operation, Maintenance and Monitoring Costs (Annual)</u>	<u>Annual Cost</u>
Operate and Maintain Biosparging System (5 years)	\$12,000
Conduct Semiannual Ground Water Monitoring of 7 wells (10 years)	\$6,000
Maintain Institutional Controls/Public Education (10 years)	\$5,000
Project Management (10 years)	\$6,000
<u>Present Worth of Alternative 2</u> ^{a/}	\$588,000

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

Based on all effectiveness criteria, 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 upgradient of the biosparging system. In addition, implementation of Alternative 2 would not effectively decrease the time frame for remediation and would not meet AFCEE's waste minimization objective as well as would Alternative 1.

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

TABLE 6.5

SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUND WATER REMEDIATION
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 1			\$147,000
- Intrinsic Remediation - Long-Term Monitoring	Continued bioventing will gradually remove BTEX source. Contaminant mass, volume, and toxicity will be significantly reduced over next three years. MCLs for BTEX not likely to be exceeded at POC.	Readily implementable. Long-term management, ground water use controls and monitoring required for an estimated 10 years. Minimal exposure of site workers if excavation is carefully controlled in source area. If MCLs are exceeded at POC, additional remedial work may be required.	
Alternative 2			\$588,000
- Biosparging - Intrinsic Remediation - Long-Term Monitoring	Similar to Alternative 1, with the addition of bioventing. Contaminant mass, volume, and toxicity will be reduced, but no more quickly than in Alternative 1. Less likely that MCLs will be exceeded at POC.	Readily implementable. Biosparging system estimated to operate for 5 years. Long-term management, ground water controls, and monitoring required for an estimated 10 years. If MCLs are exceeded at POC, additional remedial work may be required.	

and reduce soil and ground water contamination in a relatively short time frame. Implementation of either alternative will require land use and ground water use controls to be enforced for approximately 10 years, along with semiannual ground water monitoring for the same period.

The final evaluation criterion used to compare each of the two remedial alternatives was cost. It is the opinion of Parsons ES that the additional cost of Alternative 2 over Alternative 1 is not justified by the minimal additional protection it provides. Therefore, Alternative 1 is preferred.

SECTION 7

LONG-TERM MONITORING PLAN

7.1 OVERVIEW

In keeping with the requirements of the preferred remedial alternative for the Hangar 10 site (intrinsic remediation with LTM), a long-term ground water monitoring plan must be developed. The purpose of this component of the preferred remedial alternative for the Hangar 10 site is to assess site conditions over time, confirm the effectiveness of bioventing and naturally occurring processes at reducing contaminant mass and minimizing contaminant migration, and evaluate the need for additional remediation.

To demonstrate attainment with both levels of site-specific remediation goals and to verify the predictions of the Bioplume II model developed for the Hangar 10 site, the LTM plan consists of identifying the location of two separate ground water monitoring networks and developing a ground water sampling and analysis strategy. The strategy described in this section is designed to monitor plume migration over time and to verify that intrinsic remediation is occurring at rates sufficient to protect potential receptors. In the event that data collected under this LTM program indicate that naturally occurring processes are insufficient to protect human health and the environment, contingency controls to augment the beneficial effects of intrinsic remediation would be necessary.

7.2 MONITORING NETWORKS

Two separate sets of wells will be installed at the site as part of the intrinsic remediation with LTM remedial alternative. The first set will consist of four LTM wells located in, upgradient, and downgradient of the observed BTEX plume to verify the results of the Bioplume II modeling effort and to ensure that natural attenuation is occurring at rates sufficient to minimize plume expansion (i.e., meet the first level of remediation concentration goals for the site). This network of wells will consist of existing and proposed wells screened

within the shallow aquifer to provide short-term confirmation and verification of the quantitative ground water modeling results. The second set of ground water monitoring wells will be located along a line approximately 1,750 feet downgradient from the source area (the POC for this demonstration project). The purpose of the POC wells is to verify that no BTEX compounds exceeding federal MCLs migrate beyond the area under institutional control (i.e., meet the second level of remediation concentration goals for the site). This network will consist of three ground water monitoring wells screened across the first 10 feet of the shallow aquifer. The LTM and POC wells will be sampled for analysis of the parameters listed in Tables 7.1 and 7.2, respectively.

7.2.1 Long-Term Monitoring Wells

At four locations, ground water wells within, upgradient, and downgradient of the existing BTEX contaminant plume will be used to monitor the effectiveness of intrinsic remediation in reducing total contaminant mass and minimizing contaminant migration at the Hangar 10 site. As at all sites, one well upgradient of the existing plume will be monitored. Of the remaining wells, one is placed in the anaerobic treatment zone, one is placed in the aerobic treatment zone, and the last well is typically placed downgradient of the aerobic treatment zone. However, because site data indicate that anaerobic biodegradation is more significant than aerobic biodegradation and the aerobic treatment zone is not well defined, wells will not be placed in this manner. Instead, one well near the plume core and wells at two downgradient locations within and just beyond the existing BTEX plume will be monitored.

At three of the locations, existing wells will be used for this purpose. Well OU4W-2 will be used to monitor conditions upgradient of the plume, while monitoring well OU4W-4 will be used to monitor conditions near the plume core. Monitoring well ESMW-7A (the shallow well of that nest) will be used for monitoring near the plume front. For monitoring downgradient of the plume, one new well should be installed. Figure 7.1 identifies the proposed locations of the new well and the existing wells to be used for LTM. 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.

TABLE 7.1
LONG-TERM MONITORING ANALYTICAL PROTOCOL
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

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	Semiannually	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Ferrous Iron (Fe ²⁺)	Colorimetric HACH 25140-25	Alternate method; field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Semiannually	Collect 100 mL of water in a glass container	Field
Temperature	E170.1	Field only	Metabolism rates for microorganisms depend on temperature	Semiannually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to Method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume II model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Semiannually	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	Semiannually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same ground water system	Semiannually	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	Semiannually	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
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

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	Semiannually	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 ground water influences and is influenced by biologically mediated reactions; the redox potential of ground water may range from more than 200 mV to less than -400 mV	Semiannually	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Methane	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 US Environmental Protection Agency Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis)	Semiannually	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	Semiannually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤ 2	Fixed-base

a/ Protocol methods are presented by Wiedemeier *et al.* (1994).

TABLE 7.2
POINT-OF-COMPLIANCE MONITORING ANALYTICAL PROTOCOL
HANGAR 10 INTRINSIC REMEDIATION EE/CA
ELMENDORF AFB, ALASKA

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

^a Protocol methods are presented by Wiedemeier *et al.* (1994).

7.2.2 Point-of-Compliance Wells

Three POC monitoring wells will be installed approximately 1,750 feet downgradient of the existing BTEX plume. Figure 7.1 shows the proposed locations of these wells. The purpose of the POC wells is to verify that no contaminated ground water exceeding federal MCLs migrates beyond the area under institutional control. Although model results suggest that the contaminant plume will not migrate beyond this location at concentrations exceeding chemical-specific federal MCLs, these POC wells are the technical mechanisms used to demonstrate protection of human health and the environment and compliance with site-specific numerical remediation goals. These wells will be installed and monitored for the parameters listed in Table 7.2 to assure that the selected remedy is providing the anticipated level of risk reduction and remediation at the site.

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 a 10-foot screen with approximately 8 feet of screen below the ground water surface will be sufficient to intercept the contaminant plume at this site. Figure 7.2 is a proposed ground water monitoring well completion diagram for both the LTM wells and the POC wells.

7.3 GROUND WATER SAMPLING

To ensure that sufficient contaminant removal is occurring at the Hangar 10 site to protect human health and the environment and meet site-specific remediation goals, the long-term ground water monitoring plan includes a comprehensive sampling and analysis plan. Both LTM and POC wells will be sampled and analyzed semiannually to verify that naturally occurring processes are effectively reducing contaminant mass and mobility. Reductions in toxicity will be implied by mass reduction. The sampling and analysis plan will also be aimed at assuring intrinsic remediation can achieve site-specific remediation concentration goals for BTEX compounds and protect human health and the environment.

7.3.1 Analytical Protocol

All LTM and POC wells in the LTM program will be sampled and analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of

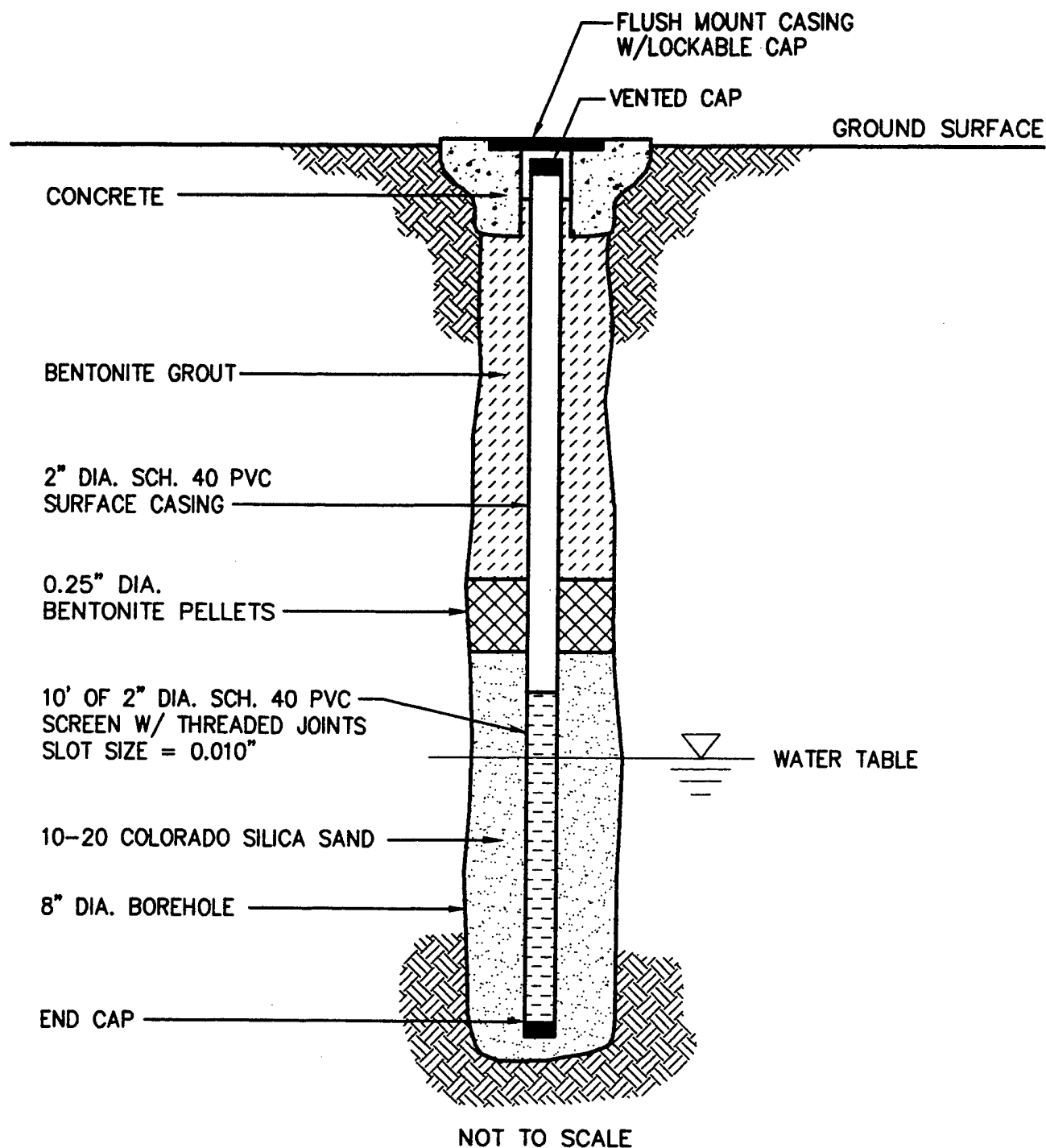


FIGURE 7.2

**PROPOSED MONITORING WELL
COMPLETION DIAGRAM**

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

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Denver, Colorado

intrinsic remediation at the site. Water level measurements will be made during each sampling event. Ground water samples will be analyzed for the parameters listed in Tables 7.1 and 7.2. A site-specific ground water 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 twice each year for 10 years. If the data collected during this time period supports the anticipated effectiveness of the intrinsic remediation alternative at this site, the sampling frequency can be reduced to once every year for all wells in the LTM program, or eliminated. If the data collected at any time during the monitoring period indicate the need for additional remedial activities at the site, sampling frequency should be adjusted accordingly.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of an EE/CA conducted to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated ground water at the Hangar 10 Site, Elmendorf AFB, Alaska. Specifically, the finite-difference ground water model Bioplume II was used in conjunction with site-specific geologic, hydrologic, and laboratory analytical data to simulate the migration and biodegradation of fuel hydrocarbon compounds dissolved in ground water. Ground water contaminant and geochemical data strongly suggest that anaerobic biodegradation of fuel hydrocarbons is occurring at the site via denitrification, iron reduction, sulfate reduction, and methanogenesis. In addition, the data also suggest that aerobic biodegradation is occurring, although due to low background DO concentrations, this process is not as significant as anaerobic biodegradation.

To collect the data necessary for the intrinsic remediation demonstration, Parsons ES and USEPA researchers collected soil and ground water samples from the site. Physical and chemical data collected under this program were supplemented with data collected during previous site characterization events. Site-specific geologic, hydrologic, and laboratory analytical data were then used in the Bioplume II numerical ground water model to simulate the effects of advection, dispersion, sorption, and biodegradation on the fate and transport of the dissolved-phase 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 Bioplume II model for this study, and therefore, the model results presented herein represent a worst-case scenario.

For one simulation (model ELMA), it was assumed that conditions which produced the calibrated model, including anaerobic decay, would persist for the duration of the simulation. This is the most optimistic scenario, suggesting that the plume would migrate a maximum of

750 feet before BTEX concentrations would be removed within 1.5 years. Model ELMB assumed that the coefficient of anaerobic decay was reduced by one-half. Results of this model suggest that the plume will migrate approximately 1,750 feet beyond the June 1994 plume margin before intrinsic remediation mechanisms effectively halt migration and shrink the plume. ELMB predicts dissipation of the BTEX plume in slightly more than 3 years. Model ELMC was run to illustrate conditions produced by a continuous source of dissolved-phase BTEX compounds. In this case, the plume migrated no more than 750 feet beyond the June 1994 plume limit before slowly retreating back to the source area within 5 years. After 5 years of simulation time, BTEX contamination was confined to the source area.

Actual dissolved-phase BTEX degradation rates observed during LTM at the site will probably be less than predicted by models ELMA and ELMC, and greater than predicted by model ELMB. This will result in a shorter plume migration distance than predicted by model ELMB. The main uncertainty inherent in the model simulations run for this site is the lack of a well-defined source area and the resulting lack of data regarding contaminant mass loading into the aquifer. However, model ELMC predicts that biodegradation mechanisms operating at the site should be quite effective in preventing migration of dissolved-phase BTEX compounds introduced by dissolution within a source area, particularly after the existing plume diminishes.

The results of this study suggest that natural attenuation of BTEX compounds is occurring at the Hangar 10 site to the extent that the dissolved-phase concentrations of these compounds in ground water should be reduced to levels below current regulatory guidelines long before potential downgradient receptors could be adversely affected (i.e., the potential contaminant migration pathway will not be complete for any of the potential receptors described in Section 6.2). Based on the distance to potential downgradient receptors (at least 2,000 feet) and rates of BTEX plume migration and degradation predicted by models ELMA, ELMB, and ELMC, Parsons ES is recommending natural attenuation, institutional controls, and LTM as the remedial option for BTEX-impacted ground water near Hangar 10. Construction activities in the plume area and ground 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 Bioplume II modeling effort, and to ensure that natural attenuation is occurring at rates sufficient to protect potential downgradient receptors, ground water from existing monitoring wells OU4W-2, OU4W-4, ESMW-7A, and one additional

proposed LTM well should be sampled semiannually and analyzed for the parameters listed in Table 7.1. In addition, three POC ground water monitoring wells should be installed downgradient from the predicted maximum travel distance of the BTEX plume and sampled semiannually for the parameters listed in Table 7.2. Figure 7.1 shows suggested locations for the three new POC monitoring wells and the new LTM well. These wells should be sampled semiannually for 10 years. If dissolved BTEX concentrations in ground water in the POC wells are found to exceed the federal MCLs of 5 µg/L for benzene, 1,000 µg/L for toluene, 700 µg/L for ethylbenzene, or 10,000 µg/L for total xylenes, additional evaluation or corrective action may be necessary at this site.

SECTION 9

REFERENCES

- Abdul, S.A., Gibson, T.L., and Rai, D.N., 1987, Statistical Correlations for Predicting the Partition Coefficient for Nonpolar Organic Contaminants Between Aquifer Organic Carbon and Water: *Hazardous Waste and Hazardous Materials*, 4(3):211-222.
- Anderson, M.P., and Woessner, W.W., 1992, *Applied Groundwater Modeling - Simulation of Flow and Advective Transport*: Academic Press, New York, 381 p.
- Battelle, 1991, Elmendorf Air Force Base, Alaska Installation Restoration Program Site Summary. October 1991.
- Black and Veatch, 1990, Installation Restoration Program Stage 3 Remedial Investigation/ Feasibility Study, Elmendorf Air Force Base Alaska. May 1990.
- Bohon, R.L., and Claussen, W.F., 1951, The Solubility of Aromatic Hydrocarbons in Water: *Journal of American Chemical Society*, 73(4):1571-1578.
- Borden, R.C., and Bedient, P.B., 1986, Transport of Dissolved Hydrocarbons Influenced by Oxygen Limited Biodegradation - Theoretical Development: *Water Resources Research*, 22 (13) 1973-1982.
- Bouwer, E.J., 1992, Bioremediation of Subsurface Contaminants, *in* Mitchell, R., ed.: *Environmental Microbiology*: Wiley-Liss, New York, New York.
- CH2M Hill, 1992, Elmendorf Air Force Base, Alaska Draft Operable Unit 4 LFI Report. September 1992.
- Chapelle, F.H., 1994, Assessing the Efficiency of Intrinsic Bioremediation, *in* Proceedings of the Symposium on Intrinsic Bioremediation of Ground Water, August 30 - September 1, 1994: US Environmental Protection Agency, p. 171.
- Cozzarelli, I.M., Eganhouse, R.P., and Baedecker, M.J., 1990, Transformation of Monoaromatic Hydrocarbons to Organic Acids in Anoxic Ground Water Environment: *Environmental and Geological Water Science*, 16.
- Cozzarelli, I.M., Baedecker, M.J., Eganhouse, R.P., and Goerlitz, D.F., 1994, The geochemical evolution of low-molecular-weight organic acids derived from the degradation of petroleum contaminants in groundwater: *Geochimica et Cosmochimica Acta*, v. 58, no. 2, p. 863 - 877.
- Davies, J.S., and Westlake, D.W.S., 1979, Crude Oil Utilization by Fungi: *Canadian Journal of Microbiology*, 25:146-156.

- Domenico, P.A., and Schwartz, F.W., 1990, *Physical and Chemical Hydrogeology*: John Wiley & Sons, New York.
- Edwards, E.A., and Grbic-Galic, D., 1992, Complete mineralization of benzene by aquifer microorganisms under strictly anaerobic conditions: *Appl. Environ. Microbiol.*, v. 58, p. 2663-2666.
- Edwards, E.A., Wells, L.E., Reinhard, M., and Grbic-Galic, D., 1992, Anaerobic degradation of toluene and xylene by aquifer microorganisms under sulfate-reducing conditions: *Appl. Environ. Microbiol.*, v. 58, p. 794-800.
- Engineering-Science, Inc., 1994, Draft Work Plan for Engineering Evaluations/Cost Analyses at Hangar 10 and Site ST41, Elmendorf Air Force Base Alaska. May 1994.
- Freeze, R.A., and Cherry, J.A., 1979, *Groundwater*: Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Goldstein, R.M., Mallory, L.M., and Alexander, M., 1985, Reasons for Possible Failure of Inoculation to Enhance Biodegradation: *Applied Environmental Microbiology*, 50(4):977-983.
- Grbic'-Galic', D., 1990, Anaerobic microbial transformation of nonoxygenated aromatic and alicyclic compounds in soil, subsurface, and freshwater sediments, *in* Bollag, J.M., and Stotzky, G., eds.: *Soil Biochemistry*: Marcel Dekker, Inc., New York, p. 117-189.
- Grbic'-Galic', D., and Vogel, T.M., 1987, Transformation of toluene and benzene by mixed methanogenic cultures: *Applied and Environmental Microbiology*, v. 53, p. 254-260.
- Hine, J., and Mookerjee, P.K., 1975, The Intrinsic Hydrophilic Character of Organic Compounds. Correlations in Terms of Structural Contributions: *Journal of Organic Chemistry*, 40(3):292-298.
- Hopper, D.J., 1978, Microbial Degradation of Aromatic Hydrocarbons In R.J. Watkinson (editor), *Developments in Biodegradation of Hydrocarbons, I*: Applied Science Publishers, Ltd., London.
- Hutchins, S.R., 1991, Biodegradation of monoaromatic hydrocarbons by aquifer microorganisms using oxygen, nitrate, or nitrous oxide as the terminal electron acceptor: *Appl. Environ. Microbiol.*, v. 57, p. 2403-2407.
- Isnard, S., and Lambert, S., 1988, Estimating Bioconcentration Factors from Octanol-Water Partition Coefficient and Aqueous Solubility: *Chemosphere*, 17(1):21-34.
- Jacobs Engineering Group, 1993, United States Air Force, Elmendorf Air Force Base Alaska. Environmental Restoration Program. Management Action Plan -- Final. December 1993.
- Jacobs Engineering Group, 1994a, United States Air Force, Elmendorf Air Force Base Alaska. Environmental Restoration Program. Basewide Monthly Water Level Data Package for January 1994. January 1994.

- Jacobs Engineering Group, 1994b, United States Air Force, Elmendorf Air Force Base Alaska. Environmental Restoration Program. Basewide Water Level Program. Fourth Quarterly Technical Memorandum. Period: October - December 1993. January 1994.
- Jamison, V.W., Raymond, R.L., and Hudson, J.O. Jr., 1975, Biodegradation of high-octane gasoline in ground water: *Developments in Industrial Microbiology*, v. 16.
- Jones, J.G., and Eddington, M.A., 1968, An Ecological Survey of Hydrocarbon-Oxidizing Microorganisms: *Journal of General Microbiology*, 52:381-390.
- Jury, W.A., Spencer, W.F., and Farmer, W.J., 1984, Behavior Assessment Model for Trace Organics in Soil: III, Application of Screening Model: *Journal of Environmental Quality*, 13(4):573-579.
- Konikow, L.F., 1978, Calibration of ground-water models, *in* *Verification of Mathematical and Physical Models in Hydraulic Engineering*: American Society of Civil Engineers, New York, pp. 87 - 93.
- Konikow, L.F., and Bredehoeft, J.D., 1978, Computer model of two-dimensional solute transport and dispersion in ground water: United States Geological Survey, *Techniques of Water Resources Investigations of the United States Geological Survey*, Book 7, Chapter C2, 90 p.
- Leslie, L.D., 1986, Alaska Climate Summaries: Alaska Climate Center, Anchorage, Alaska.
- Lovely, D.R., Baedeker, M.J., Lonergan, D.J., Cozzarelli, I.M., Phillips, E.J.P., and Siegel, D.I., 1989, Oxidation of aromatic contaminants coupled to microbial iron reduction: *Nature*, v. 339, p. 297-299.
- Lyman, W.J., Reidy, P.J., and Levy, B., 1992, *Mobility and Degradation of Organic Contaminants in Subsurface Environments*: C.K. Smoley, Inc., Chelsea, Michigan.
- Mackay, D., and Wolkoff, A.W., 1973, Rate of Evaporation of Low-Solubility Contaminants from Water Bodies to Atmosphere: *Environmental Science and Technology*, 7(7):611-614.
- Mackay, D., and Shiu, W.Y., 1981, A Critical Review of Henry's Law Constants for Chemicals of Environmental Interest: *Journal of Physical Chemistry Reference Data*, 10(4):1175-1199.
- Miller, M.M., Wasik, S.P., Huang, G.L., Shiu, W.Y., and Mackay, D., 1985, Relationships Between Octanol-Water Partition Coefficient and Aqueous Solubility: *Environmental Science and Technology*, 19(6):522-529.
- Pankow, J.F., and Rosen, M.E., 1988, Determination of Volatile Compounds in Water by Purging Directly to a Capillary Column with Whole Column Cryotrapping: *Environmental Science and Technology*, 22(4):398-405.
- Parsons Engineering Science, Inc., in preparation, *Intrinsic Remediation Engineering Evaluation for Site ST41, Elmendorf Air Force Base, Alaska*. In preparation, Fall 1994.

- Perry, J.J., 1984, Microbial Metabolism of Cyclic Alkanes, *in* Atlas, R.M. ed.: Petroleum Microbiology: Macmillan Publishing Co., New York, New York.
- Radian Corporation, 1993, United States Air Force. Elmendorf Air Force Base, Alaska. Environmental Restoration Program. Operable Unit 4 Final Management Plan, May 1993.
- Radian Corporation, 1994, United States Air Force. Elmendorf Air Force Base, Alaska. Environmental Restoration Program. Draft Remedial Investigation Report, Operable Unit 4. February 1994.
- Ribbons, D.W., and Eaton, R.W., 1992, Chemical Transformations of Aromatic Hydrocarbons that Support the Growth of Microorganisms: *in* Mitchell, R., ed.: Environmental Microbiology: Wiley-Liss, New York, New York.
- Rifai, H.S., Bedient, P.B., Wilson, J.T., Miller, K.M., and Armstrong, J.M., 1988, Biodegradation modeling at aviation fuel spill site: Journal of Environmental Engineering, v. 114, no. 5, p. 1007-1029.
- Selkregg, L.L., 1972, Alaska Regional Profiles, Southcentral Region: University of Alaska Arctic Environmental Information and Data Center, Anchorage Alaska.
- Smith, J.H., Harper, J.C., and Jaber, H., 1981, Analysis and Environmental Fate of Air Force Distillate and High Density Fuels: Report No. ESL-TR-81-54, Tyndall Air Force Base, Florida, Engineering and Services Laboratory.
- Stauffer, T.B., Antworth, T.B., Boggs, J.M., and MacIntyre, W.G., 1994, A Natural Gradient Tracer Experiment in a Heterogeneous Aquifer with Measured In Situ Biodegradation Rates: A Case for Natural Attenuation, *in* Proceedings of the Symposium on Intrinsic Bioremediation of Ground Water, August 30 - September 1, 1994: US Environmental Protection Agency, p. 73 - 84.
- US Environmental Protection Agency, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) Under CERCLA. OSWER Directive 9355.3-01.
- US Environmental Protection Agency, 1991, Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim. Publication 9285.7-01B.
- US Environmental Protection Agency, 1992b, Contract Laboratory Program Statement of Work for Inorganics Analyses, Multi-Media, Multi-Concentration: Document Number ILM03.0.
- Valsaraj, K.T., 1988, On the Physio-Chemical Aspects of Partitioning of Non-Polar Hydrophobic Organics at the Air-Water Interface: Chemosphere, 17(5):875-887.
- Verschuere, K., 1983, Handbook of Environmental Data on Organic Chemicals: Van Nostrand Reinhold Co., New York, New York.

- Vroblesky, D.A., and Chapelle, F.H., 1994, Temporal and spatial changes of terminal electron-accepting processes in a petroleum hydrocarbon-contaminated aquifer and the significance for contaminant biodegradation: *Water Resources Research*, v. 30, no. 5, p. 1561-1570.
- Walton, W.C., 1988, *Practical Aspects of Ground Water Modeling*: National Water Well Association, Dublin, Ohio, 587 p.
- Wilson, B.H., Smith, G.B., and Rees, J.F., 1986, Biotransformations of Selected Alkylbenzenes and Halogenated Aliphatic Hydrocarbons in Methanogenic Aquifer Material: A Microcosm Study: *Environmental Science and Technology*, 20(10):997-1002.
- Wilson, B.H., Wilson, J.T., Kampbell, D.H., Bledsoe, B.E., and Armstrong, J.M., 1990, Biotransformation of Monoaromatic and Chlorinated Hydrocarbons at an Aviation Gasoline Spill Site: *Geomicrobiology Journal*, 8:225-240.
- Wilson, B.H., Wilson, J.T., Kampbell, D.H., and Bledsoe, B.E., 1994, Traverse City: Geochemistry and Intrinsic Bioremediation of BTX Compounds, *in* *Proceedings of the Symposium on Intrinsic Bioremediation of Ground Water*, August 30 - September 1, 1994: US Environmental Protection Agency, p. 94 - 102.
- Wiedemeier, T.H., Downey, D.C., Wilson, J.T., Kampbell, D.H., Miller, R.N., and Hansen, J.E., 1994, Draft Technical Protocol for Implementing the Intrinsic Remediation with Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase Fuel Contamination in Ground Water: Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

APPENDIX A

BORING LOGS AND WELL COMPLETION DIAGRAMS

GEOLOGIC BORING LOG

Sheet 1 of 2

BORING NO.: ESMW-1B CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/10/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL.: 6/11/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 183.2
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: 60 F
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: MOSTLY SUNNY
 COMMENTS: PID BACKGROUND = 1.7-2.1 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
	1			No Sample								
			GP	Brown, sandy GRAVEL. Gravel is fine to coarse. Sand is fine to coarse w/trace of silt. No stratification. Subangular to subrounded sand grains.		2-4		8,9 8,8	3.4			
	5			SAA. Dry		4-6			1.7			
				SAA. Some cobbles.		6-8		5,12 13,18	1.7			
	10					8-10		12,13 17,17	1.7			
						10-12		12,15 16,19	1.7			
						12-14		18,24 21,22	1.7			
	15					14-16		7,17 14,18	1.7			
				SAA. Less sand, damp.		16-18		7,10 10,14	1.7			
				SAA. More sand, damp.		18-20		8,14 17,10	1.7			
	20			Less saturated @ lower 1'.		20-22		11,15 16,24	1.7			
				Very fine to medium SAND w/trace of gravel. Non-stratified, subangular to subrounded. Saturated at 23.5 ft bgs.		22-24		12,13 13,24	1.7			
	25					24-26		12,10 14,10	1.7			
				SAA. Less coarse gravel.		26-28		11,8 12,15	1.7			
	30					28-30		10,11 *	21	2.3		
				SAA. Slight petroleum-oily odor. No stain.		30-32		11,17	14			
						32-34		8,10	9			
	35					34-35		11,17	25	2.3		

CONTINUOUS DRIVE

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

ESMW-1
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Sheet 2 of 2

BORING NO.:	<u>ESMW-1B</u>	CONTRACTOR:	<u>HUGHES DRILLING</u>	DATE SPUD:	<u>6/10/94</u>
CLIENT:	<u>AFCEE</u>	RIG TYPE:	<u>CME 75</u>	DATE CMPL.:	<u>6/10/94</u>
JOB NO.:	<u>722450.07</u>	DRLG METHOD:	<u>HOLLOW STEM AUGER</u>	ELEVATION:	<u>103.2</u>
LOCATION:	<u>ELMENDORF AFB</u>	BORING DIA.:	<u>8 INCHES</u>	TEMP:	<u>60 F</u>
GEOLOGIST:	<u>MS/KC</u>	DRLG FLUID:	<u>NONE</u>	WEATHER:	<u>PTLY CLOUDY</u>
COMMENTS:	<u>PID BACKGROUND = 1.7-2.3 ppm</u>				

[illegible]

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above
BZ – Breathing Zone

SAMPLE TYPE

D - DRIVE
C - CORE
G - GRAB



Water level drilled

GEOLOGIC BORING LOG

ESMW-1B
Intrinsic Remediation Demonstration
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-2 CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/17/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL: 6/17/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 184.3
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: 60 F
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: MOSTLY SUNNY
 COMMENTS: PID BACKGROUND = 1.3 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
	1			No sample.								
			GP	GRAVEL with fine to medium sand. Trace of silt. Unstratified, dry & loose.		2-4		4,6 6,11	1.3			
	5			SAA. More sand & occasional cobbles.		4-6		4,5 8,11	1.3	1.3		
				SAA w/ increased sand.		6-8		8,11 11,14	1.3			
				SAA. More cobbles.		8-10		8,9 18,19	1.3			
	10			SAA. Sand is medium to coarse.		10-12		12,17 14,14	1.3			
				SAA. Moist to wet.		12-14		5,9 12,13	1.3			
	15			SAA. Moist.		14-16		4,9 10,10	1.3	1.3		
						16-18		11,14 14,14	1.3			
						18-20		5,10 10,9	1.3			
	20			SAA w/medium to coarse sand. Loose. Moist. Unstratified.		20-22		5,9 8,9	1.3	1.3		
						22-24		12,10 15,19	1.3			
	25			Saturated at 25 ft bgs.		24-26		8,13 15,19	1.3			
				No more samples.		26-28						
						28-30						
	30			Total depth at 30'		30-32						
	35											

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

ESMW-2
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

GEOLOGIC BORING LOG

Sheet 1 of 2

BORING NO.:	ESMW-3B	CONTRACTOR:	HUGHES DRILLING	DATE SPUD:	6/14/94
CLIENT:	AFCEE	RIG TYPE:	CME 75	DATE CMPL.:	6/14/94
JOB NO.:	722450.07	DRLG METHOD:	HOLLOW STEM AUGER	ELEVATION:	175.4
LOCATION:	ELMENDORF AFB	BORING DIA.:	8 INCHES	TEMP:	60 F
GEOLOGIST:	MS/KC	DRLG FLUID:	NONE	WEATHER:	CLEAR
COMMENTS:	PID BACKGROUND = 2.7 ppm				

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No sample.								
			SP	Brown, gravelly SAND with pebbles & cobbles. Subangular to subrounded grains.	2-4			6,10 12,15	2.7			
	5			SAA, w/ increasing amounts of cobbles and pebbles.	4-6			7,4 12,13	2.7			
					6-8			11,11 14,15	2.7	2.7		
					8-10			10,16 12,20	2.7			
	10		GP	Sandy GRAVEL w/subangular pebbles & cobbles. Upper 1 foot is moist.	10-12			7,14 16,18	2.7			
			SP	Gravelly SAND w/increased cobbles. Moist zone at top 14".	12-14			18,20 20,21	2.7			
	15				14-16			17,15 18,19	2.7			
			GP	Sandy, coarse GRAVEL. Some pebbles and cobbles present. Moist to wet at bottom.	16-18			19,20 17,18	2.7			
				SAA w/decreased cobbles. Wet.	18-20			7,6 13,13	1.4	2.7		
	20			Saturated at 20.5 ft bgs. SAA w/decreased fine grains at watertable. Pebbles & cobbles present.	20-22			6,11 17,18	1.4			
			SP	Gravelly SAND with cobbles at 6" to 18". Subangular to subrounded.	22-24			10,14 16,16	1.4			
	25			Black organic matter at 25 ft bgs.	24-26			7,12	192.5	1.4		
					26-28			11,12 3	711			
			GP	Grey, sandy GRAVEL. Subangular to subrounded grains.	28-30			8,8 3	34.3	1.4		
	30				30-32			6,7 5	37.3			
					32-34			10,14 4	4.4			
	35			SAA w/increased cobbles.				13,17	1.4			

CONTINUOUS DRIVE

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

ESMW-3B
 Intrinsic Remediation Demonstration
 Patrick Air Force Base, Florida

ENGINEERING-SCIENCE, INC.

Denver, Colorado

GEOLOGIC BORING LOG

Sheet 2 of 2

BORING NO.: ESMW-3B CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/14/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL.: 6/14/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 175.4
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: 60 F
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: CLEAR
 COMMENTS: PID BACKGROUND = 1.4 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	36	GP		SAA.	35-36			1.4			
			SP	Gravelly, medium- to coarse-grained SAND. Few pebbles present.	36-38		10,19	1.4			
	40										
				Total depth at 42'.							
	45										
	50										
	55										
	60										
	65										
	70										

GEOLOGIC BORING LOG

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

Water level drilled

ESMW-3B
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

GEOLOGIC BORING LOG

Sheet 1 of 2

BORING NO.: ESMW-4B CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/13/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL.: 6/13/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 177.5
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: 60 F
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: PTLY CLOUDY
 COMMENTS: PID BACKGROUND = 2.3 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No sample.								
			GW	Sandy GRAVEL. Sand is v. fine to v. coarse w/trace of silt. Subangular to subrounded sand grains.		2-4		5,10 11,14	2.3			
	5					4-6		4,10 11,10	2.3			
						6-8		9,12 15,12	2.3		2.3	
	10			SAA w/no very fine sand or silt.		8-10		5,9 11,12	2.3			
						10-12		7,10 12,16	2.3			
				SAA w/occasional cobbles.		12-14		7,11 14,12	2.3			
	15			SAA w/increased sand.		14-16		7,12 14,13	2.3			
						16-18		14,15 14,19	2.3			
				SAA. Dry.		18-20		11,15 13,15	2.3	2.3		
	20			SAA. Wet at tip.		20-22		11,15 18,18	2.3			
				SAA. Saturated.		22-24		6,12 16,17	2.3			
	25					24-26		7,12 16,*	2.3			
			SP	Gravelly SAND. Sand is v. fine to v. coarse. Unstratified. Subangular to subrounded grains.		26-28		9,9 4	2.3			
	30		GW	Sandy GRAVEL. as from 26'-28' w/ trace of silt.		28-30		5,7 11,7	2.3			
						30-32		5,9 *	2.3			
						32-24		9,13	2.3			
	35					34-35						

CONTINUOUS DRIVE

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

 Water level drilled

GEOLOGIC BORING LOG

ESMW-4B
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Sheet 2 of 2

BORING NO.:	<u>ESMW-4B</u>	CONTRACTOR:	<u>HUGHES DRILLING</u>	DATE SPUD:	<u>6/13/94</u>
CLIENT:	<u>AFCEE</u>	RIG TYPE:	<u>CME 75</u>	DATE CMPL.:	<u>6/13/94</u>
JOB NO.:	<u>722450.07</u>	DRLG METHOD:	<u>HOLLOW STEM AUGER</u>	ELEVATION:	<u>177.5</u>
LOCATION:	<u>ELMENDORF AFB</u>	BORING DIA.:	<u>8 INCHES</u>	TEMP:	<u>60 F</u>
GEOLOGIST:	<u>MS/KC</u>	DRLG FLUID:	<u>NONE</u>	WEATHER:	<u>PTLY CLOUDY</u>
COMMENTS:	<u>PID BACKGROUND = 2.3 ppm</u>				

[illegible]

SAMPLE TYPE

D - DRIVE
C - CORE
G - GRAB



 Water level drilled

ESMW-4B

Intrinsic Remediation Demonstration
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-5B CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/16/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL.: 6/16/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 176.2
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: 60 F
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: CLOUDY
 COMMENTS: PID BACKGROUND = 1.3 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
	1			No sample.								
			ML	Brown SILT w/clay. Trace of fine sand. Massive. Dense. Occasional gravel.		2-4		4.7 5.7	1.3			
	5					4-6		6.6 4.3	1.3			
				SAA w/more fine- to medium-grained sand. Moist.		6-8		4.5 7.7	1.3			
				SAA, w/occasional plant fragments.		8-10		4.5 3.2	1.3			
	10					10-12		2.2 3.3	1.3			
			SP	Silty fine- to coarse-grained SAND w/gravel.		12-14		1.1 2.1	1.3			
			CH	Blue-grey CLAY w/silt. Possibly Bootlegger Cove Formation.		14-16		6.8 12.13	1.3			
	15		GW	Sandy GRAVEL. Sand is fine- to coarse-grained w/ occasional cobbles. Subrounded to subangular grains Bottom 12" saturated		16-18			1.3			
						18-20		5.9 13	1.3			
	20					20-22		6.8 12	1.3			
						22-24		5.7 10	1.3			
	25			SAA w/occasional wood fragment present.		24-26		7.10	1.3			
						26-28		10.13	1.3			
						28-30		7.11	1.3			
	30					30-32			1.3			
				Total depth at 31'.		32-34			1.3			
	35											

CONTINUOUS DRIVE

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

Water level drilled

GEOLOGIC BORING LOG

ESMW-5B
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-6B CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/15/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL.: 6/15/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 168.3
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: 60 F
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: CLEAR
 COMMENTS: PID BACKGROUND = 1.3 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
	1			No sample.						1.3		
			S	Brown, weathered sandy LOAM w/pebbles.		2-4		6.6 6.6	1.3	1.3		
	5			SAA, w/increased cobbles.		4-6		5.3 3.5	1.3			
				Brown, moist, medium- to fine-grained SAND w/silt and pebbles.		6-8		2.2 1.3	1.3			
			CH	Grey, moist CLAY. High plasticity.		8-10		2.2 4.7	1.3			
	10		SW	Brown, well graded, subrounded SAND w/pebbles.		10-12		5.6 4.4	1.3	1.3		
			CH	Grey, moist CLAY.		12-14		4.4 15.21	1.3			
			SP	Brown, gravelly SAND w/pebbles and silt. Moist.		14-16		11.16 18.15	1.3			
			CH	Sandy CLAY w/silt and pebbles. Highly plastic.		16-18		19.15 12.15	1.3			
	15		GP	Brown sandy GRAVEL. Subrounded gravel w/subangular to subrounded, medium to coarse grained, well sorted sand. Pebbles & cobbles present.		18-20		4.8 8	1.3	1.3		
						20-22		6.10	1.3			
						22-24		8.11 2	1.3			
	25		SP	Well sorted, subrounded to subangular SAND. Black organic matter at 25.5' bgs.		24-26		7.12	1.3			
				SAA w/increased GRAVEL. Black organic matter present.		26-28		7.15	1.3	0.0		
				Well sorted, subrounded, coarse grain SAND.		28-30		5.9	1.3			
	30		CH	Grey, dense, highly plastic CLAY. Bootlegger Cove Formation		30-32		3.5 7				
				Total depth at 32'.								
	35											

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

ESMW-6B
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-7B CONTRACTOR: HUGHES DRILLING DATE SPUD: 6/16/94
 CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL.: 6/16/94
 JOB NO.: 722450.07 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 171.2
 LOCATION: ELMENDORF AFB BORING DIA.: 8 INCHES TEMP: COOLER
 GEOLOGIST: MS/KC DRLG FLUID: NONE WEATHER: OVERCAST
 COMMENTS: PID BACKGROUND = 1.3 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	BZ PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
	1			No sample.								
			SP	Brown, gravelly SAND. Medium to coarse grains, Cobbles present. Dry.		2-4		6,13 13,17	1.3	0.0		
	5					4-6		5,10 10,15	1.3			
						6-8		9,10 12,13	1.3			
	10					8-10		7,12 13,14	1.3	0.0		
						10-12		8,13 14,17	1.3			
						12-14		9,12 13,14	1.3			
	15		GP	Sandy GRAVEL w/increasing cobbles. Subrounded to subangular sand grains.		14-16		9,17 20,21	1.3			
				SAA w/increased GRAVEL at water table.		16-18		20,26 20,17	1.3	0.0		
	20					18-20		12,12 13	1.3			
						20-22		5,8	1.3			
						22-24		7,14	1.3			
	25					24-26		6,12	1.3			
						26-28		7,7	1.3			
				SAA w/black organic matter at 28'.		28-30		7,13	1.3	0.0		
	30		SP	Brown, medium to coarse grain SAND w/some gravel. Subrounded grains. Well sorted from 30.5-31.5'. Black organic material at 31'.		30-32		12,17	1.3			
				Total depth at 33'.		32-34		12,14	1.3			
	35											

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above
 BZ - Breathing Zone

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

▼ Water level drilled

GEOLOGIC BORING LOG

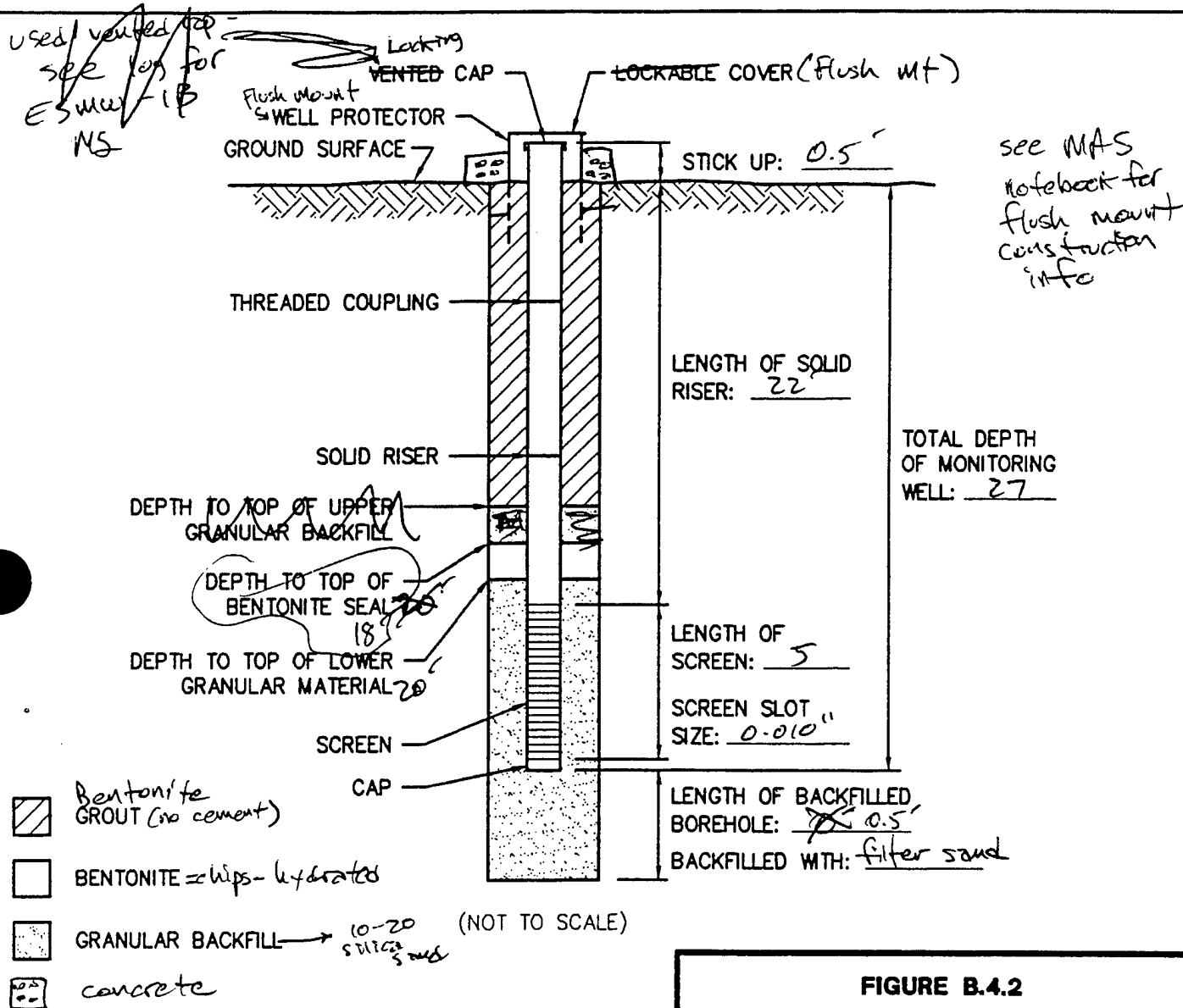
ESMW-7B
 Intrinsic Remediation Demonstration
 Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ES MW-1A
 JOB NUMBER 722450.07 INSTALLATION DATE 6/11/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 PIPER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

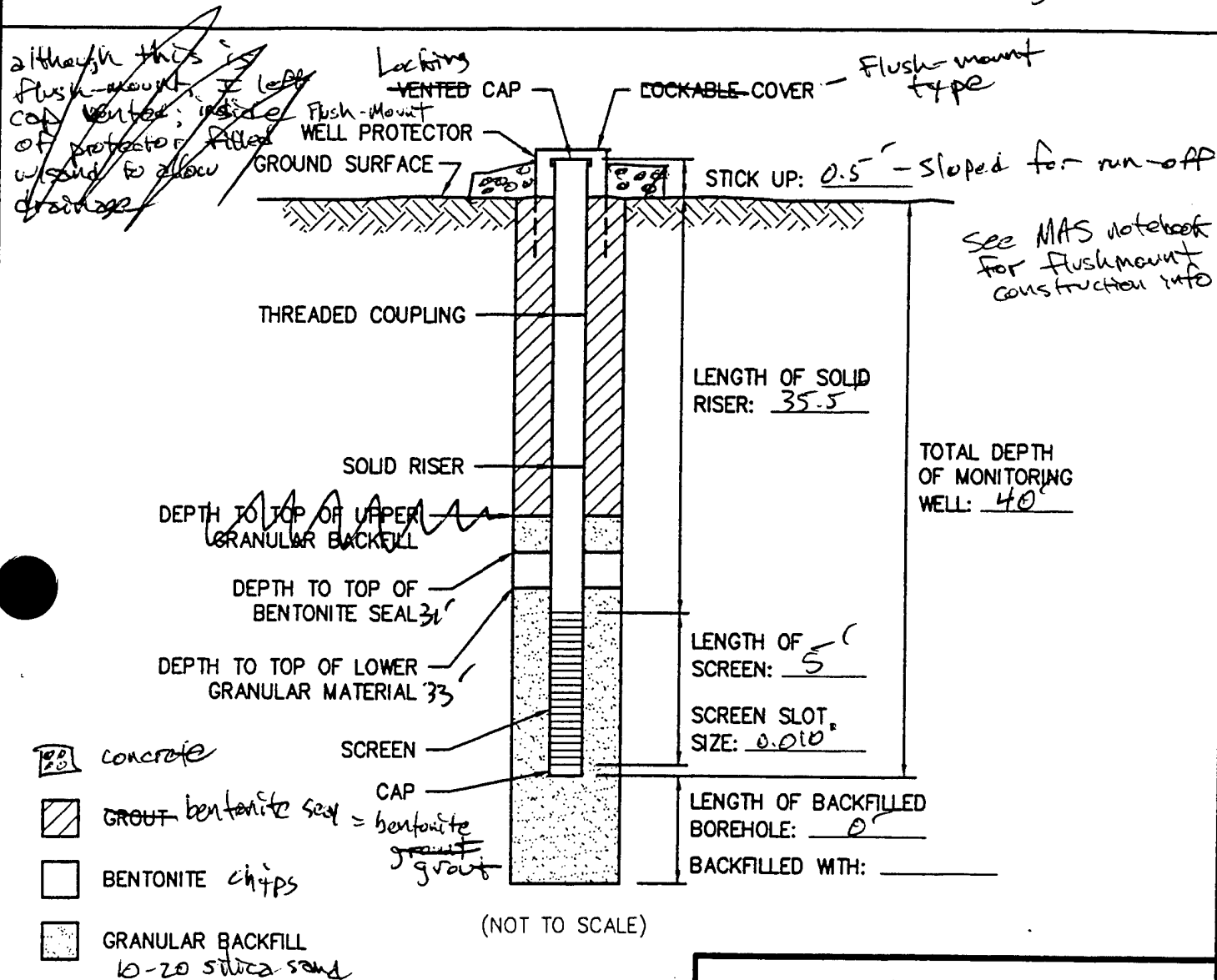
FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol
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MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMw1B
 JOB NUMBER 722450.07 INSTALLATION DATE 6/11/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

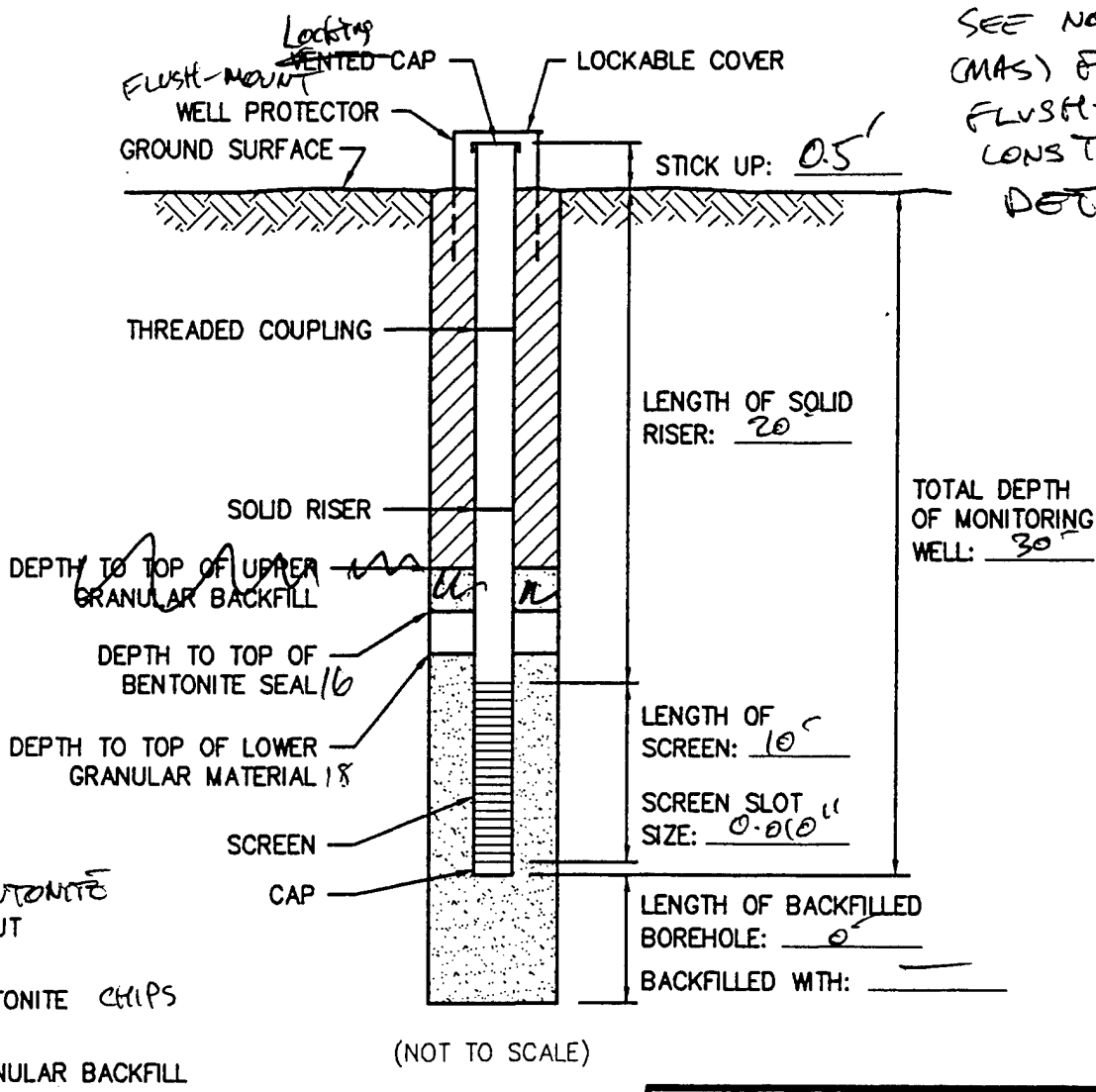
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MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-2
 JOB NUMBER 722450.07 INSTALLATION DATE 6/17/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL 10-20 silica sand TEST REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

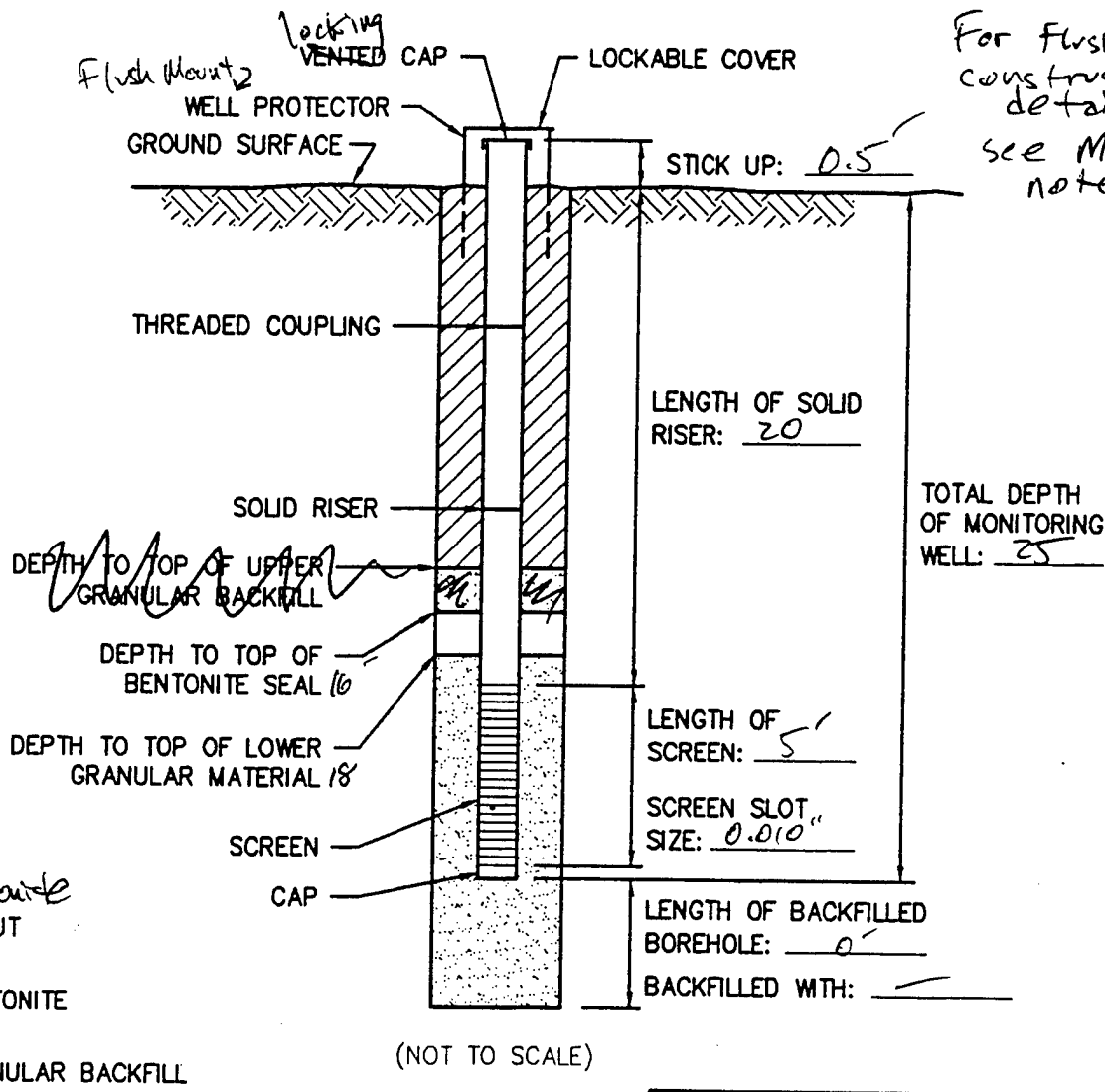
Intrinsic Remediation Protocol

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MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-3A
 JOB NUMBER 722450.07 INSTALLATION DATE 6/14/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 CASING DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



-  BENTONITE GROUT
-  BENTONITE
-  GRANULAR BACKFILL

10-20
solid sand

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

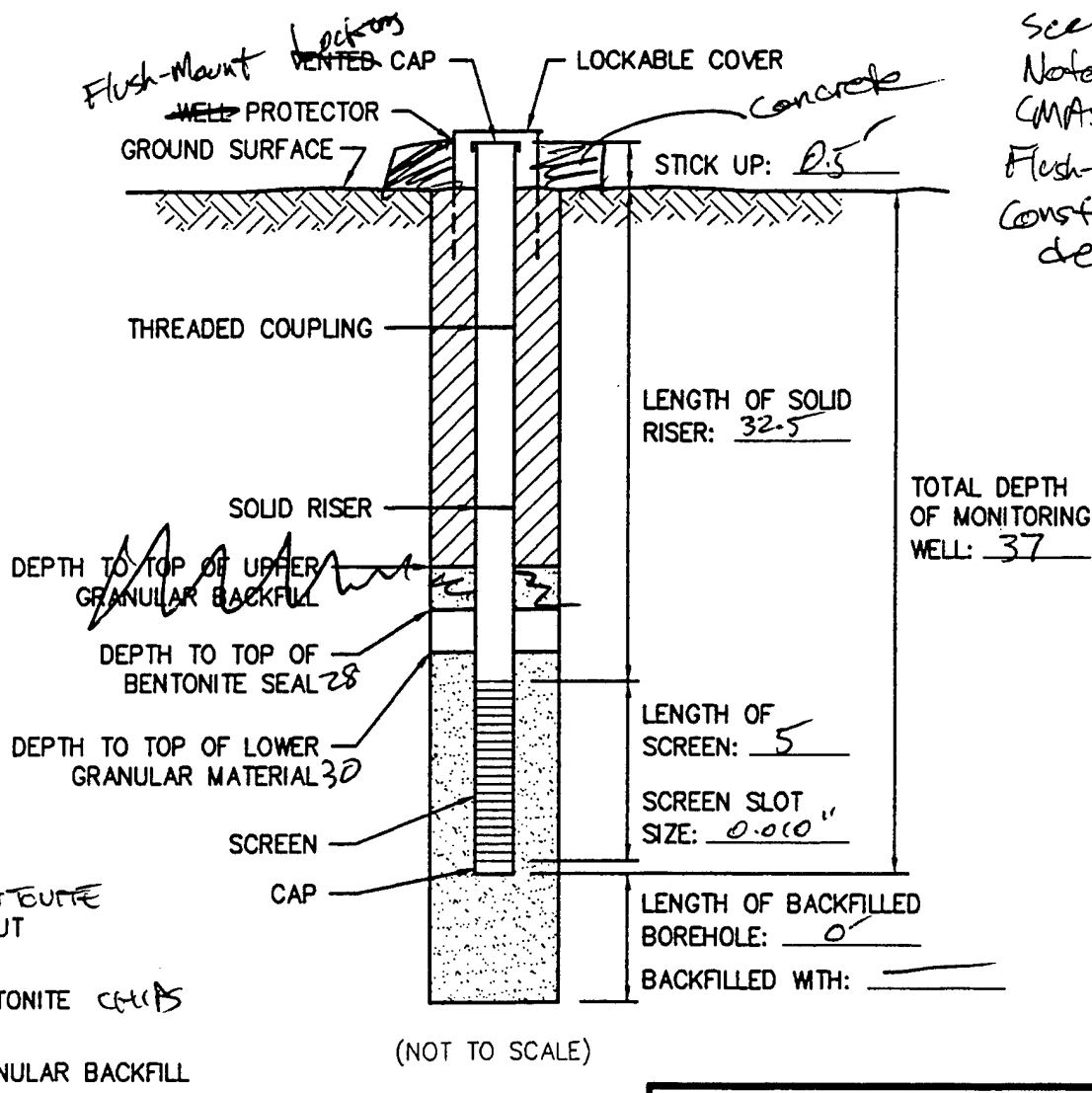
FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

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 Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-3B
 JOB NUMBER 722450.07 INSTALLATION DATE 6/14/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

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MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-4A
 JOB NUMBER 722450.07 INSTALLATION DATE 6/13/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes

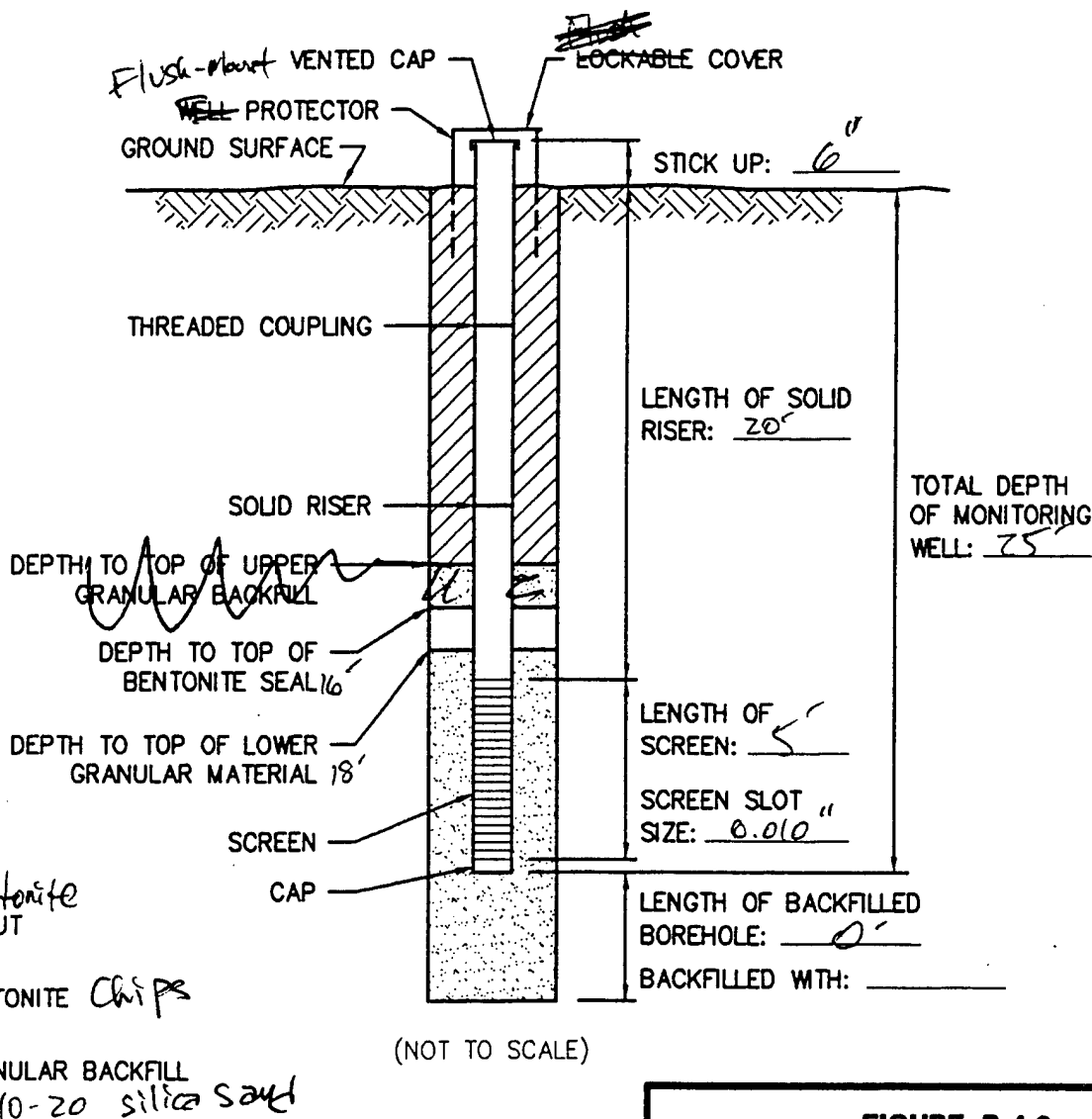


FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol

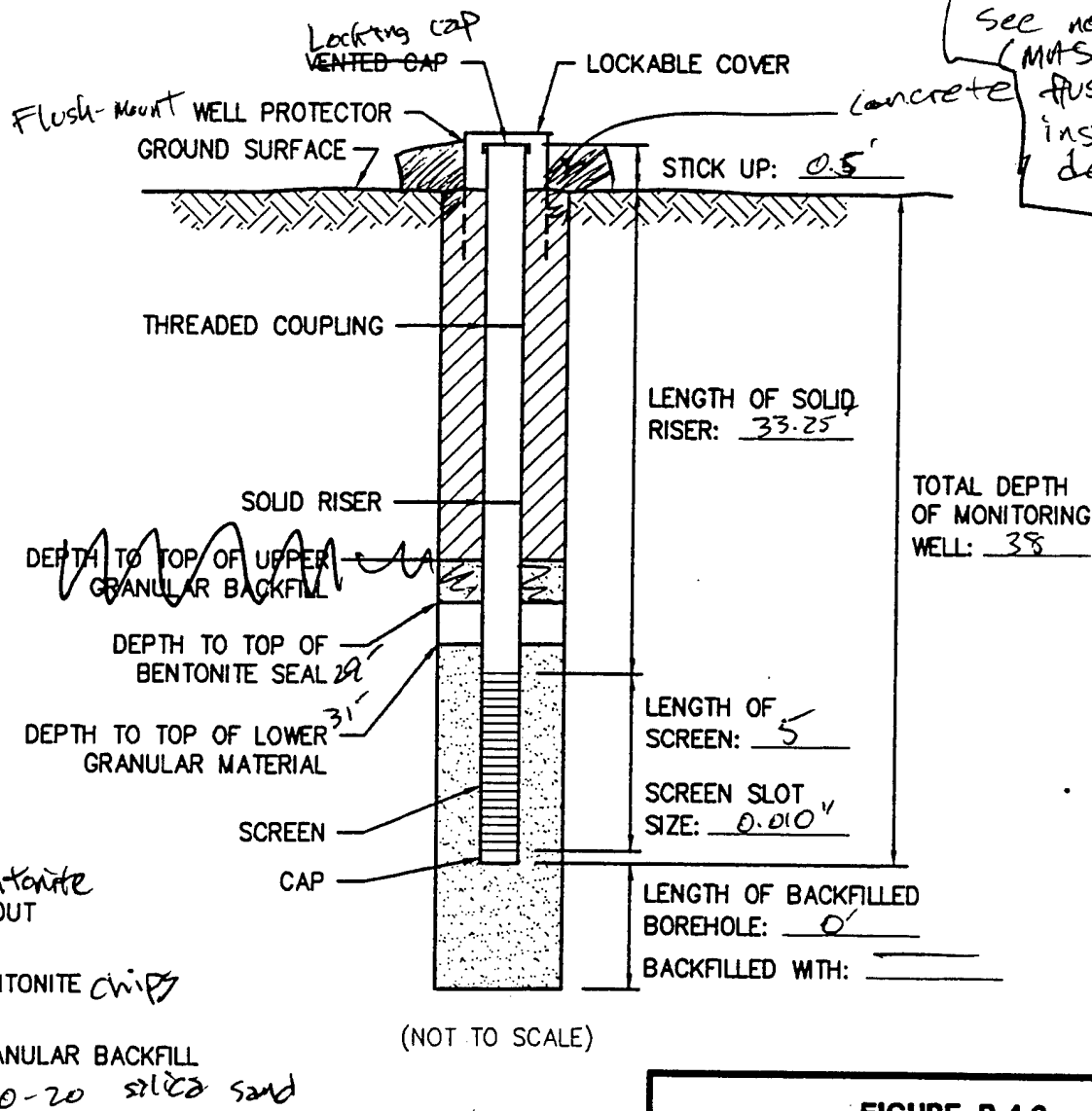
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Denver, Colorado

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-4B
 JOB NUMBER 722450.07 INSTALLATION DATE 6/11/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

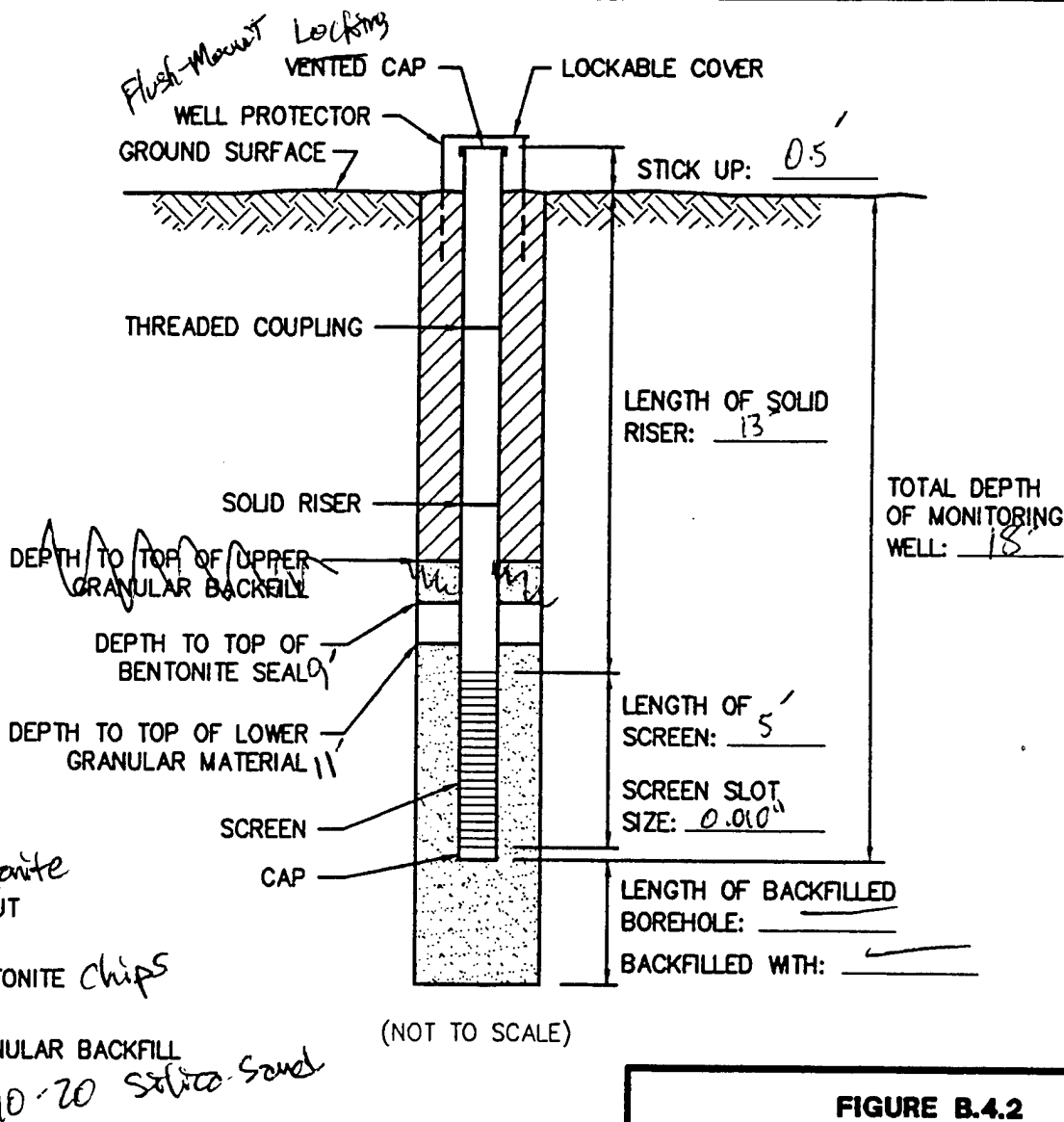
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MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER E3SMW-5A
 JOB NUMBER 722450.07 INSTALLATION DATE 6/17/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

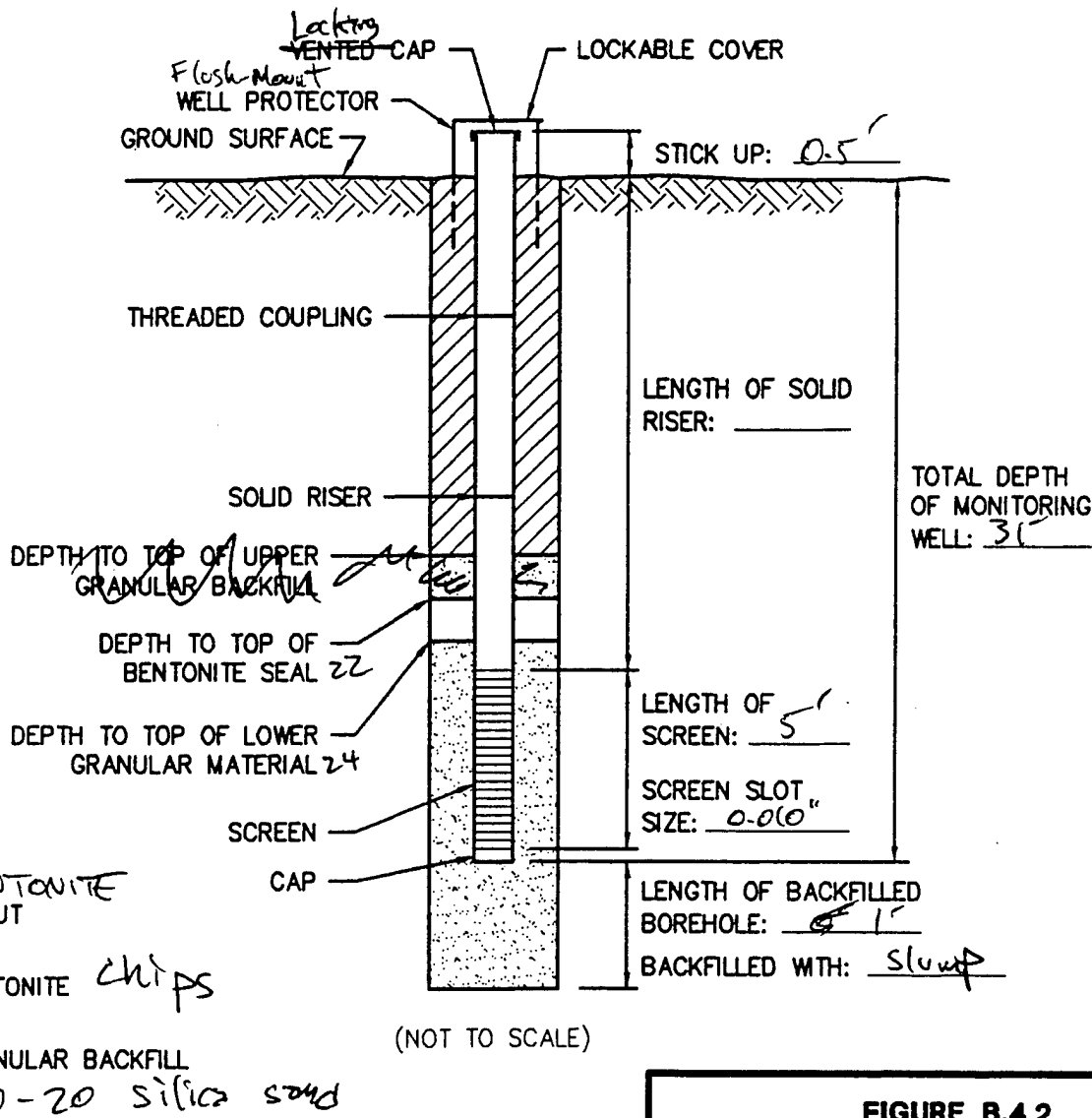
FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol
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 Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-5B
 JOB NUMBER 722450.07 INSTALLATION DATE 6/16/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol

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Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ES MW-6A
 JOB NUMBER 722450.07 INSTALLATION DATE 6/15/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes

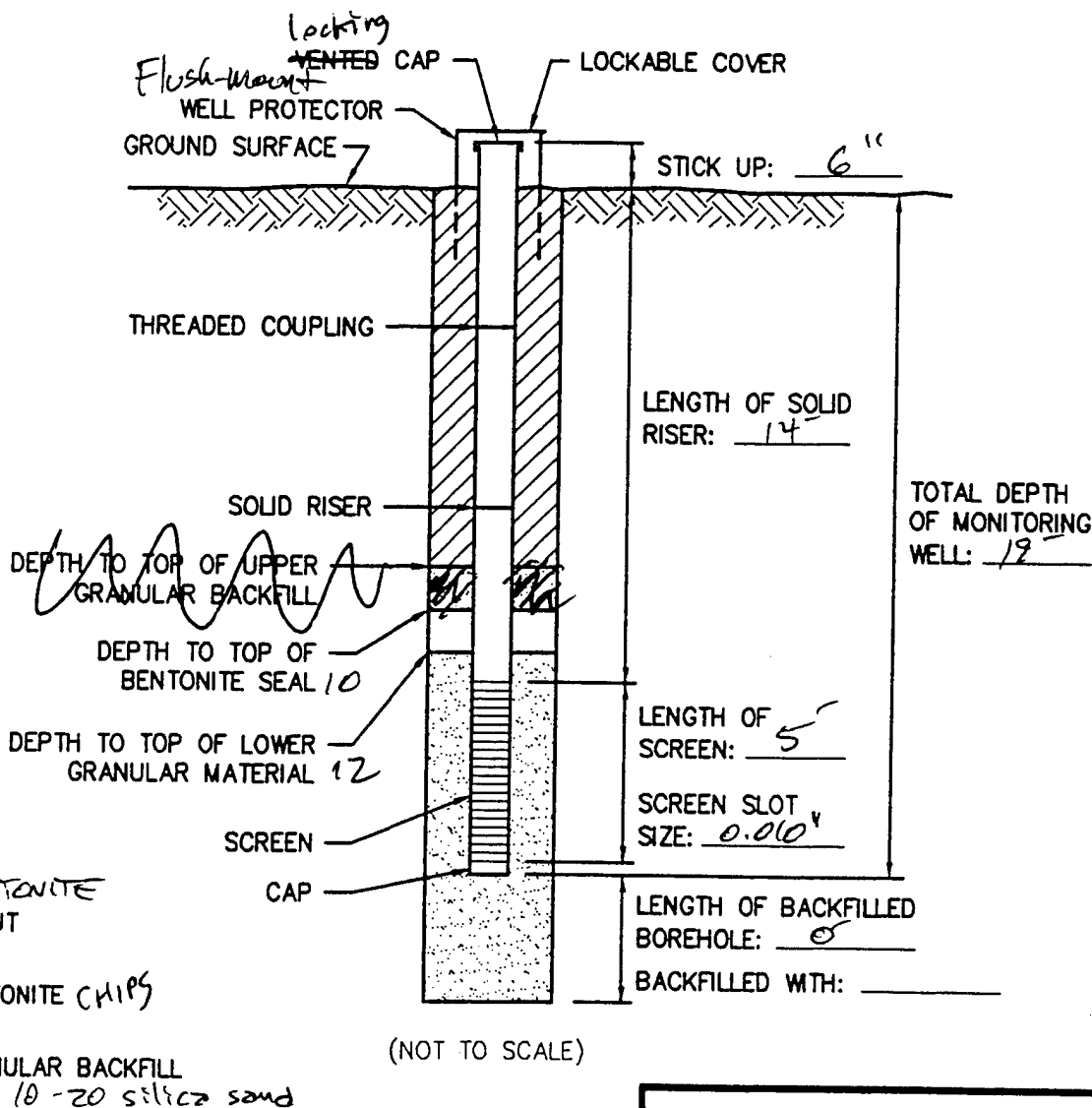


FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol

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Denver, Colorado

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE

WELL NUMBER ESMW-6B

JOB NUMBER 722450.07

INSTALLATION DATE 6/15/94

LOCATION HANGAR 10

DATUM ELEVATION _____

GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TGC

SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC

SLOT SIZE 0.01"

PIPER DIAMETER & MATERIAL 2" SCH 40 PVC

BOREHOLE DIAMETER 8 INCHES

GRANULAR BACKFILL MATERIAL SAND

ES REPRESENTATIVE MS/KC

DRILLING METHOD HOLLOW STEM AUGER

DRILLING CONTRACTOR Flugles

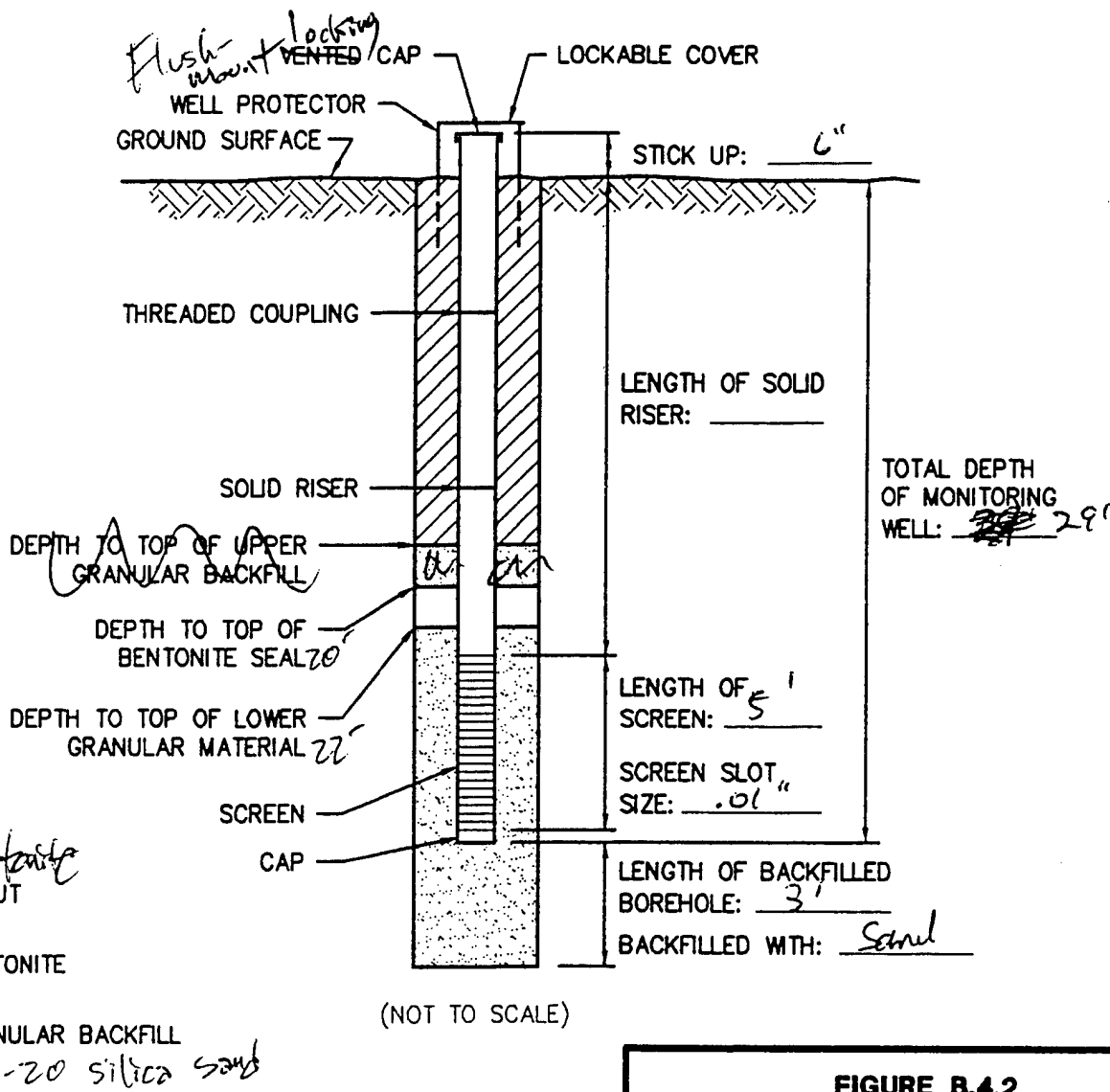


FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol

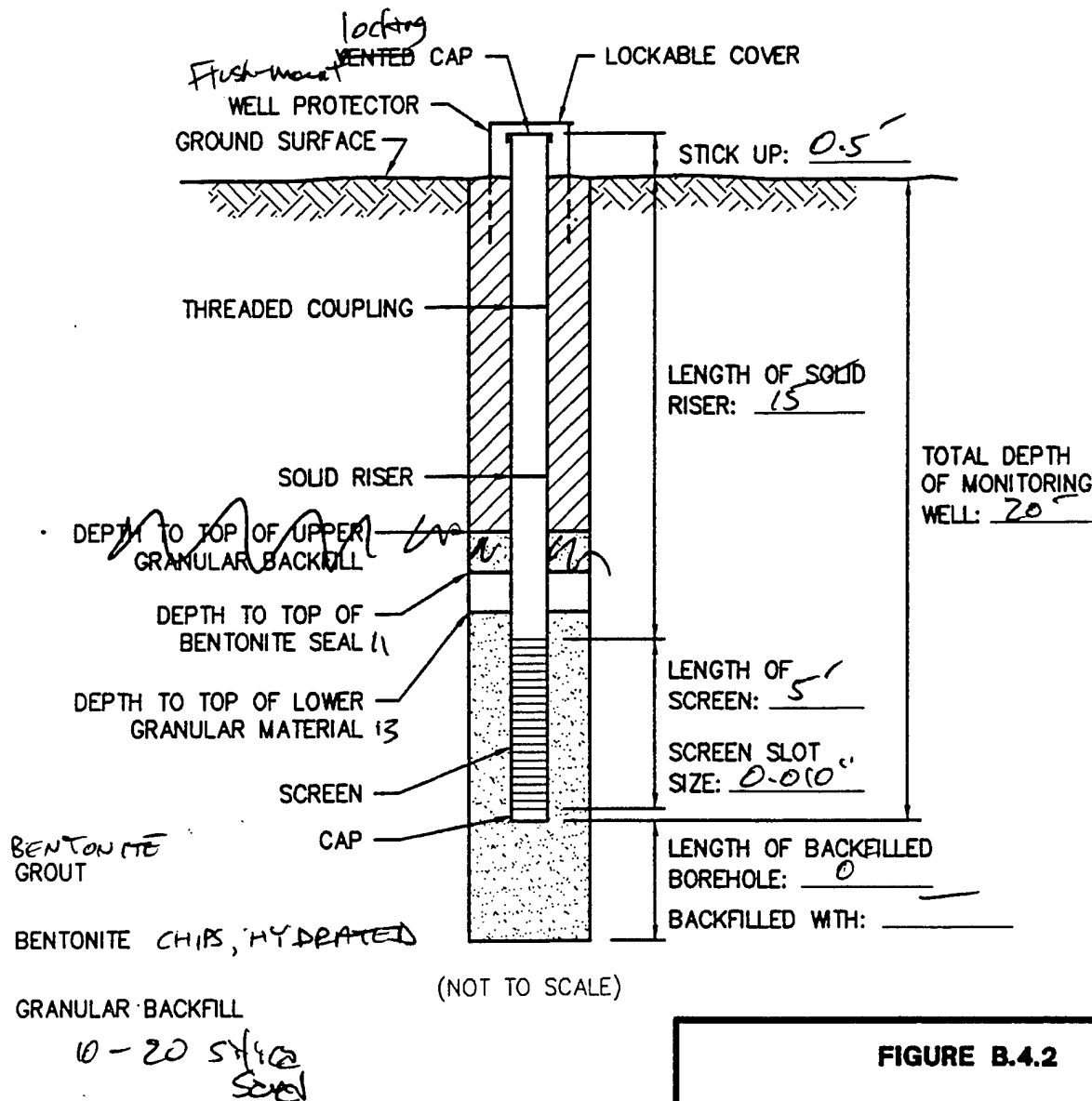
ENGINEERING-SCIENCE, INC.

Denver, Colorado

STABILIZED WATER LEVEL _____ FEET
BELOW DATUM.
MEASURED ON _____

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-7A
 JOB NUMBER 722450.07 INSTALLATION DATE 6/10/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR _____



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

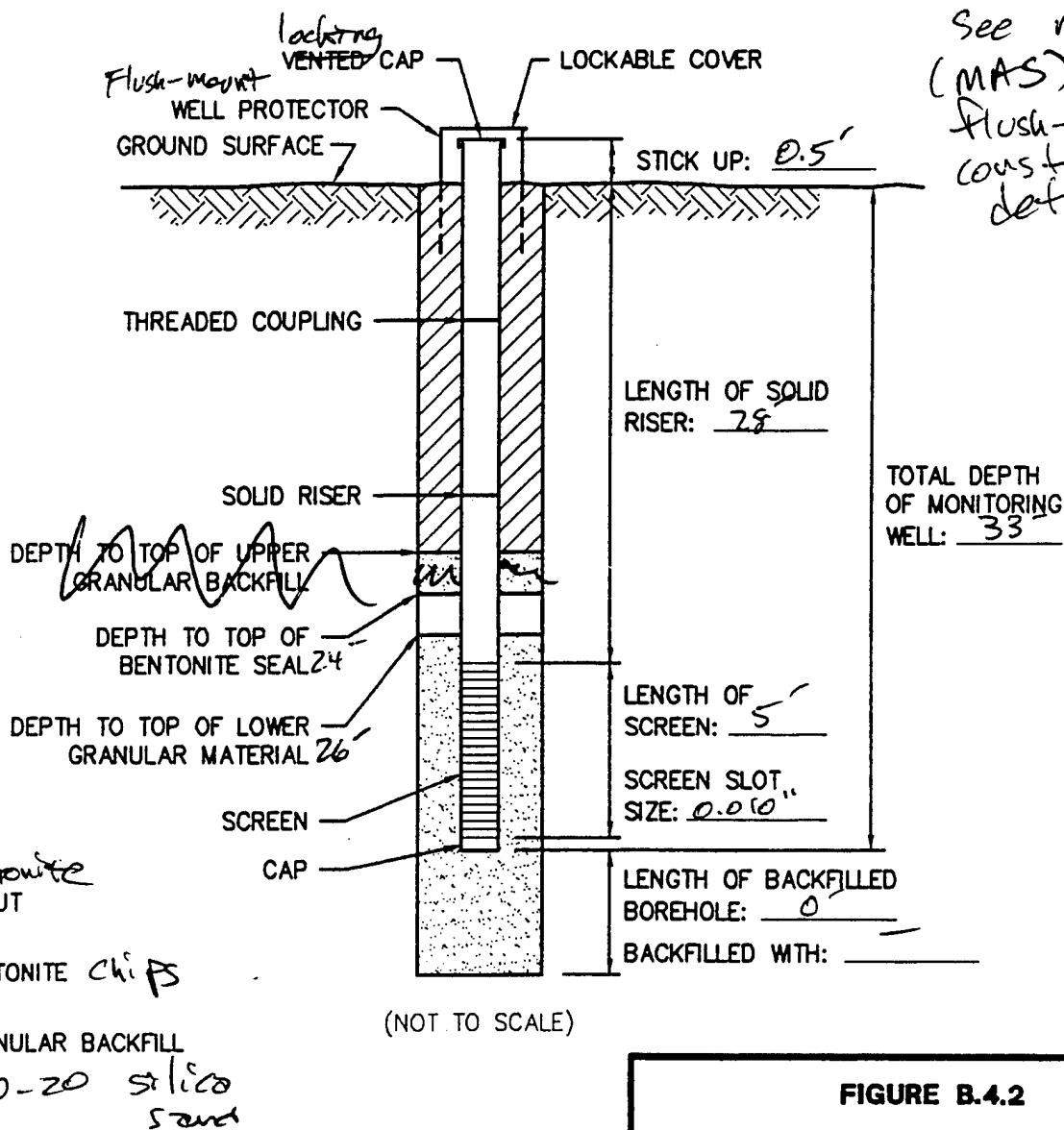
FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol
ENGINEERING-SCIENCE, INC.
 Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME ELMENDORF AIR FORCE BASE WELL NUMBER ESMW-7B
 JOB NUMBER 722450.07 INSTALLATION DATE 6/10/94 LOCATION HANGAR 10
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE MS/KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR Hughes



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE B.4.2

MONITORING WELL INSTALLATION RECORD

Intrinsic Remediation Protocol

ENGINEERING-SCIENCE, INC.

Denver, Colorado

APPENDIX B

LABORATORY ANALYTICAL DATA

MANTECH

Ref: 94-DK14/vg

July 21, 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 *SN*

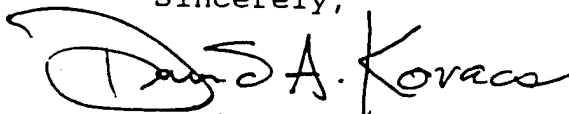
Dear Don:

This report contains the results of my GC/MSD analysis of methylene chloride core extracts from Elmendorf AFB for quantitation of benzene, toluene, ethylbenzene (EB), p-Xylene, m-Xylene, o-Xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB) and 1,2,3-trimethylbenzene (1,2,3-TMB) performed under Service Request #SF-0-65.

The analytical method was a modification of RSKSOP-124. Cool (38°C) on-column injection (0.5 µl) was used with electronic pressure control (EPC) set for a constant flow of 0.9 ml/min. A 30M X 0.25 mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5 µm film) capillary GC column with 1 foot long X 0.53 mm ID uncoated capillary precolumn was used. Quantitation was based on calibration curves of a single target ion for each compound with the addition of up to two qualifier ions recorded to verify chromatographic separation or purity. The ions chosen were those listed in EPA method 524.2 Revision 3.0. Standards calibration ranged from 0.01 to 10 µg/ml. A complete report detailing the acquisition method and calibration has been recorded. The samples were extracted by Mark Blankenship on June 15, 1994 and were analyzed for fuel carbon (GC/FID) by Randy Callaway. This GC/MSD data was acquired July 13-14, 1994.

If I can be of further assistance, please feel free to contact me.

Sincerely,



David A. Kovacs

xc: R.L. Cosby
J.L. Seeley *js*
G. Smith

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

PLE

mg/kg

BENZENETOLUENEEBXYLENEm-XYLENEo-XYLENE1,3,5-TMB1,2,4-TMB1,2,3-TMB

ES-MW1B-22-24'

ES-MW1B-26-28'

ES-MW2-22-24'

ES-MW2-24-26'

ES-MW4B-20-22'

ES-MW4B-24-26'

ES-MW5b-14-16'

ES-MW7B-17-18'

ST41-ES1-12-14'

ST41-ES1-14-16'

ST41-ES1-14-16' Rep.

1.81E-02

3.34E+00

4.44E-01

ST41-ES2-4-6'

ST41-ES2-6-8'

ST41-ES3-3-4'

ST41-ES3-4-6'

ST41-ES4B-4-6'

ST41-ES4B-6-8'

ST41-ES5-4-6'

ST41-ES5-6-8'

ST41-ES6B-10-12'

ST41-ES6B-8-10'

ST41-ES7B-10-12'

ST41-ES7B-6-8'

ST41-ES8B-6-8'

ST41-ES8B-10-12'

QC Summary

Method Blank 1

Method Blank 2

0.1 µg/ml

1 µg/ml

1 µg/ml

10 µg/ml

10 µg/ml

10 µg/ml

10 µg/ml QC

Analyst: David A. Kovacs

BLQ = <0.02 µg/ml

Printed: 7/21/94

MANTECH
TECH

Ref: 94-PR68/rc
94-MW63/rc
94-TH66/rc

June 14, 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 *SAV*

Dear Don:

Attached are the results of 2 sets of Elmendorf AFB samples submitted to ManTech Environmental as part of Service Request # RE-0-65. The samples were received on June 9 and 10 and analyzed June 9 and 13. The methods used for analysis were EPA methods 120.1 and 353.1, and Water's Capillary Electrophoresis Method N-601. Blanks, spikes, duplicates and known AQC samples were analyzed along with the samples for quality assurance.

If you have any questions concerning these results, please feel free to contact us.

Sincerely,

Priscilla Rhynes
Priscilla Rhynes

Mark White
Mark White

Tim Hensley
Tim Hensley

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

06/07/94

<u>Sample</u>	<u>mg/l</u> <u>Cl⁻</u>	<u>mg/l</u> <u>SO₄⁼</u>	<u>mg/l</u> <u>NO₂⁻+NO₃⁻(N)</u>	<u>Conductivity</u>
ST41 W7	54.3	24.6	<.05	855
ST41 W7 Dup				859
ST41 W8	33.6	7.19	1.04	391
ST41 15	74.0	18.9	<.05	942
ST41 15 Dup	73.6	18.8		
ST41 16	36.6	9.52	<.05	2050
ST41 18	31.9	55.0	12.1	642
ST41 21	126	10.3	<.05	734
ST41 21 Dup			<.05	
ST41 25	135	<.5	<.05	1150
ST41 29	14.5	8.26	<.05	226
46WL 01	41.1	5.04	<.05	410
46WL 01 Dup	40.9	5.09		411
46WL 02	17.7	5.83	<.05	184
46WL 03	33.1	7.60	.54	333
MW37A	3.50	4.14	<.05	112
MW37B	6.94	8.44	<.05	387
MW37B Dup			<.05	
Blanks	<.5	<.5	<.05	----
AQCWPO31	44.9	96.2	.45	----
True Value	42.0	92.0	.52	----
Spike Recovery 101%		103%	98%	----

06/08/94

<u>Sample</u>	<u>mg/l</u> <u>Cl⁻</u>	<u>mg/l</u> <u>SO₄⁼</u>	<u>mg/l</u> <u>NO₂⁻+NO₃⁻(N)</u>	<u>Conductivity</u>
OU4W-2	13.3	13.0	3.23	670
OU4W-4	7.71	8.41	1.71	713
OU4W-4 Rep	7.68	8.76	1.90	703
OU4W-5	19.5	13.6	8.88	659
OU4W-5 Dup			8.88	
ST41-01	4.36	15.0	.70	945
ST41-01 Rep	4.55	14.9	.65	938
ST41-2	37.3	35.4	1.03	1040
ST41-2 Dup	37.8	35.2		
ST41-07	73.9	10.4	<.05	697
ST41-07 Rep	74.0	10.2	<.05	713
W-18	7.40	10.3	.29	877
W-18 Dup			.30	
W-19	13.7	21.6	7.44	776
W-19 Dup				776
Blanks	<.5	<.5	<.05	----
AQCWPO31	42.5	93.0	.50	----
True Value	42.0	92.0	.52	----
Spike Recovery 97%		104%	100%	----

Rep - field duplicates

Dup - analytical duplicates

Coch

THIS REPORT ((CLARK.ICAP]LIST.L 93) WAS GENERATED FROM ((CLARK.ICAP]OUTPUT.DAT,1867

PROJECT: ELMENDORF AFB, ALASKA
COOK
TA5

CONCENTRATION IN: MG/L

TAG NO. 5051 MDUP
STATION W18 6-8-9
TIME 15:48
DATE 26-JUL-94
PR DIL 1.1100
DIL 1.0000

5052
ST 41-01 D
14:24
26-JUL-94
1.1100
1.0000

5053
ST 41 ES4B
14:25
26-JUL-94
1.1100
1.0000

5054
OU 4W-1 6-
14:27
26-JUL-94
1.1100
1.0000

Note: High Mn.

ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	4.70	0.49	12.0	1.2	14.9	1.5	4.30	0.46	0.1502
K	2.12	0.21	3.20	0.21	2.17	0.20	2.08	0.21	0.1803
Ca	165.	16.	144.	14.	68.5	6.8	182.	18.	0.0176
Mg	20.0	1.9	42.6	4.2	33.6	3.3	22.7	2.2	0.0129
Fe	<0.078	0.078	<0.078	0.078	4.03	0.40	2.77	0.28	0.0709
Mn	4.98	0.50	<0.021	0.021	2.64	0.27	3.34	0.34	0.0192
Co	0.0093	0.0029	0.0041	0.0029	0.0065	0.0029	0.0080	0.0029	0.0026
Mo	0.0067	0.0028	0.0051	0.0027	0.0030	0.0027	0.0068	0.0028	0.0024
Al	0.025	0.074	<0.074	0.074	0.101	0.074	0.084	0.074	0.0670
As	0.040	0.011	0.023	0.010	<0.010	0.010	0.032	0.010	0.0093
Se	0.0312	0.0043	0.0248	0.0041	0.0189	0.0037	0.0373	0.0046	0.0031
Cd	0.0047	0.0013	0.0055	0.0013	0.0033	0.0012	0.0054	0.0013	0.0011
Be	<0.0014	0.0014	<0.0012	0.0012	<0.0007	0.0007	<0.0015	0.0015	0.0004
Cu	<0.021	0.021	<0.021	0.021	<0.021	0.021	<0.021	0.021	0.0193
Cr	<0.0042	0.0042	<0.0042	0.0042	<0.0042	0.0042	<0.0042	0.0042	0.0038
Ni	0.0156	0.0032	0.0090	0.0031	0.0469	0.0045	0.0188	0.0032	0.0027
Zn	0.0234	0.0027	0.0182	0.0025	0.0154	0.0020	0.0269	0.0028	0.0016
Ag	0.0188	0.0045	0.0159	0.0044	0.0089	0.0043	0.0211	0.0045	0.0038
Tl	0.034	0.016	0.033	0.015	0.036	0.015	0.037	0.016	0.0143
Pb	0.0343	0.0094	0.0294	0.0093	0.0297	0.0092	0.0425	0.0095	0.0082
Li	<0.0020	0.0020	0.0070	0.0024	0.0030	0.0012	<0.0023	0.0023	0.0006
V	0.966	0.095	0.685	0.068	0.340	0.034	0.995	0.099	0.0003
Sr	0.027	0.010	0.022	0.010	0.015	0.010	0.034	0.010	0.0090
Ba	0.0449	0.0046	0.0487	0.0048	0.0524	0.0052	0.0487	0.0049	0.0008
B	<0.079	0.079	<0.080	0.080	<0.079	0.079	<0.079	0.079	0.0720
Ti	0.036	0.021	0.023	0.021	<0.021	0.021	0.036	0.021	0.0193

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS
EPA/RSKRL/ADA, OK

MANTECH TECH

Ref: 94-LB4
June 29, 1994

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 *SV*

Dear Don:

Please find attached the analytical results for Service Request SF-0-65 for the analysis of aqueous samples from Elmendorf AFB to be analyzed for BTEXXX & TMBs. A total of 53 Samples were received in duplicate in capped, 40 mL VOA vials between the dates of June 17-27, 1994. All samples were stored at 4°C until analyzed and were acquired and processed using the MAXIMA data system. A 4 point (1-500 ppb) external calibration curve was used to determine compound concentration.

At your request sample "OU4W-3" was analyzed for Vinyl Chloride, 1,1-DCE, trans- & cis-DCE, and TCE. A 3 point (1-100 ppb) external standard curve was used for this analysis.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" and RSKSOP-146 "Automated Purge and Trap/GC Analysis of Vinyl Chloride and other Volatile Chlorocarbons in Aqueous Samples Containing Particulates" were used for these analyses.

Sincerely,



Lisa R. Black

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

SAMPLE NAME	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Fuel Carbon
100 PPB	9.75E+01	9.50E+01	1.00E+02	9.91E+01	9.92E+01	9.60E+01	9.75E+01	9.57E+01	9.80E+01	N/A
QC, OBSERVED, PPB	5.00E+01	5.40E+01	5.33E+01	5.41E+01	5.41E+01	5.48E+01	5.69E+01	4.89E+01	5.53E+01	N/A
QC, TRUE VALUE, PPB	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	N/A
46WL01	1.96E+01	1.12E+00	1.93E+00	2.01E+00	1.23E+00	9.08E-01	1.46E+00	3.06E+00	1.66E+00	1.79E+02
46WL01 Duplicate	1.91E+01	BLQ	9.89E-01	1.16E+00	BLQ	ND	ND	1.07E+00	ND	1.85E+02
46WL02	ND	ND	BLQ	BLQ	ND	ND	ND	ND	ND	BLQ
46WL03	ND	ND	BLQ	ND	BLQ	ND	ND	ND	ND	BLQ
46WL CREEK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-02	4.13E+01	9.35E+01	1.89E+01	1.57E+01	4.41E+01	2.04E+01	2.80E+00	1.03E+01	4.26E+00	2.81E+02
ST41-07	4.93E+02	5.57E+02	1.54E+02	1.13E+02	2.59E+02	1.62E+02	1.89E+01	7.17E+01	3.09E+01	2.00E+03
ST41-W7	9.96E+00	BLQ	BLQ	BLQ	BLQ	ND	ND	ND	ND	1.09E+01
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
10 PPB	1.09E+01	1.08E+01	9.35E+00	1.03E+01	9.22E+00	9.22E+00	1.01E+01	1.01E+01	1.08E+01	N/A
ST41-W8	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ	1.08E+00	6.37E+00
ST41-15	BLQ	BLQ	BLQ	BLQ	1.10E+00	BLQ	BLQ	BLQ	BLQ	3.83E+00
ST41-16 1/100	1.65E+04	1.73E+04	1.92E+03	1.58E+03	4.36E+03	1.62E+03	1.83E+02	6.31E+02	2.83E+02	4.23E+04
ST41-18	1.01E+02	1.55E+02	2.79E+01	2.31E+01	3.54E+01	2.63E+01	3.52E+00	1.41E+01	5.92E+00	4.80E+02
ST41-18 Duplicate	9.75E+01	1.48E+02	2.61E+01	2.10E+01	5.88E+01	2.69E+01	4.37E+00	1.29E+01	4.38E+00	4.38E+02
ST41-21	2.20E+00	3.88E+00	BLQ	BLQ	1.27E+00	ND	ND	ND	ND	7.41E+00
ST41-25	4.90E+01	8.39E+00	9.83E+02	7.91E+02	ND	ND	8.80E+01	1.59E+01	1.10E+00	1.10E+04
ST41-29	BLQ	1.34E+00	1.15E+00	1.09E+00	BLQ	ND	ND	ND	ND	2.20E+01
W-9	1.26E+00	1.81E+00	9.06E-01	BLQ	1.37E+00	1.07E+00	BLQ	BLQ	BLQ	1.45E+01
W-18	7.01E+00	3.45E+01	1.08E+01	9.33E+00	2.63E+01	1.13E+01	2.39E+00	8.63E+00	3.35E+00	1.61E+02
100 PPB	9.44E+01	9.32E+01	9.61E+01	9.54E+01	1.01E+02	9.84E+01	9.85E+01	9.88E+01	9.81E+01	N/A
W-19	1.83E+01	6.08E+01	1.71E+01	1.50E+01	4.02E+01	1.73E+01	4.76E+00	1.28E+01	6.45E+00	2.04E+02
W-19 Duplicate	1.62E+01	5.85E+01	1.47E+01	1.22E+01	3.51E+01	1.66E+01	2.63E+00	1.09E+01	4.42E+00	2.14E+02
MW37-A	ND	ND	BLQ	ND	ND	ND	ND	BLQ	ND	BLQ
MW37-B	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND	BLQ
ST41-ES1	6.32E+01	1.30E+00	ND	BLQ	BLQ	ND	ND	ND	BLQ	6.07E+01
ST41-ES1 Duplicate	6.44E+01	1.56E+00	ND	BLQ	BLQ	ND	ND	ND	BLQ	5.99E+01
ST41-ES2	3.02E+00	2.19E+00	ND	ND	BLQ	ND	ND	BLQ	1.40E+00	2.21E+01
QC	4.85E+01	4.99E+01	5.10E+01	5.04E+01	4.67E+01	4.96E+01	5.32E+01	5.54E+01	5.40E+01	N/A
10 PPB	9.71E+00	9.60E+00	9.06E+00	9.75E+00	9.51E+00	9.71E+00	1.07E+01	1.05E+01	1.08E+01	N/A
ST41-ES4A	ND	BLQ	ND	ND	ND	ND	BLQ	ND	ND	BLQ
ST41-ES4B	BLQ	ND	ND	BLQ	ND	ND	ND	ND	ND	BLQ
ST41-ES5A	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	BLQ
OU4W-1	2.16E+00	3.02E+00	1.61E+00	1.07E+00	3.52E+00	1.61E+00	BLQ	2.75E+00	1.41E+00	2.28E+01
OU4W-2	2.84E+00	1.68E+01	5.27E+00	4.33E+00	1.26E+01	6.05E+00	1.32E+00	5.01E+00	2.26E+00	6.51E+01
OU4W-3	1.36E+00	2.80E+00	1.79E+00	1.88E+00	3.94E+00	1.90E+00	BLQ	2.63E+00	1.71E+00	3.80E+01
OU4W-4	2.03E+02	8.84E+00	6.58E+01	5.58E+01	8.18E+01	6.24E+01	1.54E+01	4.26E+01	2.45E+01	1.03E+03
OU4W-5	1.48E+00	3.82E+00	2.80E+00	2.40E+00	6.82E+00	3.16E+00	BLQ	3.45E+00	1.42E+00	3.47E+01
OU4W-10	1.41E+00	2.21E+00	1.39E+00	1.07E+00	2.97E+00	1.31E+00	BLQ	2.22E+00	1.86E+00	1.02E+02
SP7/10-02	BLQ	BLQ	ND	ND	9.69E-01	ND	ND	BLQ	BLQ	8.14E+00
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
500 PPB	5.22E+02	4.83E+02	5.07E+02	5.18E+02	5.18E+02	5.11E+02	4.85E+02	5.15E+02	5.10E+02	N/A

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb

SAMPLE ID	BENZENE	TOLUENE	ETHYLBENZENE	LENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,3-TMB
100 PPB	9.75E+01	9.50E+01	1.00E+02	9.91E+01	9.92E+01	9.60E+01	9.75E+01	9.57E+01
QC, OBSERVED, PPB	5.00E+01	5.40E+01	5.33E+01	5.41E+01	5.41E+01	5.48E+01	5.69E+01	4.89E+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
46WL01	1.96E+01	1.12E+00	1.93E+00	2.01E+00	1.23E+00	9.08E-01	1.46E+00	3.06E+00
46WL01 Duplicate	1.91E+01	BLQ	9.89E-01	1.16E+00	BLQ	ND	ND	1.07E+00
46WL02	ND	ND	BLQ	BLQ	ND	ND	ND	ND
46WL03	ND	ND	BLQ	ND	BLQ	ND	ND	ND
46WL CREEK	ND	ND	ND	ND	ND	ND	ND	ND
ST41-01	ND	ND	ND	ND	ND	ND	ND	ND
ST41-02	4.13E+01	9.35E+01	1.89E+01	1.57E+01	4.41E+01	2.04E+01	2.80E+00	1.03E+01
ST41-07	4.93E+02	5.57E+02	1.54E+02	1.13E+02	2.59E+02	1.62E+02	1.89E+01	7.17E+01
ST41-W7	9.96E+00	BLQ	BLQ	BLQ	BLQ	ND	ND	ND
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND
10 PPB	1.09E+01	1.08E+01	9.35E+00	1.03E+01	9.22E+00	9.22E+00	1.01E+01	1.01E+01
ST41-W8	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ
ST41-15	BLQ	BLQ	BLQ	BLQ	1.10E+00	BLQ	BLQ	BLQ
ST41-16 1/100	1.65E+04	1.73E+04	1.92E+03	1.58E+03	4.36E+03	1.62E+03	1.83E+02	6.31E+02
ST41-18	1.01E+02	1.55E+02	2.79E+01	2.31E+01	6.34E+01	2.63E+01	3.52E+00	1.41E+01
ST41-18 Duplicate	9.75E+01	1.48E+02	2.61E+01	2.10E+01	5.88E+01	2.69E+01	4.37E+00	1.29E+01
ST41-21	2.20E+00	3.88E+00	BLQ	BLQ	1.27E+00	ND	ND	ND
ST41-25	4.90E+01	8.39E+00	9.83E+02	7.91E+02	ND	ND	8.80E+01	1.59E+01
ST41-29	BLQ	1.34E+00	1.15E+00	1.09E+00	BLQ	ND	ND	ND
W-9	1.26E+00	1.81E+00	9.06E-01	BLQ	1.37E+00	1.07E+00	BLQ	BLQ
W-18	7.01E+00	3.45E+01	1.08E+01	9.33E+00	2.63E+01	1.13E+01	2.39E+00	8.63E+00
100 PPB	9.44E+01	9.32E+01	9.61E+01	9.54E+01	1.01E+02	9.84E+01	9.85E+01	9.88E+01
W-19	1.83E+01	6.08E+01	1.71E+01	1.50E+01	4.02E+01	1.73E+01	4.76E+00	1.28E+01
W-19 Duplicate	1.62E+01	5.85E+01	1.47E+01	1.22E+01	3.51E+01	1.66E+01	2.63E+00	1.09E+01
MW37-A	ND	ND	BLQ	ND	ND	ND	ND	BLQ
MW37-B	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND
ST41-ES1	6.32E+01	1.30E+00	ND	BLQ	BLQ	ND	ND	ND
ST41-ES1 Duplicate	6.44E+01	1.56E+00	ND	BLQ	BLQ	ND	ND	ND
ST41-ES2	3.02E+00	2.19E+00	ND	BLQ	BLQ	ND	ND	BLQ
QC	4.85E+01	4.99E+01	ND	ND	BLQ	ND	ND	BLQ
10 PPB	9.71E+00	9.60E+00	5.10E+01	5.04E+01	4.67E+01	4.96E+01	5.32E+01	5.54E+01
ST41-ES4A	ND	BLQ	9.06E+00	9.75E+00	9.51E+00	9.71E+00	1.07E+01	1.05E+01
ST41-ES4B	BLQ	ND	ND	ND	ND	ND	BLQ	ND
ST41-ES5A	ND	BLQ	ND	ND	ND	ND	ND	ND
OU4W-1	2.16E+00	3.02E+00	1.61E+00	1.07E+00	3.52E+00	1.61E+00	BLQ	2.75E+00
OU4W-2	2.84E+00	1.68E+01	5.27E+00	4.33E+00	1.26E+01	6.05E+00	1.32E+00	5.01E+00
OU4W-3	1.36E+00	2.80E+00	1.79E+00	1.88E+00	3.94E+00	1.90E+00	BLQ	2.63E+00
OU4W-4	2.03E+02	8.84E+00	6.58E+01	5.58E+01	8.18E+01	6.24E+01	1.54E+01	4.26E+01
OU4W-5	1.48E+00	3.82E+00	2.80E+00	2.40E+00	6.82E+00	3.16E+00	BLQ	3.45E+00
OU4W-10	1.41E+00	2.21E+00	1.39E+00	1.07E+00	2.97E+00	1.31E+00	BLQ	2.22E+00
SP7/10-02	BLQ	BLQ	ND	ND	9.69E-01	ND	ND	BLQ
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND
500 PPB	5.22E+02	4.83E+02	5.07E+02	5.18E+02	5.18E+02	5.11E+02	4.85E+02	5.15E+02

SAMPLE NAME	BENZENE	TOLUENE	ETHYLBENZENE	P-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
100 PPB	9.53E+01	1.01E+02	9.75E+01	9.71E+01	1.01E+02	9.79E+01	1.01E+02	9.89E+01	9.57E+01
QC, OBSERVED, PPB	4.69E+01	5.00E+01	5.10E+01	5.07E+01	4.93E+01	4.92E+01	4.87E+01	5.25E+01	5.05E+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
ES-MW1A	BLQ	ND	ND	ND	BLQ	ND	ND	ND	ND
ES-MW1B	5.30E+00	2.35E+00	2.97E+01	4.33E+01	4.24E+01	5.37E+01	2.27E+01	7.17E+01	3.86E+01
ST41-ES3	2.24E+00	3.18E+00	ND	ND	ND	ND	ND	BLQ	1.25E+00
ST41-ES5B	4.34E+00	2.91E+00	ND	ND	ND	ND	ND	ND	ND
ST41-ES6A	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ST41-ES6B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-ES6B Duplicate	ND	ND	ND	ND	ND	ND	ND	BLQ	ND
ST41-ES7A	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-ES7B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-ES8A	ND	ND	ND	ND	ND	ND	ND	ND	ND
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND
10 PPB	1.03E+01	9.85E+00	8.97E+00	9.71E+00	9.14E+00	9.19E+00	9.31E+00	9.40E+00	9.71E+00
ST41-ES8B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-02	2.15E+00	2.29E+00	1.50E+00	1.53E+00	1.36E+00	1.09E+00	1.54E+00	1.61E+00	1.79E+00
ESMW-3A	BLQ	BLQ	ND	ND	ND	ND	ND	ND	BLQ
ESMW-3B	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-04A	1.52E+00	1.54E+00	ND	ND	ND	ND	ND	ND	ND
ESMW-04B	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-5A	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-5B	ND	1.34E+00	ND	ND	ND	ND	ND	ND	ND
ESMW-6A	ND	BLQ	ND	ND	BLQ	ND	ND	ND	ND
ESMW-6B	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
500 PPB	4.93E+02	4.58E+02	4.71E+02	4.72E+02	4.77E+02	4.97E+02	5.37E+02	5.55E+02	5.95E+02
ESMW-7A	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-7B	BLQ	9.65E-01	ND	ND	ND	ND	ND	ND	ND
10 PPB	1.06E+01	1.04E+01	1.01E+01	1.01E+01	1.03E+01	1.06E+01	1.02E+01	9.44E+00	9.90E+00

SAMPLE NAME	Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE
OU4W-3	BLQ	9.98E-01	5.56E+00	BLQ	1.51E+00
QC, OBSERVED, PPB	1.99E+01	4.50E+01	5.09E+01	5.31E+01	5.51E+01
QC, TRUE VALUE, PPB	2.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01
10 PPB	1.03E+01	1.10E+01	1.10E+01	1.08E+01	1.09E+01

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb

SAMPLE I	BENZENE	TOLUENE	ETHYLBENZENE	P-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	.B	1,2,3-TMB
100 PPB	9.53E+01	1.01E+02	9.75E+01	9.71E+01	1.01E+02	9.79E+01	1.01E+02	9.89E+01	9.57E+01
QC, OBSERVED, PPB	4.69E+01	5.00E+01	5.10E+01	5.07E+01	4.93E+01	4.92E+01	4.87E+01	5.25E+01	5.05E+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
ES-MW1A	BLQ	ND	ND	ND	BLQ	ND	ND	ND	ND
ES-MW1B	5.30E+00	2.35E+00	2.97E+01	4.33E+01	4.24E+01	5.37E+01	2.27E+01	7.17E+01	3.86E+01
ST41-ES3	2.24E+00	3.18E+00	ND	ND	ND	ND	ND	BLQ	1.25E+00
ST41-ES5B	4.34E+00	2.91E+00	ND	ND	ND	ND	ND	ND	ND
ST41-ES6A	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ST41-ES6B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-ES6B Duplicate	ND	ND	ND	ND	ND	ND	ND	BLQ	ND
ST41-ES7A	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-ES7B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ST41-ES8A	ND	ND	ND	ND	ND	ND	ND	ND	ND
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND
10 PPB	1.03E+01	9.85E+00	8.97E+00	9.71E+00	9.14E+00	9.19E+00	9.31E+00	9.40E+00	9.71E+00
ST41-ES8B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-02	2.15E+00	2.29E+00	1.50E+00	1.53E+00	1.36E+00	1.09E+00	1.54E+00	1.61E+00	1.79E+00
ESMW-3A	BLQ	BLQ	ND	ND	ND	ND	ND	ND	BLQ
ESMW-3B	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-04A	1.52E+00	1.54E+00	ND	ND	ND	ND	ND	ND	ND
ESMW-04B	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-5A	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-5B	ND	1.34E+00	ND	ND	ND	ND	ND	ND	ND
ESMW-6A	ND	BLQ	ND	ND	BLQ	ND	ND	ND	ND
ESMW-6B	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
500 PPB	4.93E+02	4.58E+02	4.71E+02	4.72E+02	4.77E+02	4.97E+02	5.37E+02	5.55E+02	5.95E+02
ESMW-7A	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW-7B	BLQ	9.65E-01	ND	ND	ND	ND	ND	ND	ND
10 PPB	1.06E+01	1.04E+01	1.01E+01	1.01E+01	1.03E+01	1.06E+01	1.02E+01	9.44E+00	9.90E+00

SAMPLE NAME	Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE
OU4W-3	BLQ	9.98E-01	5.56E+00	BLQ	1.51E+00
QC, OBSERVED, PPB	1.99E+01	4.50E+01	5.09E+01	5.31E+01	5.51E+01
QC, TRUE VALUE, PPB	2.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01
10 PPB	1.03E+01	1.10E+01	1.10E+01	1.08E+01	1.09E+01

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb

ELMENDORF AIR FORCE BASE - ALASKA
FIELD DATA

Sample #	Date	Redox	Cond	pH	Total alk mg/l CaCO ₃	Ferrous iron mg/l	Hydrogen sulfide mg/l
46WL01	6-07-94	-24	432	6.3	150	9.1	<.1
46WL02	6-07-94	102	190	6.1	61	2.1	---
46WL03	6-07-94	119	340	6.7	108	<.05	---
MW37A	6-07-94	104	114	7.1	50	<.05	---
MW37B	6-07-94	-25	388	7.4	170	<.05	<.1
ST41-29	6-07-94	10	232	6.1	92	.7	<.1
ST41-W8	6-07-94	20	402	6.9	49	<.05	---
ST41-W7	6-07-94	115	880	7.5	388	<.05	---
ST41-25	6-07-94	-53	1224	6.8	460	10.5	<.1
ST41-21	6-08-94	258	755	6.3	150	<.05	<.1
ST41-15	6-08-94	15	961	6.8	375	1.0	---
ST41-16	6-08-94	-30	2170	6.6	1210	40.5	---
41-18	6-08-94	110	647	6.4	223	<.05	<.1
41-2	6-08-94	121	1039	6.7	554	<.05	---
W-19	6-08-94	165	876	7.0	347	<.05	---
W-18	6-08-94	-120	902	7.0	467	4.3	<.1
OU4W-2	6-08-94	33	683	7.2	326	<.05	---

ELMENDORF AIR FORCE BASE - ALASKA
FIELD DATA

Sample #	Date	Redox	Cond	pH	Total alk mg/l CaCO ₃	Ferrous iron mg/l
ST41-01	6-09-94	---	954	7.1	512	<.05
ST41-07	6-09-94	---	702	7.2	270	.2
OU4W-4	6-09-94	-80	733	7.1	353	4.6
OU4W-5	6-09-94	60	662	7.1	274	<.05
OU4W-3	6-09-94	-20	834	7.0	428	.4
OU4W-10	6-09-94	20	544	6.9	265	.3
OU4W-1	6-09-94	-39	1013	6.9	456	2.9
SP7/10-02	6-09-94	40	790	6.9	269	<.05
W-9	6-09-94	123	812	7.0	345	<.05
ST41ES4A	6-10-94	168	214	6.1	76	<.05
ST41ES4B	6-10-94	20	660	6.6	251	2.1
ST41ES5A	6-10-94	126	109	6.7	47	<.05
ST41ES5B	6-10-94	91	280	7.9	115	<.05
ST41ES1	6-10-94	110	1060	6.8	481	<.05
ST41ES2	6-10-94	11	747	6.7	271	3.6

ELMENDORF AIR FORCE BASE - ALASKA
FIELD DATA

[illegible]

MANTECH TECH

Ref: 94-PR77/vg

July 1, 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 *SAV*

Dear Don:

Attached are the results of 11 Elmendorf AFB samples submitted to ManTech as part of S.R. #SF-0-65. The samples were received on June 24 and 27 and analyzed June 27, 28, and 29, 1994. The methods used for analysis were EPA Methods 120.1, 310.1, and 353.1 and Water's capillary electrophoresis method N-601. Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results please feel free to contact me.

Sincerely,



Priscilla Rhynes

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

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> <u>NO₂⁻+NO₃⁻(N)</u>	<u>mg/l</u> <u>Cl⁻</u>	<u>mg/l</u> <u>SO₄⁼</u>	<u>Cond.</u>	<u>Total</u> <u>Alkalinity</u>
ES MW 02	9.10	3.14	21.3	865	365
ES MW 3A	7.64	8.04	2.12	817	386
ES MW 3B	1.13	5.64	8.14	793	385
ES MW 3B Dup	1.09	5.79	8.28		
ES MW 4A	9.98	3.09	26.7	388	115
ES MW 4B	.24	2.74	27.7	272	93.9
ES MW 5A	4.58	4.26	15.0	558	230
ES MW 5B	.68	1.72	22.5	312	114
ES MW 6A	49.2	5.36	17.3	1140	368
ES MW 6B	.60	6.89	4.32	780	380
ES MW 7A	3.08	4.69	4.47	799	393
ES MW 7A Dup	3.02			800	393
ES MW 7B	.23	4.82	8.78	827	406
Blanks	<.05	<.05	<.05	---	---
AQCWP031	.54	40.7	89.1	---	---
True Value	.52	41.2	92.0	---	---
Spike Rec.	96%	97%	95%	---	---

8.

MANTECH

Ref: 94-BN36/vg

July 5, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Find attached results for methane on Elmendorf AFB samples as per Service Request #SF-0-65. Samples were received on June 9, 10, 14, 24, and 27, 1994 and analyzed on June 13, 16, and 29, 1994. Samples were prepared as described in the paper "Dissolved Oxygen and Methane in Water by a GC Headspace Equilibration Technique", by Kampbell et al., in International Journal of Environmental Analytical Chemistry, Volume 36, pp.249-257. Analysis and calculations were performed as per RSKSOP-147.

If you have any questions, please feel free to see me.

Sincerely,

Bryan Newell

Bryan Newell

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

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

SF-0-65 DATA

ANALYZED 6/13/94

SAMPLE	METHANE
LAB BLANK	BLQ
ST41-01	BLQ
ST41-02	0.008
ST41-07	0.054
ST41-W7	0.489
* FIELD DUP	0.503
ST41-W8	BLQ
ST41-15	0.001
ST41-16	0.046
ST41-18	0.040
ST41-21	0.003
ST41-25	0.922
ST41-29	0.044
MW37A	BLQ
MW37B	0.002
OU4W-2	0.008
OU4W-4	0.993
OU4W-5	0.001
W-18	6.020
W-19	0.004
* LAB DUP	0.003
46WL01	0.519
46WL02	BLQ
46WL03	0.001

ANALYZED 6/16/94

SAMPLE	METHANE
LAB BLANK	BLQ
OU4W-1	4.079
* FIELD DUP	4.774
OU4W-3	0.136
W-9	0.002
OU4W-10	BLQ
ESMW-1A	2.373
ESMW-1B	8.500
ST41-ES1	0.004
ST41-ES2	1.481
ST41-ES3	0.002
ST41-ES4A	0.001
ST41-ES4B	0.051
ST41-ES5A	BLQ
ST41-ES5B	0.052

SAMPLE	METHANE
ST41-ES6A	BLQ
ST41-ES6B	0.006
ST41-ES7A	1.553
ST41-ES7B	0.194
* LAB DUP	0.180
ST41-ES8A	0.811
ST41-ES8B	0.007
SP7/10-02	0.001
* FIELD DUP	0.001

ANALYZED 6/29/94

SAMPLE	METHANE
LAB BLANK	BLQ
ESMW2	BLQ
ESMW3A	0.063
ESMW3B	0.192
ESMW4A	BLQ
ESMW4B	0.063
ESMW5A	BLQ
ESMW5B	0.133
ESMW6A	BLQ
ESMW6B	0.344
ESMW7A	0.002
ESMW7B	0.008
* LAB DUP	0.007

STANDARDS	METHANE
10 PPM CH4	9.57
100 PPM CH4	103.54
1060 PPM CH4	999.65
1 % CH4	1.04
4 % CH4	3.81
10 % CH4	10.07

LOWER LIMIT OF QUANTITATION

0.001

ND DENOTES NONE DETECTED.

BLQ DENOTES BELOW LIMIT OF QUANTITATION.

SF-0-65 DATA

UNITS FOR SAMPLES ARE mg/L

UNITS FOR STANDARDS CORRESPOND TO THE UNITS
THE SAMPLE COLUMN.

12

MANTECH TECH

Ref: 94-RC25/vg

July 7, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached is a report of the data generated from the analyses of 24 sample core extracts from Elmendorf AFB, AK. The extracts, which were submitted under Service Request #SF-0-65, 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 with 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 Quantifiable Limit of JP-4 in these samples is 14.79 μ g/g. Please refer to ManTech report letter 93-RC19/vg, dated October 29, 1993, for a detailed explanation of the calculations used to arrive at this value.

Sample extracts were received June 16 and 27, 1994. Analyses were started June 16, 1994 and completed June 28, 1994. Sample extracts and quality control samples were analyzed according to RSKSOP-72, Rev. #1, excepting the modifications listed in the attached outline.

Sincerely,

Randy Callaway
Randy Callaway

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

SR#SF 5 / Kampbell / Elmendorf AFB, AK all concn. 1g/g
Sam. D.D.

Dilution Factor		JP-4	Fuel Carbon (JP-4 x 0.85)
ST41 ES MW1B 22-24'	1	0.06	0.05
ST41 ES MW1B 26-28'	1	0.07	0.06
ST41 ES MW2 22-24'	1	0.21	0.18
ST41 ES MW2 24-26'	1	1.10	0.94
ST41 ES MW4B 20-22'	1	0.15	0.13
ST41 ES MW4B 24-26'	1	0.80	0.68
ST41 ES MW5B 14-16'	1	0.34	0.29
ST41 ES MW7B 17-18'	1	0.12	0.10
ST41 ES 1 12-14'	1	0.12	0.10
ST41 ES 1 14-16'	1	0.21	0.17
ST41 ES 2 4-6'	1	12.80	10.90
ST41 ES 2 6-8'	1	1.77	1.50
ST41 ES 3 3-4'	1	0.15	0.13
ST41 ES 3 4-6'	1	0.15	0.13
ST41 ES 4B 4-6'	1	0.05	0.04
ST41 ES 4B 6-8'	1	0.20	0.17
ST41 ES 5 4-6'	1	0.09	0.08
ST41 ES 5 6-8'	1	0.11	0.10
ST41 ES 6B 8-10'	1	0.13	0.11
ST41 ES 6B 10-12'	1	0.19	0.16
ST41 ES 7B 6-8'	1	0.30	0.26
ST41 ES 7B 10-12'	1	1.44	1.22
ST41 ES 8B 6-8'	1	0.35	0.30
ST41 ES 8B 10-12'	1	0.32	0.27

NOTE: all reported values are corrected for dilution factors where applicable
nd = none detected

SR#SF-C / Kampbell / QC Table all conc. are ng/ul

S	I.D.	Date Analyzed	JP-4
blank MeCl2		16JUN94	2.23
Method blank			0.19
500 ng/ul jp4			506.00
5000 ng/ul jp4			5060.00
50000 ng/ul jp4			44400.00
blank MeCl2		27JUN94	1.80
Method blank			0.67
100 ng/ul jp4			98.50
1000 ng/ul jp4			1010.00

nd = none detected
 MeCl2 = methylene chloride solvent blank
 jp4 = JP-4 fuel standard

I. HP5890 GC - OPERATING CONDITIONS

- A. Instrument Control
 - 1. Analyses: "EGLIN AFB"
 - 2. Program: "RWC-AS10"
 - 3. Calibration: "BTEX-13JUN94"
- 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 = 1.0°C/min to 75°C, Final Time = 0.00
 - 4. Level 3: Rate = 10°C/min to 290°C, Final Time = 15.50
 - 5. Run Time: 60.00 min
 - 6. 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 $\mu\text{V}\cdot\text{sec}$
 - 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. 7.00: Enable Peak Detection
 - 4. 21.97: Set Baseline
 - 5. 27.13: Set Baseline
 - 6. 32.30: Set Baseline
 - 7. 36.80: Set Baseline
 - 8. 39.59: Set Baseline
 - 9. 41.52: Set Baseline

III. MAXIMA DATA ACQUISITION

- A. Preacquisition Delay: 7.00 min
- B. Duration: 43.00 min
- C. Rate: 3.00 points/sec
- D. Run Time: 50.00 min

IV. MAXIMA CALIBRATION CURVES

- A. JP-4
 - 1. Calibration Range = 50 - 50,000 ng/ μl
 - 2. Summation of all peaks detected from 7.00 - 50.00 minutes

MANTECH
TECH

Ref: 94-MB9/rc

July 7, 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 *for SAV*

Dear Don:

The fuel carbon extractions of the Elmendorf core samples, as requested by Service Request SF-0-65, have been completed. The samples were placed on a wrist action shaker for 30 minutes and sonicated approximately 2 minutes prior to the extraction procedure. A total of 24 samples and 2 method blanks were delivered to Randy Callaway June 27, 1994 for GC analysis.

Please find attached a copy of the % moisture determinations from my lab book.

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

Sincerely,

Mark Blankenship
Mark Blankenship

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

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

SE-0 -65
 Elmerdorf AFB AK
 S. 7-5-94
 6-

Dry Wt. Basis
 % moisture determinations

Sample	Tare	Tare + Wet	Tare + Dry	% moisture
ES MW 1B 21-24	50.87	67.81	66.78	6.4%
ES MW 1B 26-28	48.95	78.64	76.79	6.6%
ST 41 ES 1 12-14	30.42	43.97	42.45	12.6%
ST 41 ES 1 14-16	29.77	46.41	38.67	19.5%
ES 2 4-6	29.12	35.81	34.56	22.9%
ES 2 6-8	28.23	35.28	34.48	12.8%
ES 3 3-4	66.28	90.35	88.26	9.5%
ES 3 4-6	49.39	71.66	69.95	8.3%
ES 4B 4-6	50.94	73.25	69.59	19.6%
ES 4B 6-8	31.48	43.50	41.33	16.7%
ES 5 4-6	30.24	47.53	46.68	5.1%
ES 5 6-8	26.12	38.75	37.28	13.5%
ES 6B 8-10	50.53	76.19	74.44	7.3%
ES 6B 10-12	31.15	53.23	50.12	16.3%
ES 7B 6-8	31.15	47.04	45.81	8.3%
ES 7B 10-12	29.25	50.78	48.65	10.2%
ES 8B 6-8	49.25	70.94	67.72	17.4%
ST ES 8B 10-12	55.49	78.69	77.16	7.1%
MW 3B 24-25				
MW 3B 22-24				
MW 2 22-24				
MW 2 24-26				
MW 4B 20-22				
MW 4B 24-26				
ES 5B 14-16				
MW 7B 17-18				

no % moisture
 for these samples

ELMENDORF AIR FORCE BASE - ALASKA
FIELD DATA

Sample #	Date	Redox	Cond	pH	Total alk mg/l CaCO ₃	Ferrous iron mg/l	Hydrogen sulfide mg/l
46WL01	6-07-94	-24	432	6.3	150	9.1	<.1
46WL02	6-07-94	102	190	6.1	61	2.1	---
46WL03	6-07-94	119	340	6.7	108	<.05	---
MW37A	6-07-94	104	114	7.1	50	<.05	---
MW37B	6-07-94	-25	388	7.4	170	<.05	<.1
ST41-29	6-07-94	10	232	6.1	92	.7	<.1
ST41-W8	6-07-94	20	402	6.9	49	<.05	---
ST41-W7	6-07-94	115	880	7.5	388	<.05	---
ST41-25	6-07-94	-53	1224	6.8	460	10.5	<.1
ST41-21	6-08-94	258	755	6.3	150	<.05	<.1
ST41-15	6-08-94	15	961	6.8	375	1.0	---
ST41-16	6-08-94	-30	2170	6.6	1210	40.5	---
ST41-18	6-08-94	110	647	6.4	223	<.05	<.1
ST41-2	6-08-94	121	1039	6.7	554	<.05	---
W-19	6-08-94	165	876	7.0	347	<.05	---
W-18	6-08-94	-120	902	7.0	467	4.3	<.1
OU4W-2	6-08-94	33	683	7.2	326	<.05	---

ELMENDORF AIR FORCE BASE - ALASKA
FIELD DATA

Sample #	Date	Redox	Cond	pH	Total alk mg/l CaCO ₃	Ferrous iron mg/l
ST41-01	6-09-94	---	954	7.1	512	<.05
ST41-07	6-09-94	---	702	7.2	270	.2
OU4W-4	6-09-94	-80	733	7.1	353	4.6
OU4W-5	6-09-94	60	662	7.1	274	<.05
OU4W-3	6-09-94	-20	834	7.0	428	.4
OU4W-10	6-09-94	20	544	6.9	265	.3
OU4W-1	6-09-94	-39	1013	6.9	456	2.9
SP7/10-02	6-09-94	40	790	6.9	269	<.05
W-9	6-09-94	123	812	7.0	345	<.05
ST41ES4A	6-10-94	168	214	6.1	76	<.05
ST41ES4B	6-10-94	20	660	6.6	251	2.1
ST41ES5A	6-10-94	126	109	6.7	47	<.05
ST41ES5B	6-10-94	91	280	7.9	115	<.05
ST41ES1	6-10-94	110	1060	6.8	481	<.05
ST41ES2	6-10-94	11	747	6.7	271	3.6

ELMENDORF AIR FORCE BASE - ALASKA
FIELD DATA

[illegible]

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MANTECH

Ref: 94-LP46/vg

July 18, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are TOC results for a set of 18 soils from Elmendorf AFB submitted to ManTech Environmental June 15, 1994 as a part of Service Request #SF-0-65 Mod. 1. The samples were stored at 6°C until analyses were begun June 30 using RSKSOP-120.

A Leco standard soil was analyzed along with your samples for quality control.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Lynda Pennington

Lynda Pennington

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

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

DON KAMPBELL'S ELMENDORF AFB TX TOC RESULTS (SF-0-65)

SAMP		SOIL FILT.		SOLIDS	TOTAL SOIL		MEAN	SAMPLE	SOIL FILT.		SOLIDS	TOTAL SOIL	
		% OC	% OC		% OC	% TOC			% OC	% OC		% OC	% TOC
ESMW-1B-1	22-24'	0.019	3.240	3.259	3.250			ST41-ES7B-1	6-8'	0.072	0.189	0.261	0.264
ESMW-1B-2	22-24'	0.019	3.219	3.238				ST41-ES7B-2	6-8'	0.072	0.195	0.267	
ESMW-1B-1	26-28'	0.005	0.132	0.137	0.125			ST41-ES7B-1	10-12'	0.043	0.167	0.210	0.203
ESMW-1B-2	26-28'	0.005	0.107	0.112				ST41-ES7B-2	10-12'	0.038	0.158	0.196	
ST41-ES1-1	12-14'	0.006	0.201	0.207				ST41-ES8B-1	6-8'	0.082	0.382	0.464	0.457
ST41-ES1-2	12-14'	0.010	0.151	0.161	0.173			ST41-ES8B-2	6-8'	0.079	0.371	0.450	
ST41-ES1-3	12-14'	0.012	0.138	0.150				ST41-ES8B-1	10-12'	0.026	0.114	0.140	0.149
ST41-ES1-1	14-16'	0.009	0.179	0.188	0.193			ST41-ES8B-2	10-12'	0.031	0.126	0.157	
ST41-ES1-2	14-16'	0.010	0.188	0.198				LECO STD. SOIL			0.970		
ST41-ES2-1	4-6'	1.251	24.620	25.870	25.900			LECO STD. SOIL			1.003		
ST41-ES2-2	4-6'	1.216	24.730	25.950				LECO STD. SOIL			0.997		
ST41-ES2-1	6-8'	0.591	12.450	13.040									
ST41-ES2-2	6-8'	0.490	8.195	8.685	10.600								
ST41-ES2-3	6-8'	0.543	9.555	10.100									
ST41-ES3-1	2-4'	0.016	0.148	0.164									
ST41-ES3-2	2-4'	0.014	0.104	0.118	0.138								
ST41-ES3-3	2-4'	0.012	0.119	0.131									
ST41-ES3-1	4-6'	0.008	0.103	0.111	0.107								
ST41-ES3-2	4-6'	0.006	0.096	0.102									
ST41-ES4B-1	4-6'	0.381	0.462	0.843	0.860								
ST41-ES4B-2	4-6'	0.383	0.494	0.877									
ST41-ES4B-1	6-8'	0.219	0.271	0.490	0.467								
ST41-ES4B-2	6-8'	0.203	0.242	0.445									
ST41-ES5-1	4-6'	0.024	0.082	0.106	0.107								
ST41-ES5-2	4-6'	0.025	0.083	0.108									
ST41-ES5-1	6-8'	0.024	0.095	0.119	0.129								
ST41-ES5-2	6-8'	0.025	0.114	0.139									
ST41-ES6B-1	8-10'	0.015	0.054	0.069	0.071								
ST41-ES6B-2	8-10'	0.016	0.056	0.072									
ST41-ES6B-1	10-12'	0.019	0.056	0.075	0.076								
ST41-ES6B-2	10-12'	0.020	0.056	0.076									

TRUE VALUE OF LECO STD. SOIL = 1.00 +/- .04.

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MANTECH TECHNOLOGY

Ref: 94-LP38/lm

June 17, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached are TOC results for 44 liquid samples from Elmendorf AFB submitted to ManTech as a part of Service Request # SF-0-65 Mod. 1. Dates of sample receipt and analysis are included with sample data on the following pages.

Blanks, duplicates, and known AQC samples were analyzed along with your samples for quality control.

If you have any questions concerning this data, please feel free to ask 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

Samples Received: 06/09/94
Samples Analyzed: 06/10/94

<u>Sample</u>	<u>mg/L</u> <u>TOC</u>
46 WL 01	15.2
46 WL 02	3.7
46 WL 03	2.8
ST 41-15	6.4
ST 41-16	109
ST 41-W7	4.6
ST 41-W7 (FD)	4.8
ST 41-W8	1.8
ST 41-21	8.8
ST 41-21 (LD)	8.8
ST 41-25	24.4
ST 41-29	8.5
ST 41-18	11.4
MW 37 A	0.5
MW 37 B	2.4
MW 37 B (LD)	2.5
Millipore H ₂ O	<0.1
WPO31 I	28.3
	28.5
WPO31 I T.V.	28.0

Samples Received: 06/10/94
Samples Analyzed: 06/10/94

<u>Sample</u>	<u>mg/L</u> <u>TOC</u>
OU 4W-2	1.1
OU 4W-4	2.0
OU 4W-5	1.6
ST41-01	2.9
ST41-02	13.7
ST41-02 (LD)	13.6
ST41-07	7.2
W-18	1.6
W-19	1.3
Millipore	<.01
WPO31 I	27.5
WPO31 I T.V.	28.0

Samples Received: 06/14/94

Samples Analyzed: 06/17/94

Note:

The samples were analyzed for dissolved gases by Bryan Newell prior to TOC analysis resulting in a 3-day delay between sample receipt and analysis.

<u>Sample</u>	<u>mg/L TOC</u>
OU 4W-1	4.6
OU 4W-1 (FD)	2.4
OU 4W-3	1.3
W-9	1.6
OU 4W-10	1.8
ES-MW-1A	2.3
ES-MW-1B	4.1
ST41-ES-1	7.3
ST41-ES-2	7.6
ST41-ES-3	3.5
ST41-ES-3 (LD)	3.5
ST41-ES-4A	19.1
ST41-ES-4B	13.1
ST41-ES-5A	2.0
ST41-ES-5B	4.8
ST41-ES-6A	3.3
ST41-ES-6B	3.1
ST41-ES-7A	38.1
ST41-ES-7B	11.2
ST41-ES-8A	6.8
ST41-ES-8B	3.6
SP7/10-02	1.2
SP7/10-02 (LD)	1.2
SP7/10-02 (FD)	1.1
Millipore H ₂ O	0.1
WPO31 I	27.6
WPO31 I	27.3
WPO31 I T.V.	28.0

FD = Field Duplicate LD = Lab Duplicate TV - True Value

MANTECH

Ref: 94-PR69/rc
94-TH67/rc

June 15, 1994

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

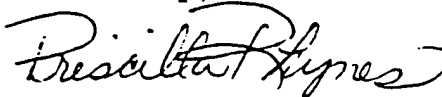
THRU: S.A. Vandegrift *SAV*

Dear Don:

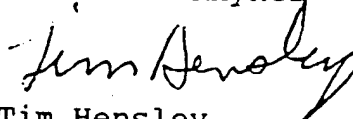
Attached are the results of 21 Elmendorf AFB samples submitted to ManTech Environmental as part of Service Request # SF-0-65. The samples were received on June 15 and analyzed June 15 and 16. The methods used for analysis were EPA methods 120.1 and 353.1, and Water's Capillary Electrophoresis Method N-601. Blanks, spikes, duplicates and known AQC samples were analyzed along with the samples for quality assurance.

If you have any questions concerning these results, please feel free to contact us.

Sincerely,



Priscilla Rhynes



Tim Hensley

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> <u>Cl⁻</u>	<u>mg/l</u> <u>SO₄⁼</u>	<u>mg/l</u> <u>NO₂⁻+NO₃⁻(N)</u>	<u>Conductivity</u>
W-9	15.5	3.58	15.5	752
OU4W-1	8.87	3.39	9.04	908
OU4W-3	3.48	5.02	15.4	751
OU4W-10	3.04	4.49	8.27	495
ES-MW1A	.13	5.14	15.7	571
ES-MW1B	.07	5.49	<.5	770
ST41-ES1	.80	21.4	61.4	965
ST41-ES2	.10	59.3	13.1	686
ST41-ES2 Dup				679
ST41-ES3	.17	28.2	31.1	422
ST41-ES4A	.11	8.45	4.72	196
STR1-ES4A Dup	.12			
ST41-ES4B	.07	50.3	12.2	593
ST41-ES5A	.18	4.18	2.07	101
ST41-ES5B	.14	8.23	9.97	259
ST41-6A	.28	.71	3.44	112
ST41-6A Dup		.63	3.51	
ST41-ES6B	.12	1.34	5.40	198
ST41-ES7A	.06	10.3	3.10	568
ST41-ES7A Dup	.06			
ST41-ES7B	.06	27.8	5.38	450
ST41-ES8A	.23	3.00	8.28	303
ST41-ES8A Dup				301
ST41-ES8B	.08	3.38	7.21	306
SP7/10-02	25.6	18.6	15.1	742
SP7/10-02 Dup		18.6	15.1	
4B	50.3	12.0	***	604
Blanks	<.05	<.05	<.05	----
AQCWPO31	10.9	40.8	91.6	----
True Value	11.0	40.2	92.0	----
Spike Recovery	100%	99%	103%	----

*** No sample

APPENDIX C

MODEL INPUT PARAMETERS AND RELATED CALCULATIONS

The assumptions used for determining longitudinal dispersivity are:

- A. Plume migration is sufficiently aligned along the longitudinal axis of the grid that a longitudinal moment may be calculated.
- B. Longitudinal dispersivity is 1/10 of the distance from the source of contamination to the center of contamination.

From the June 1993 BTEX plume map, an estimate for the center of mass will be taken by calculating the longitudinal moment around cell 10,8 which is near the suspected source of contamination. Mass is computed by summing the concentration of contamination in all cells in that row. Because all cells have equal volume, the concentration at a cell will be directly proportional to the mass of BTEX in the cell.

<u>Row</u>	<u>Mass</u>	<u>Distance From cell (10,8)</u>	<u>Mass x Dist. From Cell (10,8)</u>
9	25,700	200	5,140,000
10	20,350	400	8,140,000
11	12,100	600	7,260,000
12	5,300	800	4,240,000
13	1,600	1,000	1,600,000
14	700	1,200	840,000
15	300	1,400	420,000
Total	66,050		27,640,000

The estimated longitudinal centroid of the plume is:

$$27,640,000 / 66,050 = 418.5 \text{ ft (from the center of cell 10,8)}$$

The estimated distance between the source of contamination and the longitudinal center of mass is:

$$418.5 \text{ ft}$$

From assumption B, the estimated longitudinal dispersivity is 1/10 of the distance between the source of contamination and the longitudinal center of mass and is:

$$\text{Estimated Long. Dispersivity} = 418.5 \times 0.1 = 41.85 \text{ or } 42 \text{ ft.}$$

Calculation of Anaerobic Decay Constant - [Based on methods outlined in the Intrinsic Remediation Primer] (Coefficient of Anaerobic Decay [K])

Based on decrease in BTEX concentrations between W-18 & 004W-3

	B	T	E	X	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	
upgradient)	W-18	7.01	34.5	10.8	46.93	2.39	5.63	3.35
downgradient)	004W-3	1.36	2.8	1.79	7.72	< 1	2.63	1.71

(µg/L)

$$\frac{C}{C_0} = e^{-kt}$$

where C = concentration at time t

C₀ = initial concentration

k = Coefficient of Anaerobic Decay

t = time

To correct for dilution & dispersion, BTEX data are normalized to TMB data. TMB is believed to be a good tracer because it has similar sorptive properties, but is recalcitrant under anaerobic conditions.

Adequate groundwater velocity, $\bar{v} = 1,600 \text{ ft/yr}$

Distance between 004W-3 and W-18 = 375'

$$\text{travel time (t)} = \frac{375 \text{ ft}}{1,600 \text{ ft/yr}} = 0.23 \text{ yr.}$$

Normalization Factors

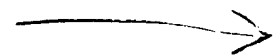
$$\left. \begin{array}{l} 1,3,5\text{-TMB: } \frac{1.0}{2.39} = 0.42 \\ 1,2,4\text{-TMB: } \frac{2.63}{5.63} = 0.47 \\ 1,2,3\text{-TMB: } \frac{1.71}{3.35} = 0.51 \end{array} \right\} \text{Average} = 0.41$$

$$\text{Benzene: } 1.36/0.41 = 3.32 \text{ µg/L (normalized)}$$

$$\text{Toluene: } 2.8/0.41 = 6.83 \text{ µg/L (normalized)}$$

$$\text{Ethylbenzene: } 1.79/0.41 = 4.37 \text{ µg/L (normalized)}$$

$$\text{Xylenes: } 7.72/0.41 = 18.8 \text{ µg/L (normalized)}$$



Anaerobic Decay Constant Calculations

For benzene:

$$\frac{C}{C_0} = \frac{3.32}{7.01} = 0.47 = e^{-kt}; -0.75 = -kt$$

$$\boxed{k = 3.25 \frac{1}{yr}} = 0.009 \frac{1}{d}$$

For toluene:

$$\frac{C}{C_0} = \frac{6.83}{34.5} = 0.20 = e^{-kt}; -1.62 = -kt$$

$$\boxed{k = 7.04 \frac{1}{yr}} = 0.02 \frac{1}{day}$$

For ethylbenzene:

$$\frac{C}{C_0} = \frac{4.37}{10.8} = 0.40 = e^{-kt}; -0.90 = -kt$$

$$\boxed{k = 3.91 \frac{1}{yr}} = 0.011 \frac{1}{day}$$

for xylenes:

$$\frac{C}{C_0} = \frac{18.8}{46.93} = 0.40 = e^{-kt}; -0.90 = -kt$$

$$\boxed{k = 3.91 \frac{1}{yr}} = 0.011 \frac{1}{day}$$

Client _____

Job No. _____

Sheet _____ of _____

Subject MODEL GRID

By MS

Date _____

Checked _____

Rev. _____

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1																					
2		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	• = 0.8
3									0.7	0.7	0.7	0.7									
4									0.6	0.5	0.5	0.5	0.5	0.7							
5									0.6	0.5	0.3	0.3	0.3	0.3	0.5	0.7					
6									0.6	0.5	0.3	0.2	0.1	0.1	0.3	0.5	0.7				
7									0.7	0.5	0.4	0.2	0.1	0.1	0.3	0.5	0.7				
8									0.7	0.6	0.5	0.3	0.1	0.1	0.2	0.4	0.6				
9									0.7	0.6	0.5	0.3	0.2	0.1	0.1	0.2	0.5	0.6			
10									0.7	0.5	0.4	0.2	0.1	0.1	0.1	0.2	0.5	0.6			
11									0.7	0.5	0.3	0.1	0.1	0.1	0.1	0.2	0.5	0.7			
12									0.7	0.5	0.3	0.3	0.3	0.2	0.1	0.1	0.3	0.5	0.7		
13									0.7	0.6	0.5	0.5	0.5	0.5	0.3	0.2	0.1	0.2	0.5	0.7	
14									0.7	0.7	0.7	0.6	0.4	0.5	0.5	0.3	0.2	0.3	0.5	0.7	
15									0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.6	0.7			
16									0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7				
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RMS Error Calculations for Calibrated Flow Model
Hangar 10 Site, Elmendorf AFB

Measured Head	Simulated Head		
H_m	H_s	$H_m - H_s$	$(H_m - H_s)^2$
159.66	159.88	-0.22	0.05
159.25	159.75	-0.50	0.25
159.48	159.26	0.22	0.05
159.76	159.57	0.19	0.04
158.75	158.77	-0.02	0.00
158.37	158.07	0.30	0.09
157.92	157.60	0.32	0.10
156.71	156.06	0.65	0.42
156.05	155.15	0.90	0.81
155.05	154.58	0.47	0.22
155.42	154.54	0.88	0.77
154.72	154.16	0.56	0.31
154.14	154.11	0.03	0.00
Sum of Squares of Remainders			3.12
Average of Squares of Remainders			0.24
RMS			0.49
RMS as a percentage of the head drop over the model domain:			4.19%

ground water. It was assumed that this source area is present in the vicinity of Pump House 2 and the nearby valve pit. Contaminants were introduced to the aquifer using simulated injection wells located in cells 9,8; 9,9; 10,8; and 10,9, as indicated on Figure 5.13. This scenario was run to assess the effects of a continuing source of contamination, although firm evidence of such a source does not exist. As with model ELMA, model ELMC assumed that all other calibrated model conditions continued throughout the entire simulation.

While the term "injection well" suggests contaminants are being introduced at a point, Bioplume II assumes that contamination introduced at a well instantly equilibrates throughout the entire cell in which the well is located. The injection rate for the cells was set at $1 \times 10^{-3} \text{ ft}^3/\text{sec}$, a value low enough so that the flow calibration and water balance was not affected. Relatively high BTEX concentrations were injected through the wells because of the low pumping rate. The total BTEX injection concentration was set at 100 mg/L. After the mass is dispersed throughout the entire cell volume, this results in the total BTEX concentration in the source area being maintained at approximately 450 $\mu\text{g/L}$. Therefore, this simulations illustrates the effects of a source that would continuously introduce enough BTEX to produce a total BTEX concentration of 450 $\mu\text{g/L}$.

Although the loading rate indicated above results in a total of 245 kg of BTEX per day being introduced at each well (a total of 1 metric ton of BTEX per day), this does not imply that an equivalent loading would be necessary to actually produce such concentrations within the aquifer. This is because the model assumes the mass of BTEX that enters each cell from the wells is instantly dispersed throughout a volume of water equivalent to the area of the cell times its saturated thickness. Because the aquifer is assumed to be 60 feet thick in the vicinity of the injection wells, the injected BTEX equilibrates with a very large volume of water. In most situations, BTEX is actually introduced near the water table and generally is most concentrated in the vicinity of the water table, where monitoring wells water table then intercept the contamination. As a result, it would require only a fraction of the simulated mass loading rate to produce BTEX concentrations of 450 $\mu\text{g/L}$ within the aquifer.

This simulation indicates that BTEX contamination will degrade rapidly despite the continued source loading. At $T = 0$ years, the plume configuration in Figure 5.14 is very similar to the original calibrated plume. After 1 year of prediction time the plume reaches

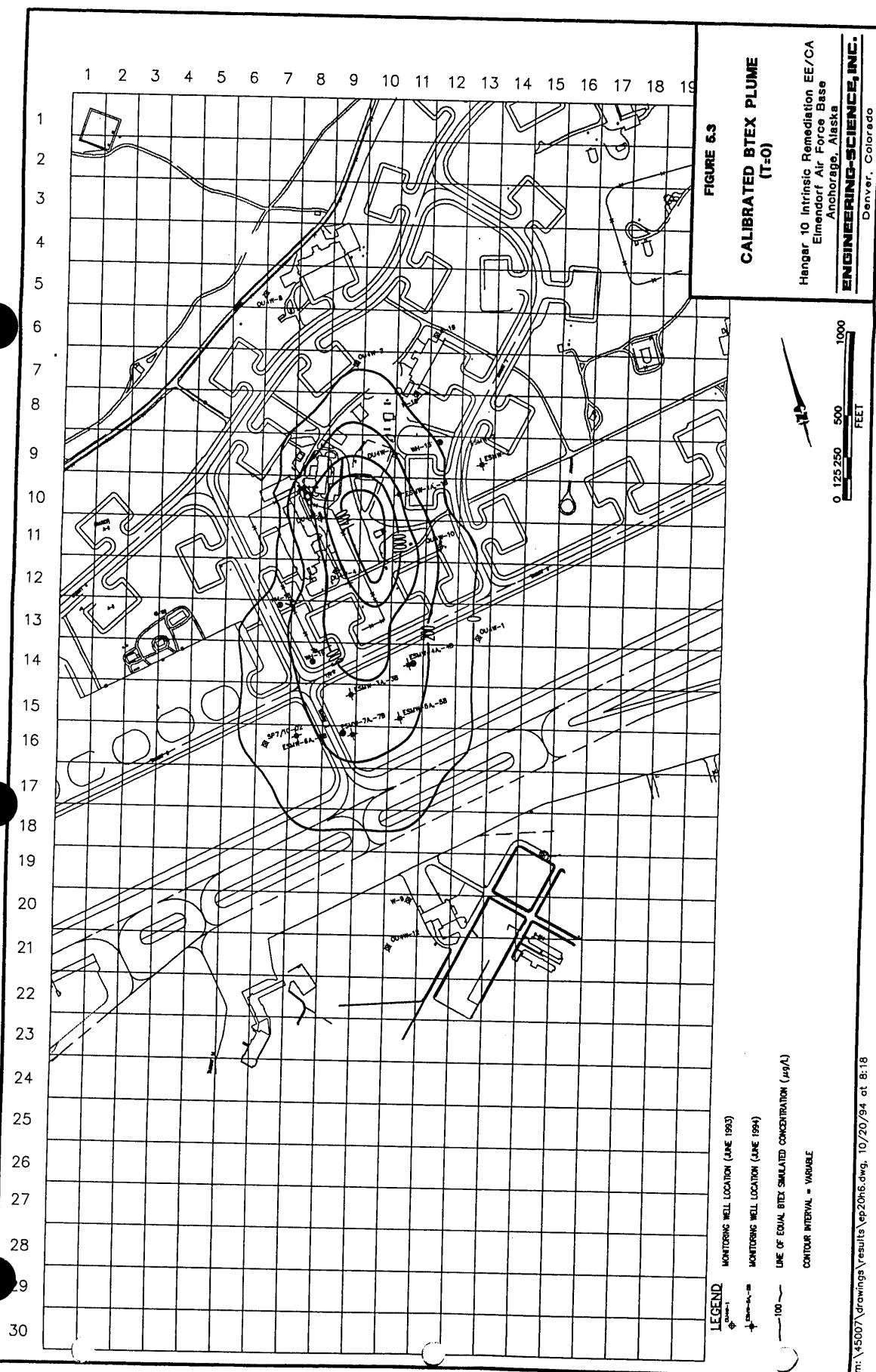


FIGURE 6.3

CALIBRATED BTEX PLUME (T=0)

Hanger 10 Intrinsic Remediation EE/CA
 Elmendorf Air Force Base
 Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
 Denver, Colorado

LEGEND

○ MONITORING WELL LOCATION (JUNE 1993)

⊗ MONITORING WELL LOCATION (JUNE 1994)

— LINE OF EQUAL BTEX SIMULATED CONCENTRATION (µg/L)

--- CONTOUR INTERVAL = VARIABLE

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INTRINSIC REMEDIATION
ENGINEERING EVALUATION/COST ANALYSIS

for the

HANGAR 10 SITE

ELMENDORF AIR FORCE BASE

ANCHORAGE, ALASKA

October 1994

Prepared for:

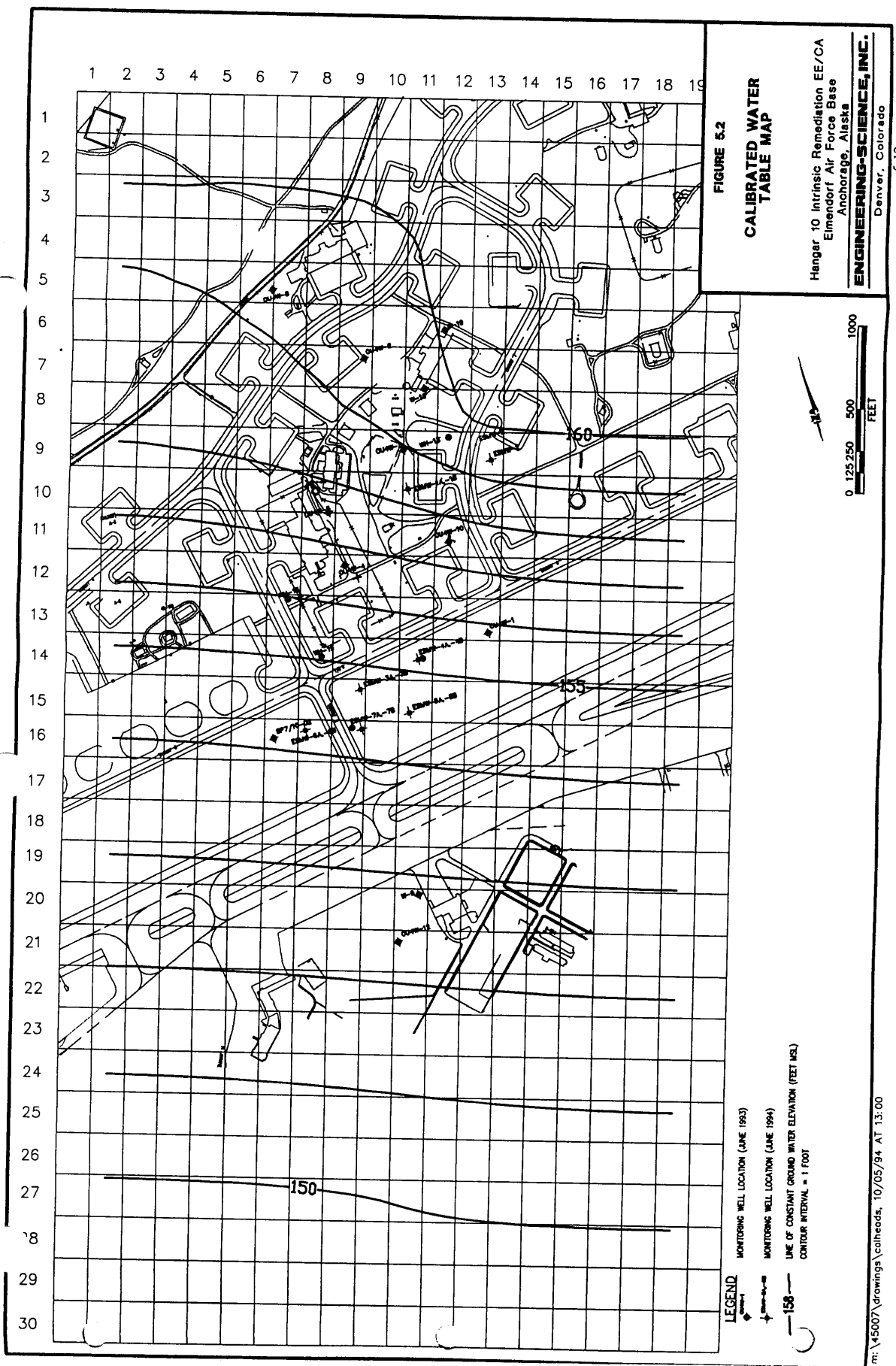
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

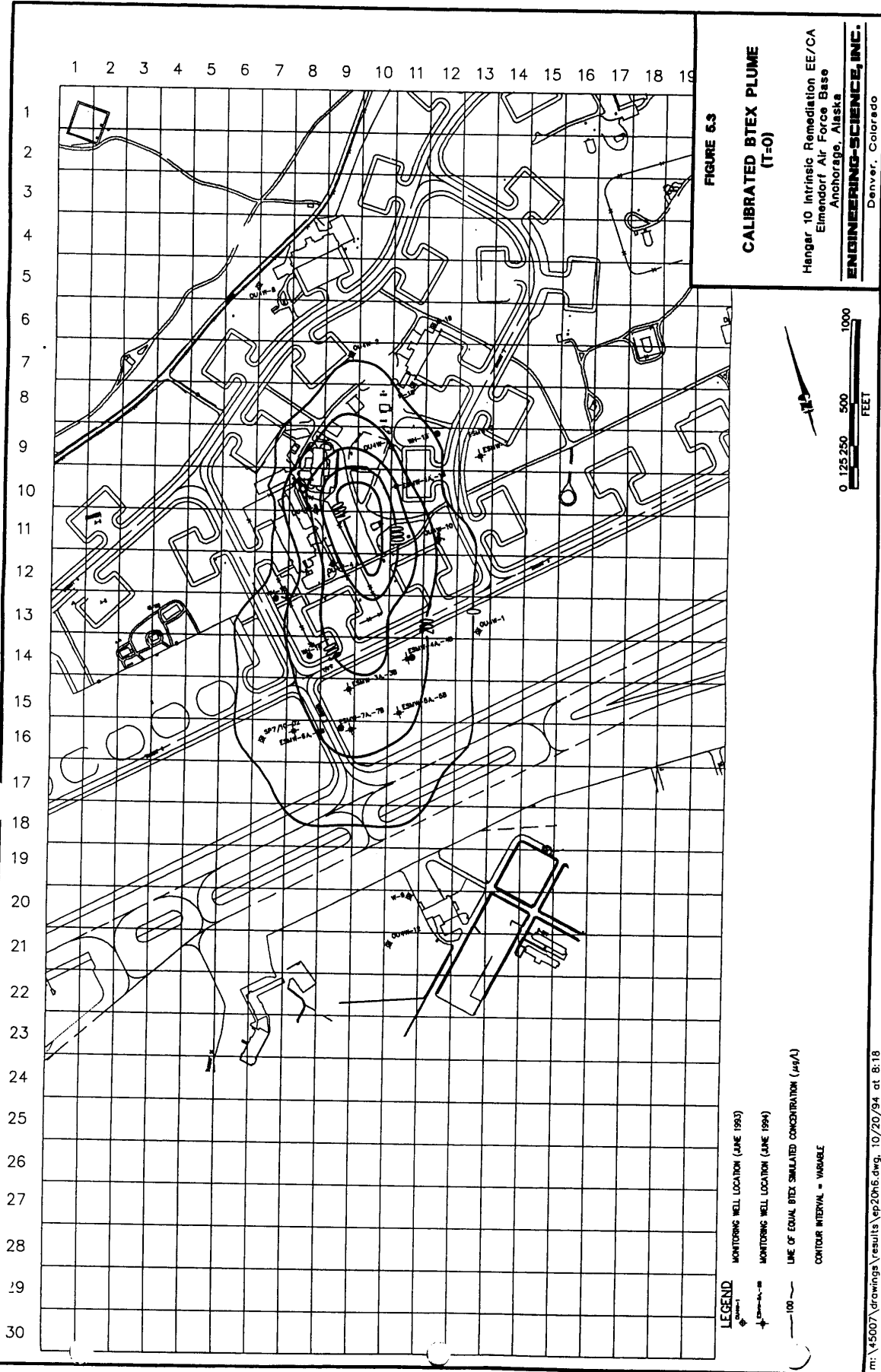
AND

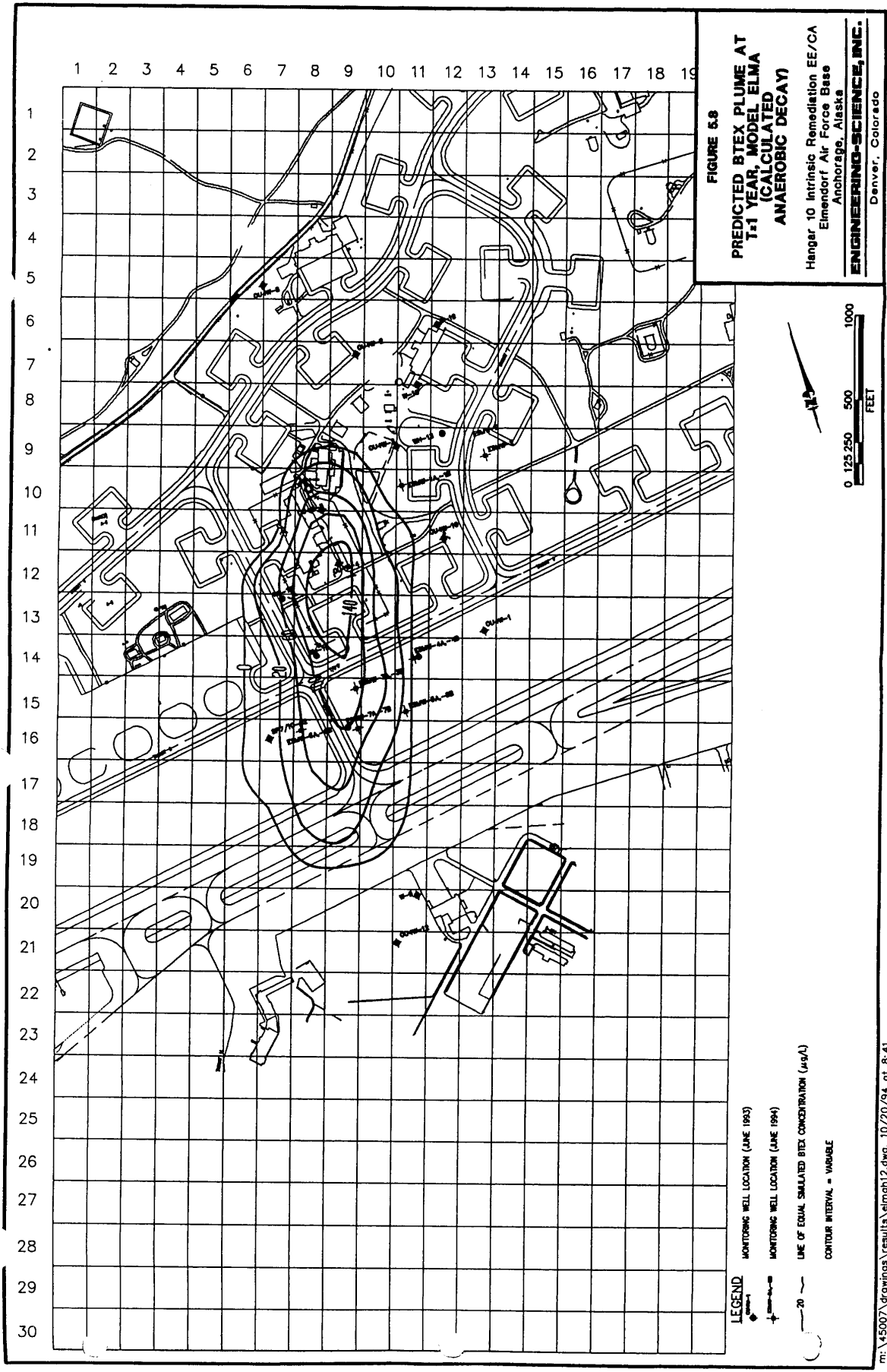
ELMENDORF AIR FORCE BASE
ANCHORAGE, ALASKA

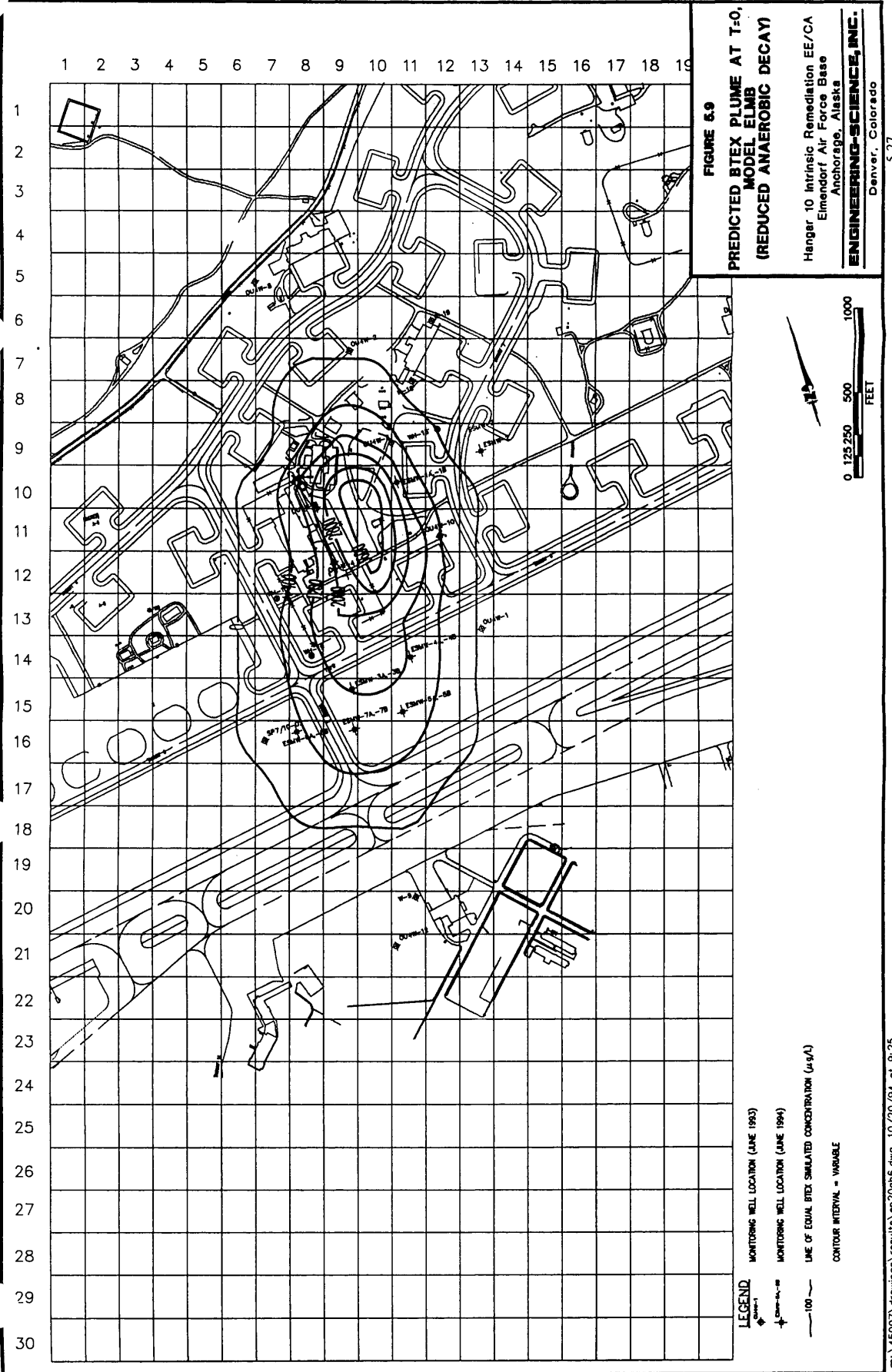
Prepared by:

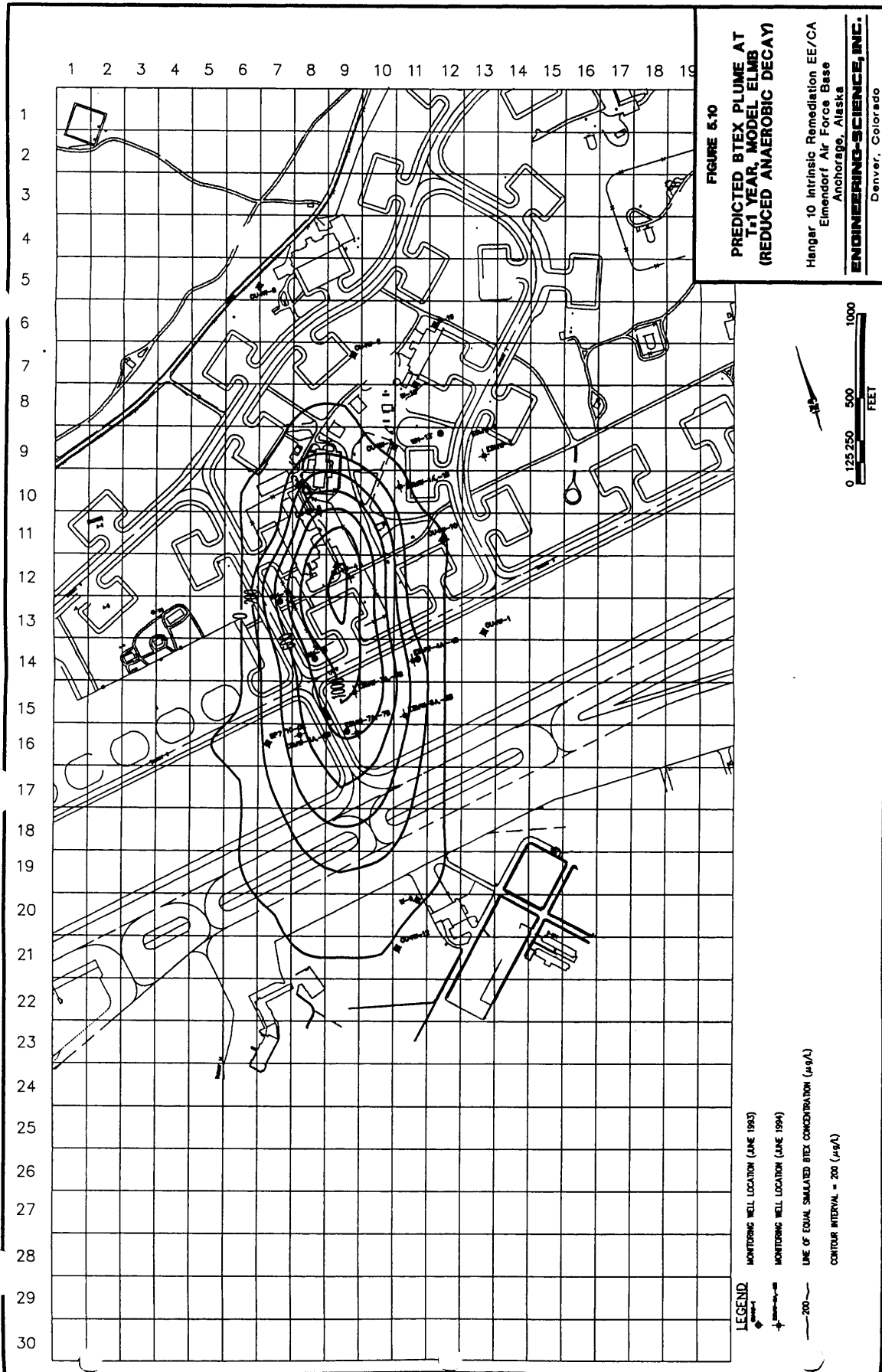
Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

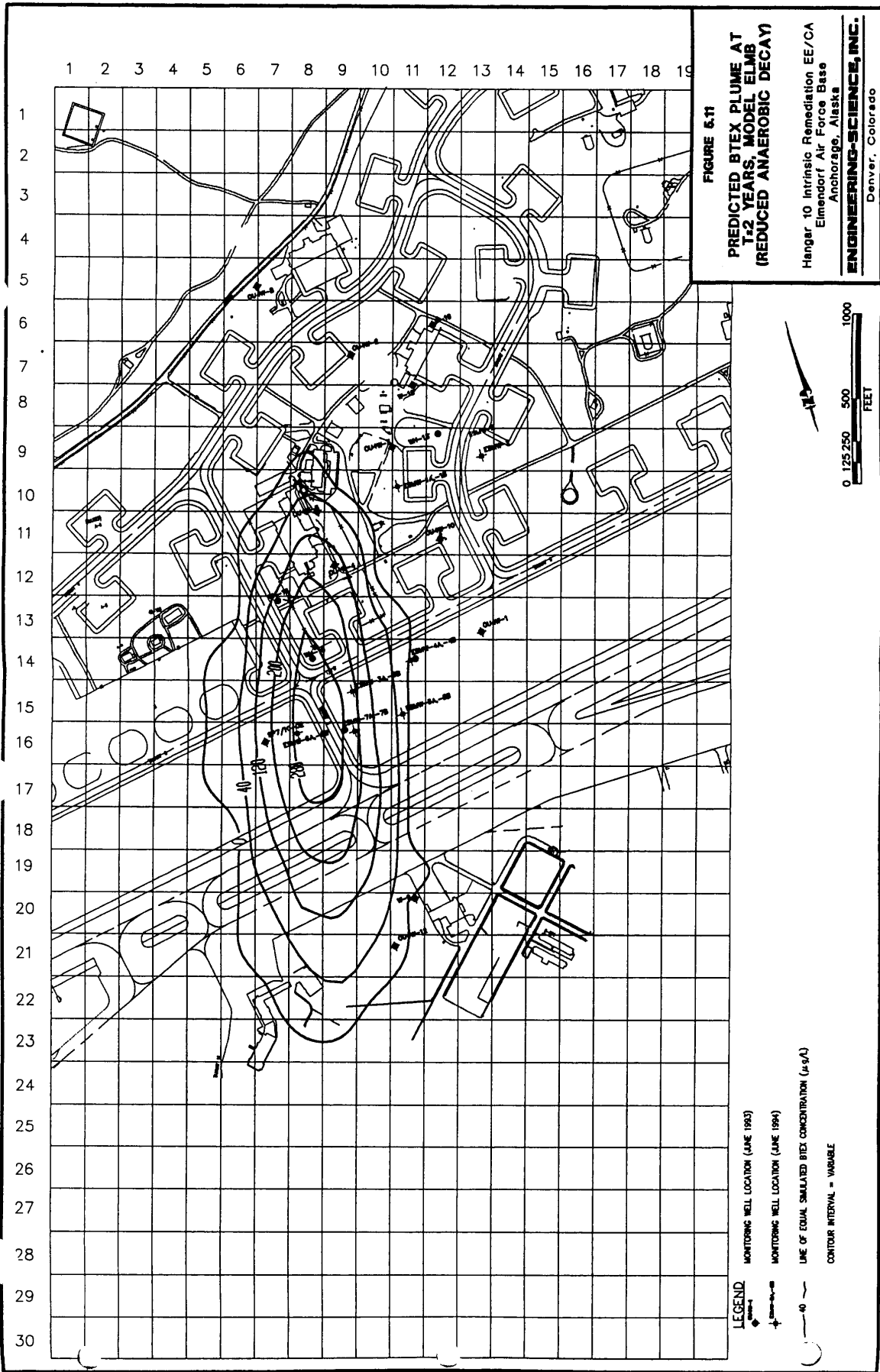


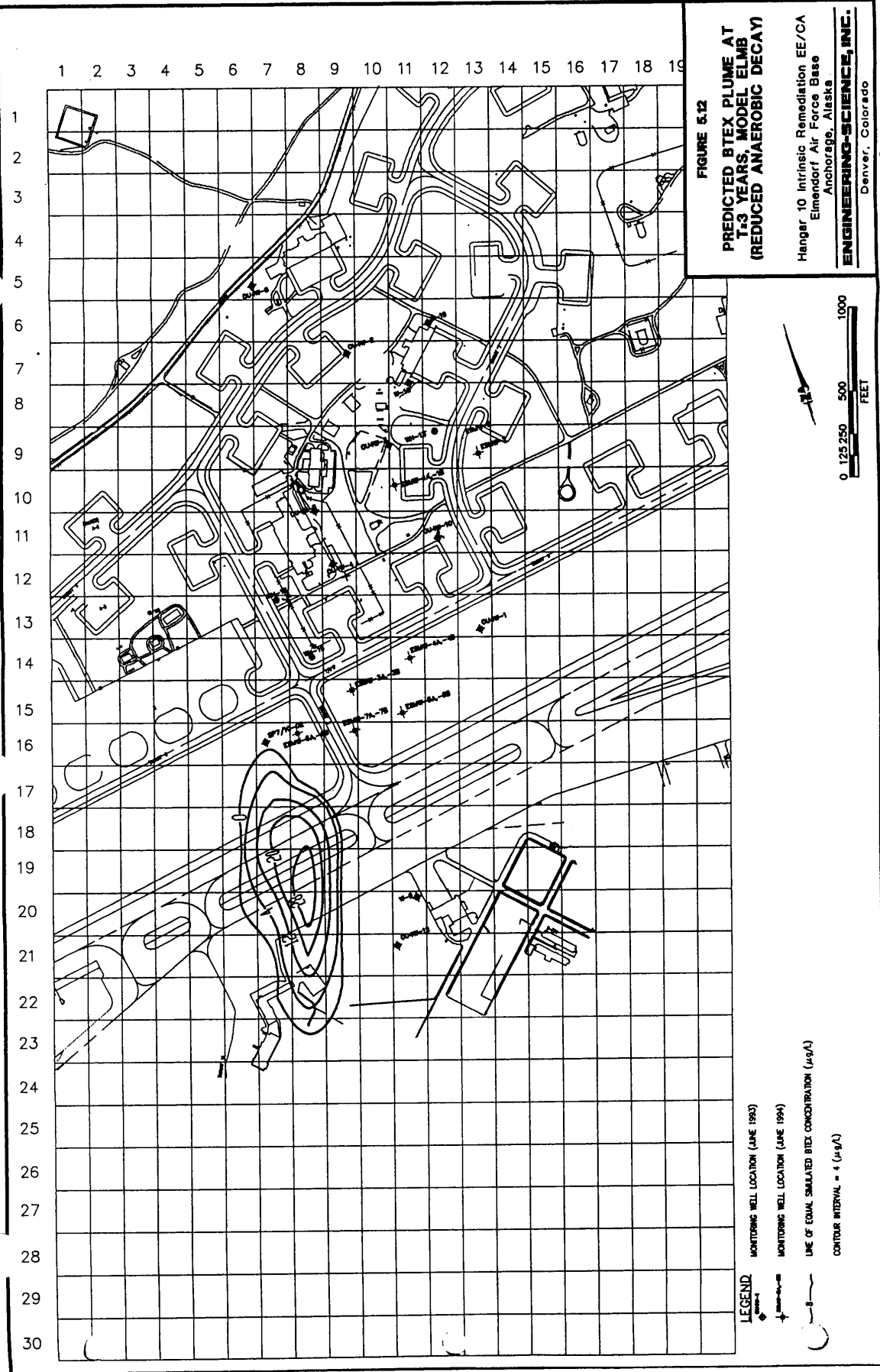


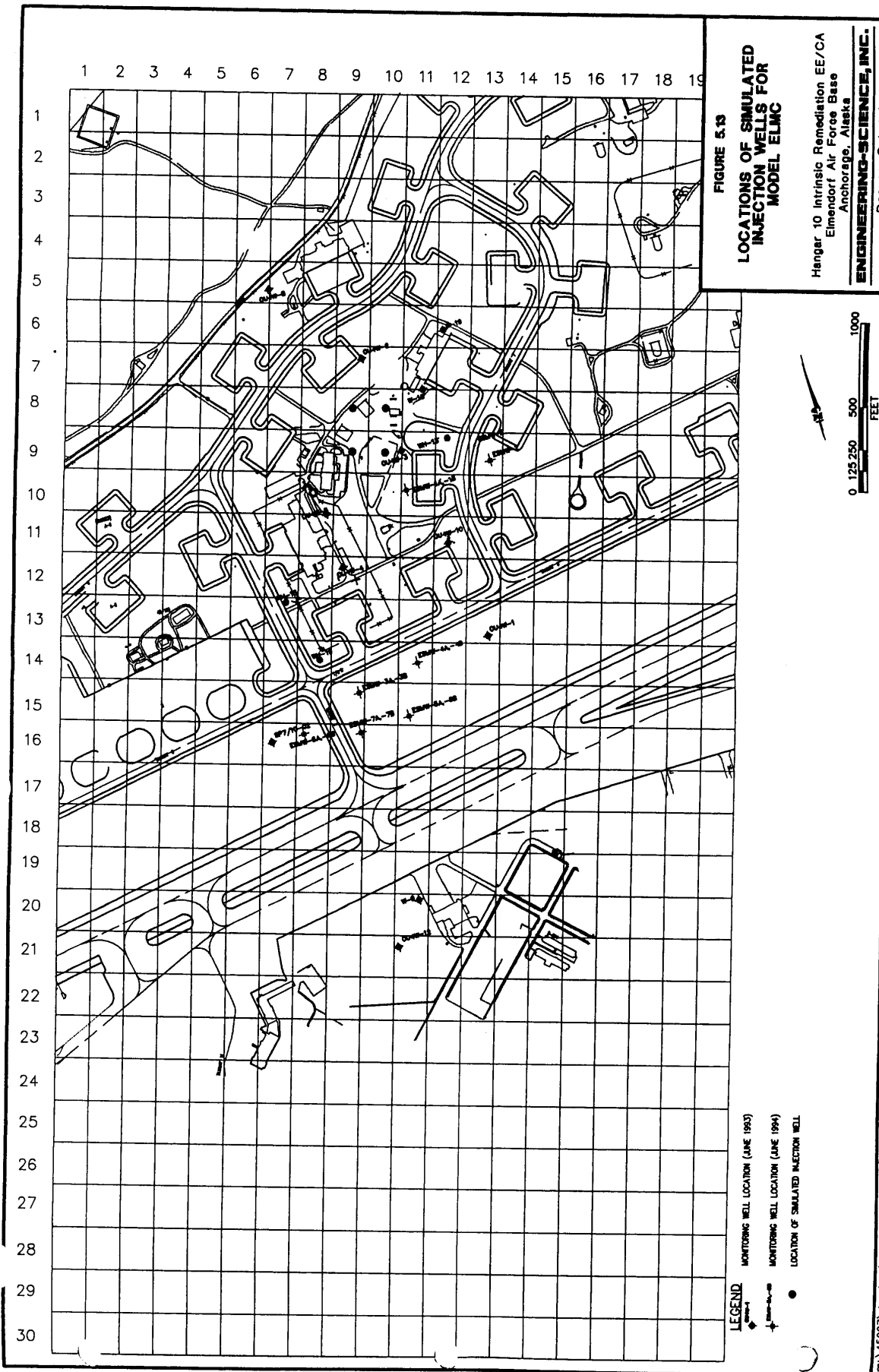


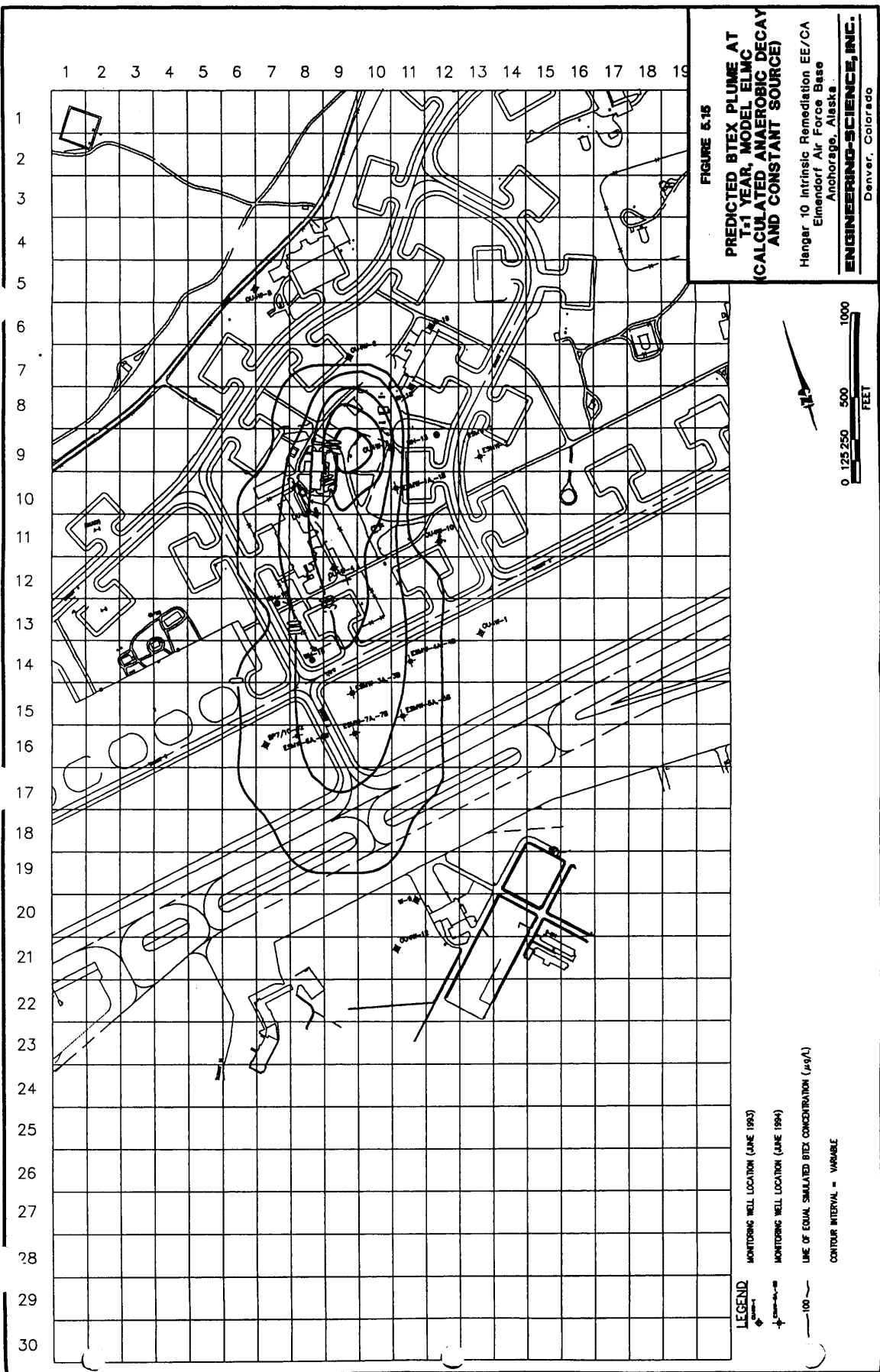












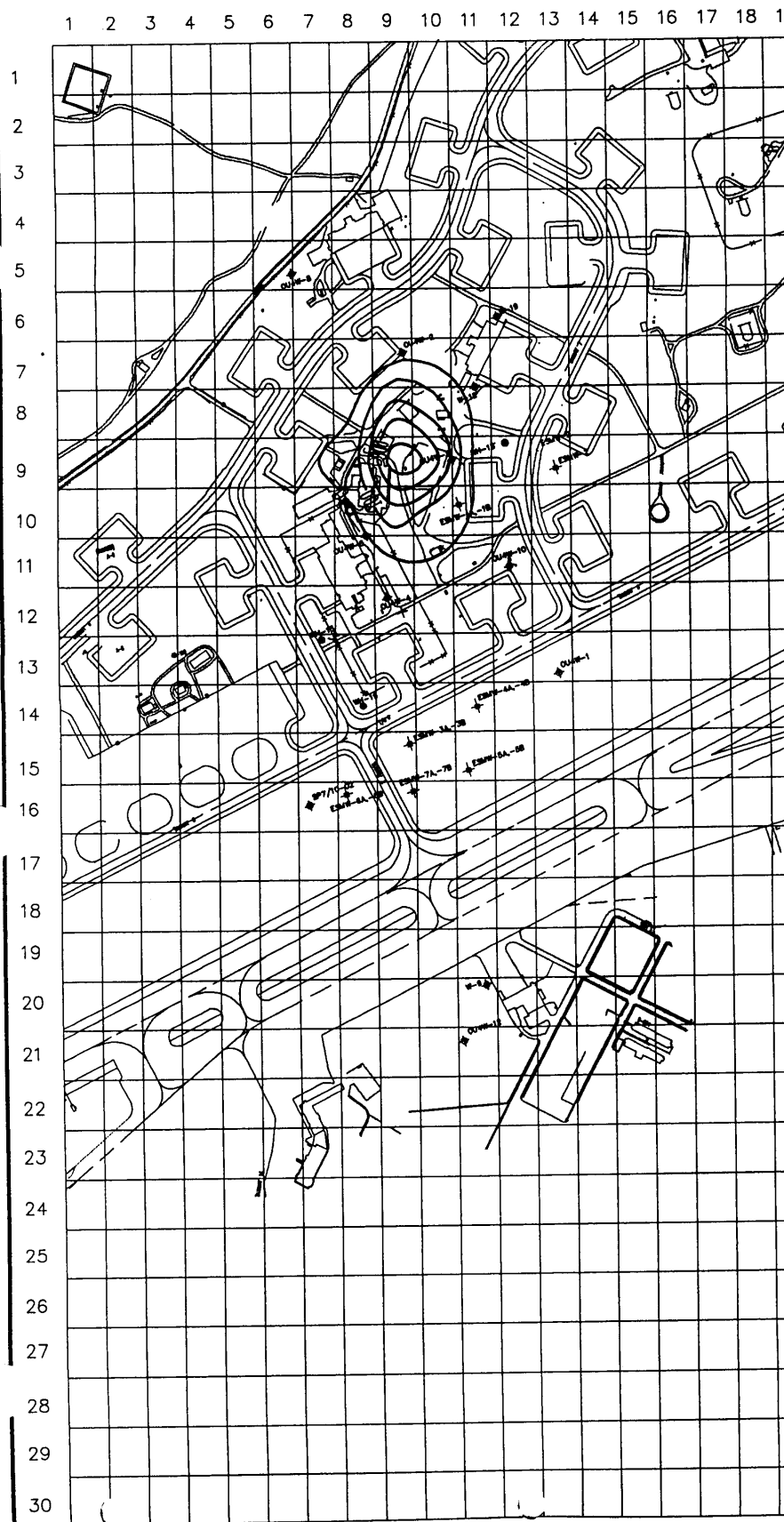


FIGURE 5.16

PREDICTED BTEX PLUME AT
T-5 YEARS, MODEL ELMC
(CALCULATED ANAEROBIC DECAY
AND CONSTANT SOURCE)

Hanger 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

LEGEND

- MONITORING WELL LOCATION (JUNE 1993)
- MONITORING WELL LOCATION (JUNE 1994)
- LINE OF EQUAL SIMULATED BTEX CONCENTRATION ($\mu\text{g/L}$)
- CONTOUR INTERVAL = 100 ($\mu\text{g/L}$)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

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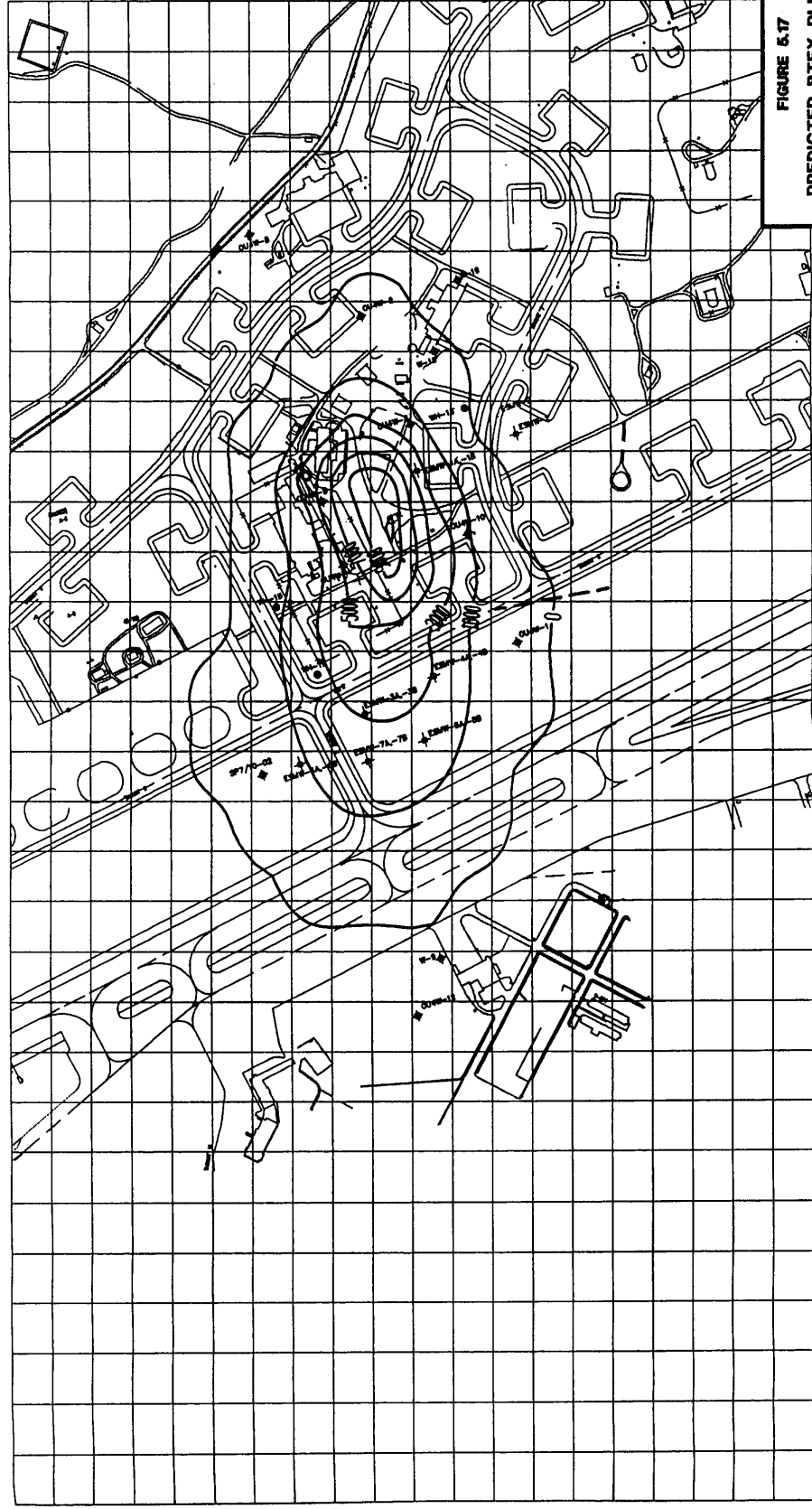


FIGURE 5.17
PREDICTED BTX PLUME AT
T-0 YEARS, MODEL ELMF
(NO ANAEROBIC DECAY)

Hangar 10 Intrinsic Remediation EE/CA
Elmendorf Air Force Base
Anchorage, Alaska
ENGINEERING-SCIENCE, INC.
Denver, Colorado

- LEGEND**
- MONITORING WELL LOCATION (JUNE 1993)
 - MONITORING WELL LOCATION (JUNE 1994)
 - LINE OF EQUAL SIMULATED BTX CONCENTRATION ($\mu\text{g/L}$)
 - CONTOUR INTERVAL = 1000 ($\mu\text{g/L}$)