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**Work Plan for a
Treatability Study to Evaluate
Intrinsic Remediation of Groundwater at CCFTA-2 (FT-17)**



**Cape Canaveral Air Station
Florida**

Prepared For

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

and

**45 CES/CEVR
Cape Canaveral Air Station
Florida**

January 1996



**PARSONS
ENGINEERING SCIENCE, INC.**

1700 Broadway, Suite 900 • Denver, Colorado 80290

AGM01-02-0404

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WORK PLAN FOR A TREATABILITY STUDY
IN SUPPORT OF THE INTRINSIC REMEDIATION
(NATURAL ATTENUATION) OPTION FOR
SITE CCFTA-2 (FT-17)

at

CAPE CANAVERAL AIR STATION, FLORIDA

December 1995

Prepared for:

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

AND

45 CES/CEVR
PATRICK AIR FORCE BASE, FLORIDA

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for remediation of groundwater contaminated with petroleum hydrocarbons and chlorinated aliphatic hydrocarbons (CAHs) at Site CCFTA-2 (FT-17), located at Cape Canaveral Air Station (AS), Florida (the Base). Hydrogeologic and groundwater chemical data collected under this program can also be used to evaluate various remedial options; however, this work plan is oriented toward the collection of hydrogeologic data to be used as input into groundwater flow and solute transport models in support of intrinsic remediation with long-term monitoring for restoration of groundwater contaminated with benzene, toluene, ethylbenzene, and xylenes (BTEX) and CAHs. At Site CCFTA-2 (FT-17), some remedial actions are already planned or in pilot testing stages, such as bioventing, source excavation, and installation of a downgradient air sparging curtain to contain the CAH plume.

As used in this report, the term "intrinsic remediation" refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control receptor exposure risks associated with contaminants in the subsurface. "Natural attenuation" refers to the actual physical, chemical, and biological processes that facilitate intrinsic remediation. Mechanisms for

natural attenuation of BTEX and CAHs include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. Intrinsic bioremediation occurs when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of intrinsic remediation can vary markedly from site to site depending on governing physical and chemical processes.

As part of the TS, the contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The modeling efforts for Site CCFTA-2 (FT-17) at Cape Canaveral AS will involve completion of several tasks, which are described in the following sections.

This work plan was developed based on discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE), 45 CES/CEVR personnel, and Parsons ES, and on a review of available site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993a) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and the 45 CES/CEVR. This work is not intended to fulfill requirements for a contamination assessment report, a remedial action plan, or any other document specified in federal or

state regulations; rather, it is provided for the use of the Base, its prime environmental contractors, and regulators as information to be used for future decision-making regarding this site, unless otherwise requested by AFCEE or the Base.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide a TS for the use of intrinsic remediation of groundwater contamination in conjunction with other remedial actions at CCFTA-2 (FT-17). However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) and Parsons ES to document the biodegradation and resulting attenuation of fuel hydrocarbons and solvents dissolved in groundwater, and to model this degradation using numerical or analytical groundwater models. For this reason, the work described in this work plan is directed toward the collection of data in support of implementation of this initiative. The other remedial actions planned for this site include source removal and downgradient plume treatment with air sparging. The effects of these actions will also be considered. Data required to develop alternative remedial strategies, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program.

The intent of the intrinsic remediation demonstration program sponsored by AFCEE is to develop a systematic process for scientifically investigating and documenting naturally occurring subsurface attenuation processes that can be factored into overall site remediation plans. The objective of the program and this specific demonstration is to provide solid evidence of intrinsic remediation of dissolved fuel hydrocarbons and chlorinated solvents in groundwater so that this information can be used by the Base and its prime environmental contractor(s) to develop an effective groundwater

remediation strategy. As a result, these demonstrations are not necessarily intended to fulfill specific federal or state requirements regarding site assessments, remedial action plans (RAPs), or other such mandated investigations and reports. A secondary goal of this multi-site initiative is to provide a database from multiple sites that demonstrates that natural processes of contaminant degradation often can reduce contaminant concentrations in groundwater to below acceptable cleanup standards before potential receptor exposure pathways are completed.

This work plan describes the site characterization activities to be performed by personnel from Parsons ES and the Subsurface Protection and Remediation Division of the NRMRL (formerly the USEPA's Robert S. Kerr Environmental Research Laboratory) in support of the TS and the groundwater modeling effort. Field activities will be performed to determine the extent of dissolved contamination and to evaluate the potential for intrinsic remediation of dissolved BTEX and CAHs. The data collected during the TS will be used along with data from previous investigations to characterize contaminant and geochemical patterns at the site, and for use in the groundwater flow and solute transport models to make predictions of the future concentrations and extent of contamination.

Site characterization activities in support of the TS will include: 1) determination of preferential contaminant migration and potential receptor exposure pathways; 2) soil sampling using Geoprobe® direct-push technology; 3) groundwater grab sampling using the Geoprobe®; 4) groundwater sampling from monitoring wells; and 5) aquifer testing. The materials and methodologies to accomplish these activities are described herein. Previously reported site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the groundwater flow and solute transport models. Where site-specific data are not

available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the model results, and where possible, the model will be calibrated using historical site data. Upon completion of the modeling, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not an appropriate remedial option, Parsons ES will suggest another appropriate groundwater remedial technology on the basis of available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of available previously reported, site-specific data and conceptual models for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There is one appendix to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for soil and groundwater samples.

1.2 BACKGROUND

Cape Canaveral AS is located on the east coast of Florida on a barrier island in Brevard County. The main complex occupies about 25 square miles of assembly and launch facilities for missiles and space vehicles. The property is bounded by the Atlantic Ocean on the east and the Banana River on the west. The southern boundary is a man-made shipping channel, and the John F. Kennedy Space Center adjoins Cape

Canaveral AS to the north. Since 1950, Cape Canaveral AS has been a proving ground for the country's military missile programs, including the Bomarc, Matador, Redstone, Atlas, Titan, and the Navy Trident Programs.

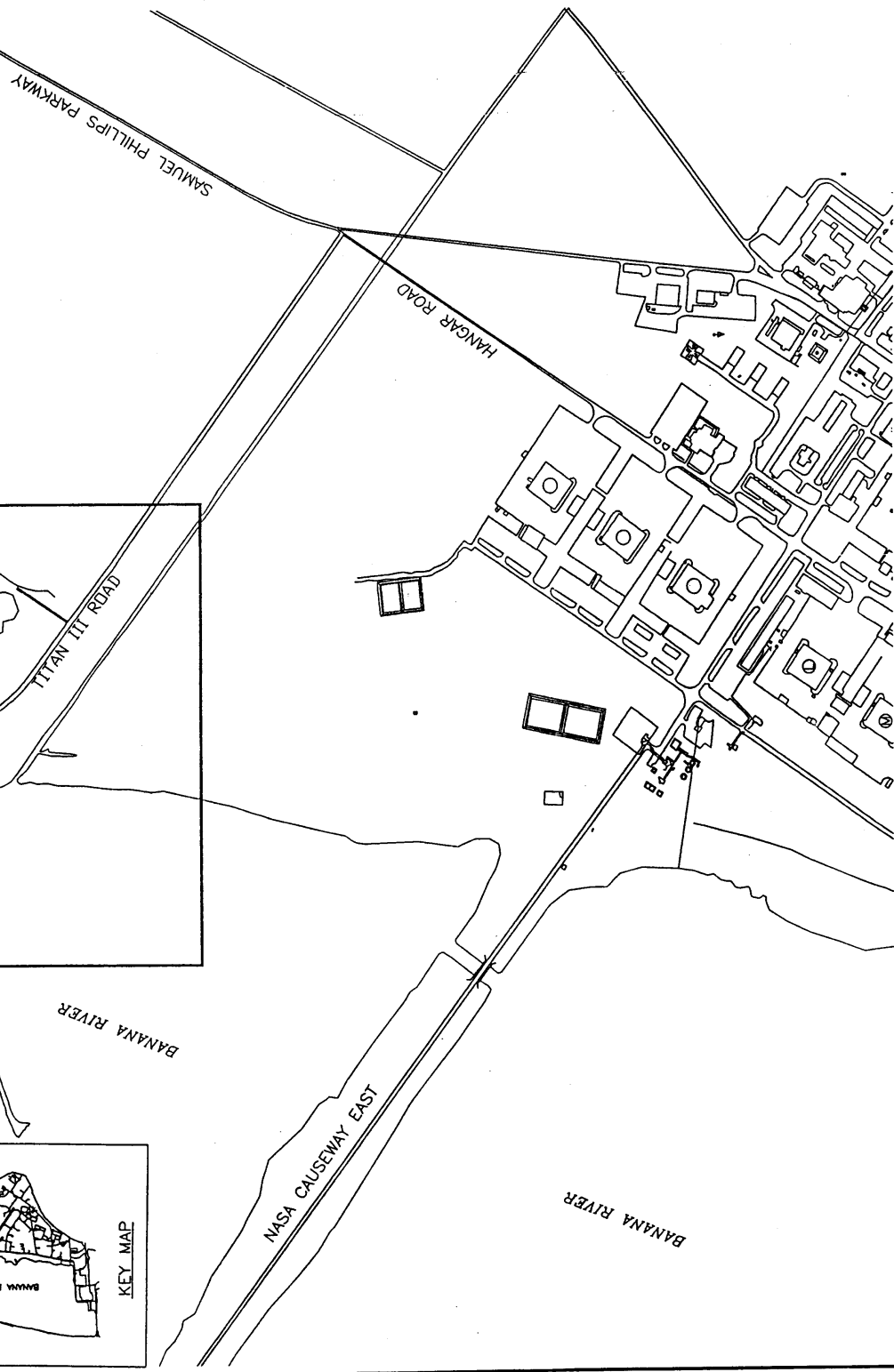
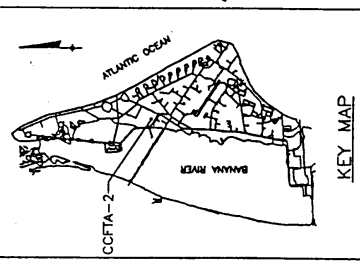
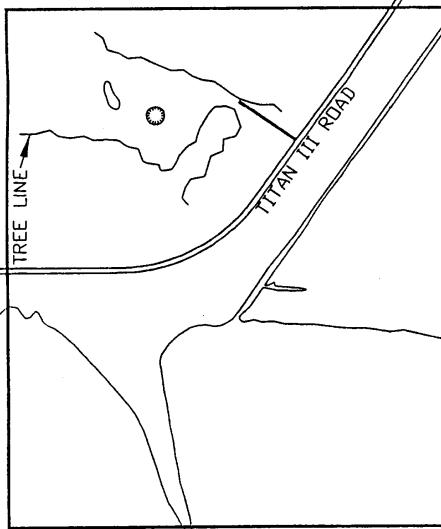
Former fire training area CCFTA-2 (FT-17) is about 1,000 feet from the Banana River, on the western side of Cape Canaveral AS (Figure 1.1). The site was used for firefighter training between 1965 and 1985. During training exercises, waste fuels and waste oils (including halogenated and nonhalogenated solvents) were burned in the unlined fire training pit. Fuel was stored onsite in aboveground storage tanks (ASTs) and was delivered to the burn pit via aboveground pipelines. Information regarding the amount of fuel and solvents burned during these exercises is not available. The burn area is a sparsely vegetated, circular, sandy pit approximately 75 feet in diameter and about 1 foot deep.

Containers of fuel and solvents were reportedly buried in disposal trenches at the site (OBG, 1995b). Empty drums were discovered buried in a trench approximately 200 feet north of the burn pit. Since 1985, the ASTs and the associated piping have been removed from the site. The site has no man-made structures other than supports for the former ASTs and a pilot bioventing system. Major site surface features consist of a burn pit and some mounds of sandy marine soil with grass cover and shrubs. The site is bordered on all sides by scrub oak and hardwood hammock. Figure 1.2 shows the site and its major features.

1.2.1 Previous Site Investigations

In 1984, an Installation Restoration Program (IRP) records search was conducted by Environmental Science and Engineering, Inc. (ESE, 1984). At that time, CCFTA-2 (FT-17) was identified as a site with potential for environmental contamination. In

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CPT (ARA)
after Spring 94?



LEGEND

- ROADWAY
- CANAL
- FORMER BURN PIT
- BURIAL TRENCH
- SITE LOCATION AREA

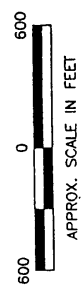
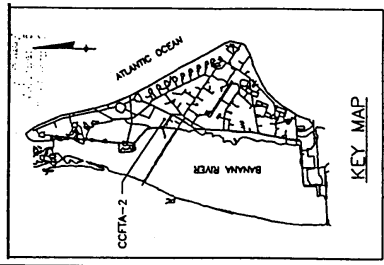
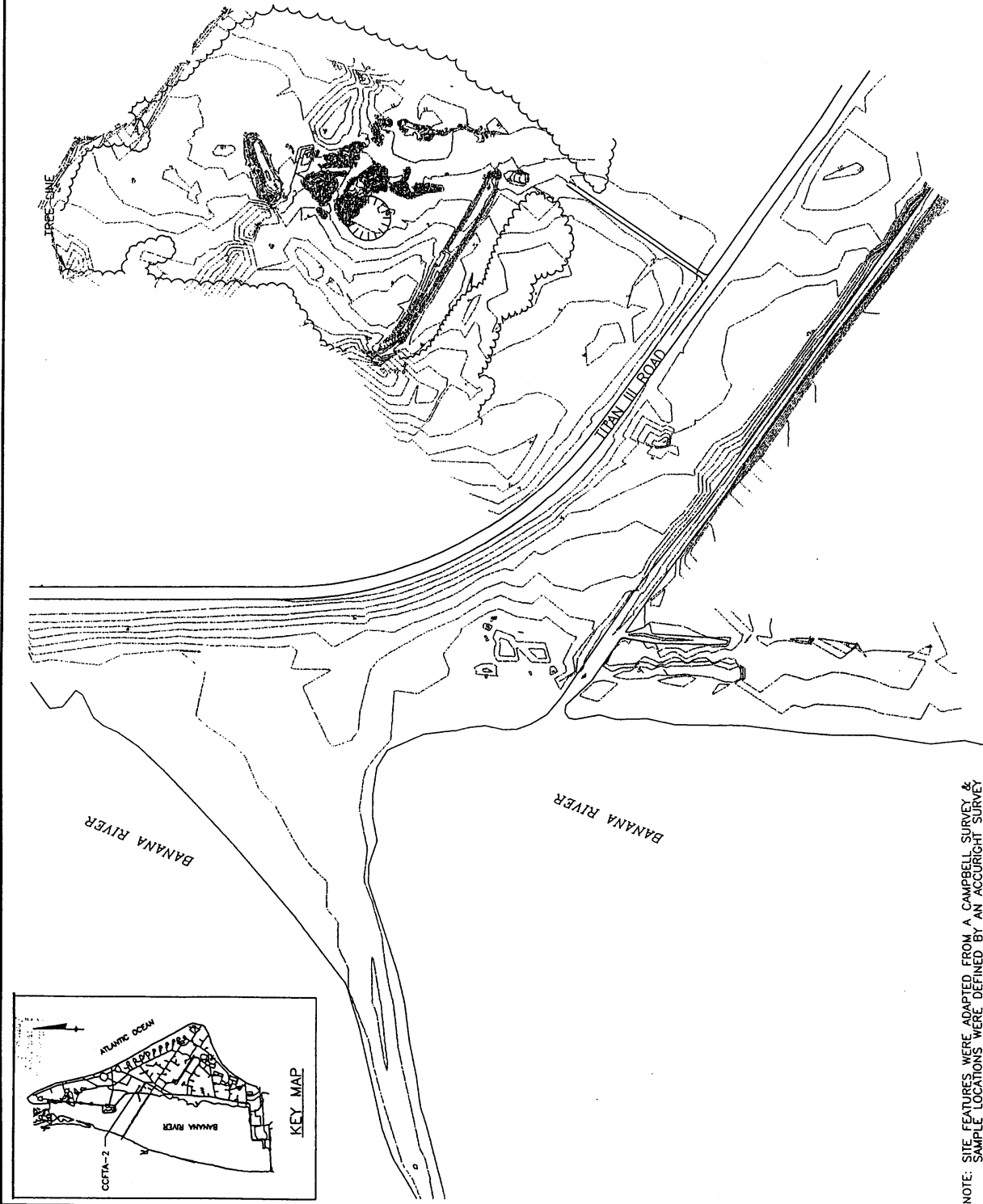


FIGURE 1.1

SITE LOCATION MAP

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

- ROADWAY
- CANAL
- FORMER BURN PIT
- BURIAL TRENCH
- TOPOGRAPHIC CONTOUR (1 FT. INTERVAL)

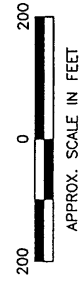


FIGURE 1.2

SITE MAP

CCFTA-2 (FT-17)
 Intrinsic Remediation TS
 Cape Canaveral AS, Florida

PARSONS ENGINEERING SCIENCE, INC.
 Denver, Colorado

NOTE: SITE FEATURES WERE ADAPTED FROM A CAMPBELL SURVEY & SAMPLE LOCATIONS WERE DEFINED BY AN ACCURIGHT SURVEY
 Source: OBG, 1995b.

1985, a Resource Recovery and Conservation Act (RCRA) Corrective Action process commenced with a survey, site tour, and preparation of plan for field activities. Phase II, Stage 1 sampling was completed in 1987, and the results were presented in a report in 1988 (ESE, 1988). A second stage of sampling (Phase II, Stage 2) was undertaken in order to more fully describe the extent of contamination, and the results of this work were presented in 1991 (ESE, 1991a). In 1992, O'Brien and Gere Engineers, Inc. (OBG, 1992) presented a conceptual treatability study report for CCFTA-2 (FT-17) as part of the Phase II, Stage 3, Remedial Investigation/Feasibility Study (RI/FS). In May 1995, OBG (1995a) presented an Engineering Evaluation/Cost Analysis (EE/CA) of test remedial measures (TRMs) for the site. In July, OBG (1995b) presented an RI/FS report for the site.

Results of groundwater sampling during the Phase II, Stage 1 and 2 investigations indicated the presence of dissolved petroleum hydrocarbons and CAHs exceeding Florida Class G-II Groundwater Quality Standards (GWQSs) (ESE, 1991a). Compounds of regulatory concern included benzene, trichloroethene (TCE), vinyl chloride (VC), 1,1-dichloroethene (1,1-DCE), and methylene chloride. In addition, 6 inches of mobile light nonaqueous-phase liquid (LNAPL, also known as free product) was detected in two wells at the site. Analysis of mobile LNAPL samples suggested the product in each well came from separate sources (ESE, 1991a). Soil sampling during these investigations detected elevated concentrations of individual petroleum compounds, total petroleum hydrocarbons (TPH), polychlorinated biphenyls (PCBs), pesticides, and chlorinated organic compounds.

Results of the Stage 3 RI/FS (OBG, 1995b) supported the results of the previous investigations and further defined the extent of contamination at the site. In addition, human health and ecological risk assessments were conducted, along with comparisons

of site data to applicable or relevant and appropriate requirements (ARARs) and to-be-considered criteria (TBCs). The extent of the dissolved groundwater contaminant plume was more fully defined, along with the extents of the LNAPL bodies. The TBC and ARAR evaluation concluded that benzene, TCE, and VC exceed GWQSS. In conjunction with the results of the EE/CA (OBG, 1995b), the FS portion of the RI/FS recommended a remedial alternative consisting of deed restrictions, groundwater monitoring, soil excavation and washing, groundwater biosparging near the source area, and downgradient *in situ* air sparging of groundwater.

In the fall of 1995, OBG installed several additional wells at the site as part of the work directed towards implementing temporary remedial measures recommended in the EE/CA. Exact locational data for these wells were not available to Parsons ES at the time this work plan was prepared.

1.2.2 Other Site Activity

In 1993, ES installed a pilot bioventing system in the burn pit at Site CCFTA-2 (FT-17) (ES, 1993b). Three air injection vent wells and three vapor monitoring points were installed, and tests were conducted to determine the radius of influence of each vent well and the rates of oxygen utilization and hydrocarbon degradation. Results of the tests indicated that air injection could increase available oxygen in the subsurface within a 30-foot radius of the vent wells, and that the system was capable of degrading 210 to 1,350 milligrams (mg) of fuel hydrocarbon per kilogram (kg) of soil per year (ES, 1993b). Extended testing of the system is ongoing. There has been no evaluation of the effects of this system on CAHs in the vadose zone.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were reviewed and used to develop conceptual models for groundwater flow and contaminant transport at CCFTA-2 (FT-17). The conceptual models guided the development of sampling locations and analytical data requirements needed to support the modeling efforts and to evaluate potential remediation technologies, including intrinsic remediation. Section 2.1 presents a synopsis of available site characterization data. Section 2.2 presents the preliminary conceptual groundwater flow and contaminant transport models that were developed based on these data.

2.1 DATA REVIEW

The following sections are based upon review of data from the following sources:

- Draft Bioventing Test Work Plan and Interim Results Report (ES, 1993b);
- Engineering Evaluation/Cost Analysis for Test Remedial Measures (OBG, 1995a); and
- RI/FS Report (OBG, 1995b).

2.1.1 Topography, Surface Hydrology, and Climate

Cape Canaveral AS is located on a barrier island between the Atlantic Ocean (to the east) and the Banana River. The CCFTA-2 (FT-17) site is located about 1,000 feet east of the Banana River, north of the Industrial Area on the west side of Cape

Canaveral AS (Figures 1.1 and 1.2). The site has no man-made surface structures except for the bioventing system and supports for the removed ASTs. Surficial topography at the site is characterized by little relief other than some sand mounds and berms. Ground surface elevations range from 3.2 to 11.8 feet above mean sea level (msl); the average elevation at the site is about 7.3 feet above msl. Most of the site is covered with sparse vegetation, and the site area is bordered by dense vegetation such as scrub oak and hardwood hammock. The former burn pit is a depression in sandy soil about 500 feet north of Titan III Road (Figure 1.2). An earthen berm borders the southwestern margin of the burn pit area.

The CCFTA-2 (FT-17) site is about 800 feet northeast of a drainage canal and is within 1,000 feet of the Banana River. In the portion of the site north and east of Titan III Road, topography is variable, but south of the road the land surface generally slopes gently to the southwest. However, due to the relatively level land surface and the sandy surficial soils, nearly all precipitation at the site is likely to infiltrate rapidly, and runoff is likely to be negligible.

The climate of the barrier island is humid subtropical. Monthly mean high temperatures range from 69 degrees Fahrenheit (°F) in January to 87°F in July and August. Extreme high and low temperatures for the period from 1950 to 1980 were 99°F and 27°F, respectively. Rainfall is unevenly distributed throughout the year, with the period from June through October having distinctly more precipitation than the rest of the year. A 30-year (1950 to 1980) mean of the annual precipitation recorded at Patrick Air Force Base (AFB) south of Cape Canaveral, is 44.7 inches, with a mean annual evapotranspiration of 40.3 inches (ESE, 1991b).

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional Geology and Hydrogeology

Cape Canaveral AS is situated on undifferentiated marine sands overlying the Pleistocene-age Anastasia Formation and Caloosahatchee'Marl Formation; these three units comprise the surficial unconsolidated deposits in the area. The Anastasia Formation is a discontinuous layer of undifferentiated sands with silt and shells, and may not be present in this area. According to OBG (1995b), the Anastasia Formation was not observed at site CCFTA-2 (FT-17). The Caloosahatchee Marl Formation consists primarily of calcareous sand and shell deposits with interbedded calcareous sand, silt, and clay deposits.

Underlying the Caloosahatchee Formation is the Tamiami Formation, which consists of limestones, marls, silty sands, and clay. The Tamiami Formation forms a shallow bedrock aquifer. The marine sands, clays, and limestones of the Hawthorn Formation underlie the Tamiami Formation. Interspersed limestone layers form localized aquifers within the Hawthorn Formation. Beneath the Hawthorn Formation is the Floridan Aquifer, which consists of Ocala Formation limestone and extends to a depth of over 1,500 feet below msl. Figure 2.1 shows the generalized stratigraphic sequence for the area.

The surficial aquifer at Cape Canaveral AS includes the undifferentiated marine sands, the Anastasia Formation, the Caloosahatchee Marl, and the Tamiami Formation. The bottom of the surficial aquifer at Cape Canaveral is about 110 feet below msl, and is formed by clay units within the Hawthorn Formation (ESE, 1991a).

The likelihood of contamination of the deep aquifers from sources in the shallow aquifer is thought to be minimal. This is because the deep aquifers in the region

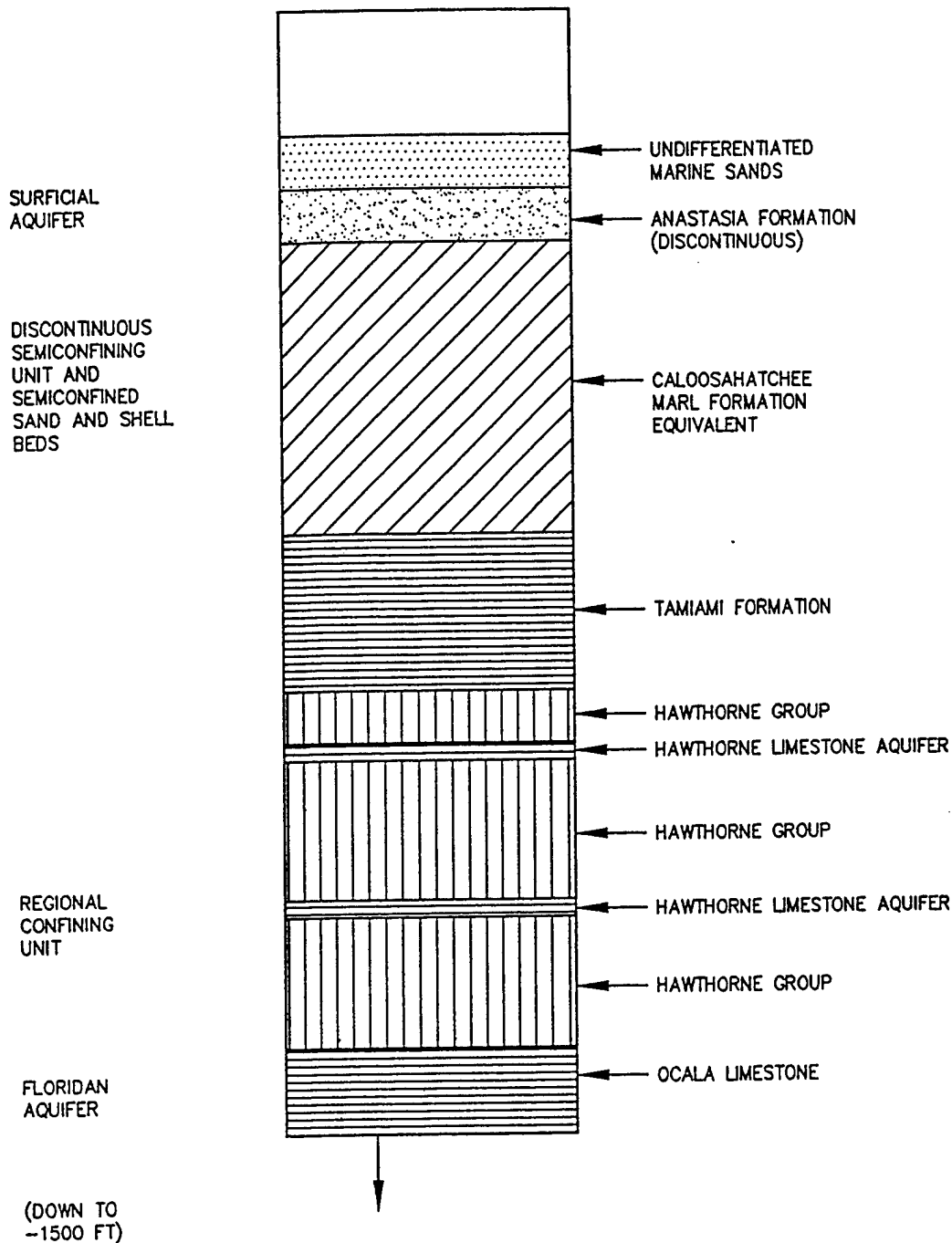


FIGURE 2.1

REGIONAL STRATIGRAPHIC SEQUENCE

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida

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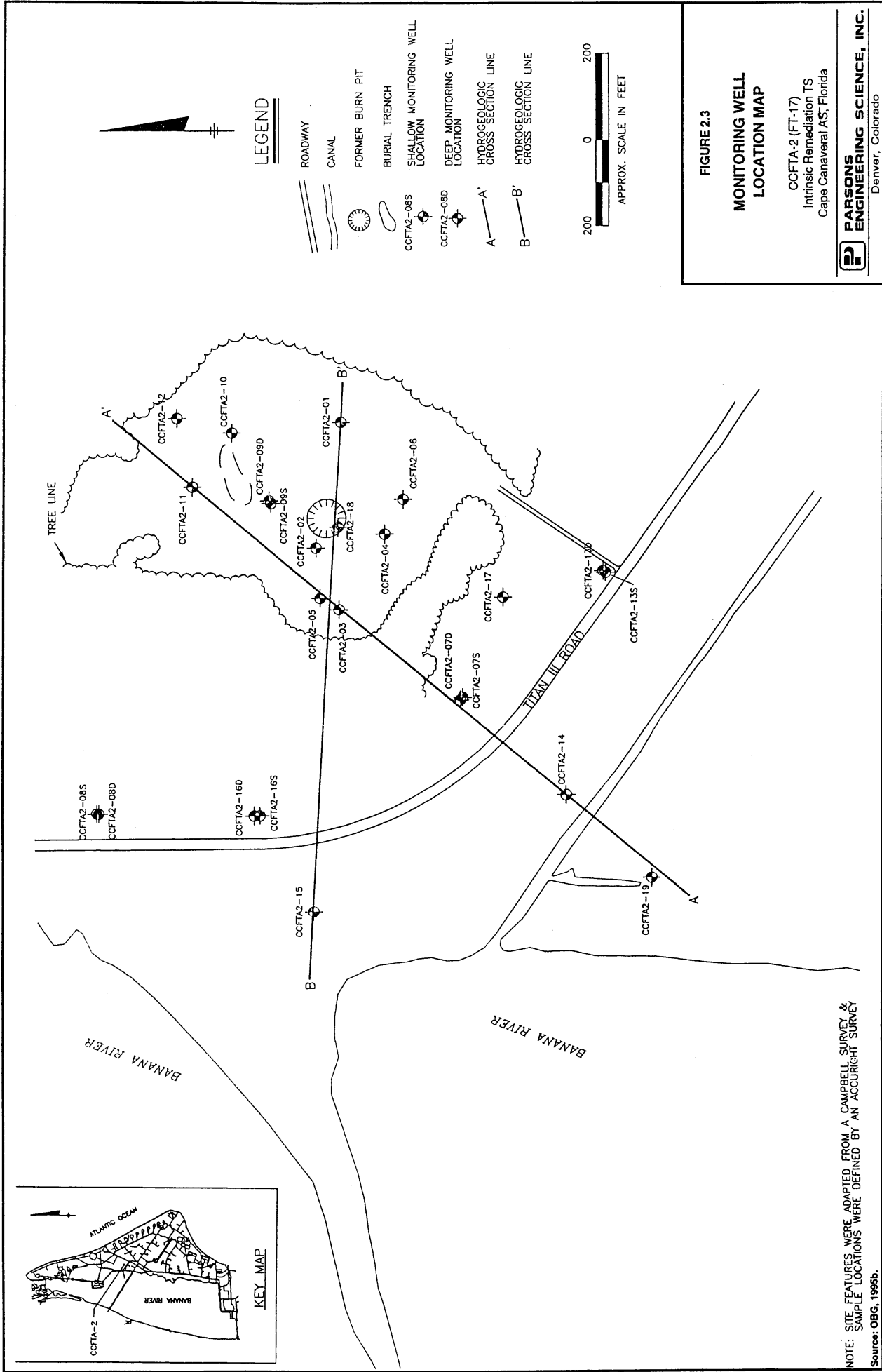
generally have sufficient pressure head to cause the potentiometric surface for the deep aquifers to be higher than the water table within the shallow unconfined aquifer, thus preventing downward vertical groundwater flow (and the associated migration of contaminants) from the shallow aquifer into the deeper units. Groundwater from beneath Cape Canaveral is not used for water supply purposes; the AS receives potable water from the city of Cocoa, Florida.

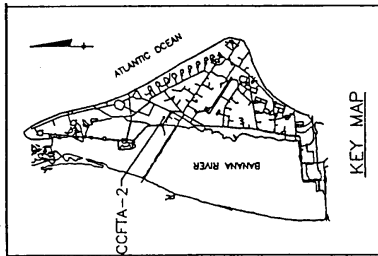
2.1.2.2 Site CCFTA-2 (FT-17) Geology and Hydrogeology

Characterization of the vadose zone and shallow aquifer system in the vicinity of Site CCFTA-2 (FT-17) has been the objective of several investigations. Multiple soil boreholes and monitoring wells (permanent and temporary) have been installed at the site since 1987. Figure 2.2 shows the locations of soil borings at the site, Figure 2.3 shows the locations of permanent monitoring wells at the site, and Figure 2.4 shows the locations of temporary groundwater monitoring points installed at the site.

Surface soil at the site consists of yellowish-brown and yellowish-gray, fine to coarse sand with some shell fragments. The soil is classified as Canaveral-Urban land complex according to the Soil Survey of Brevard County (US Department of Agriculture, 1974). This soil consists of Canaveral sand and Urban land that is a mixture of sand and shells that have been dredged from the Indian and Banana Rivers and used as fill in tidal marshes.

The shallowest geologic unit is an undifferentiated marine sand unit, which is a well-sorted terrace deposit of Holocene age. The sand unit extends to depths ranging from 10 to 12 feet below ground surface (bgs). These deposits are beach, eolian, estuarine, fluvial, and marsh sands containing minor amounts of silt and interbedded





CCFTA2-160
CCFTA2-165

KEY MAP

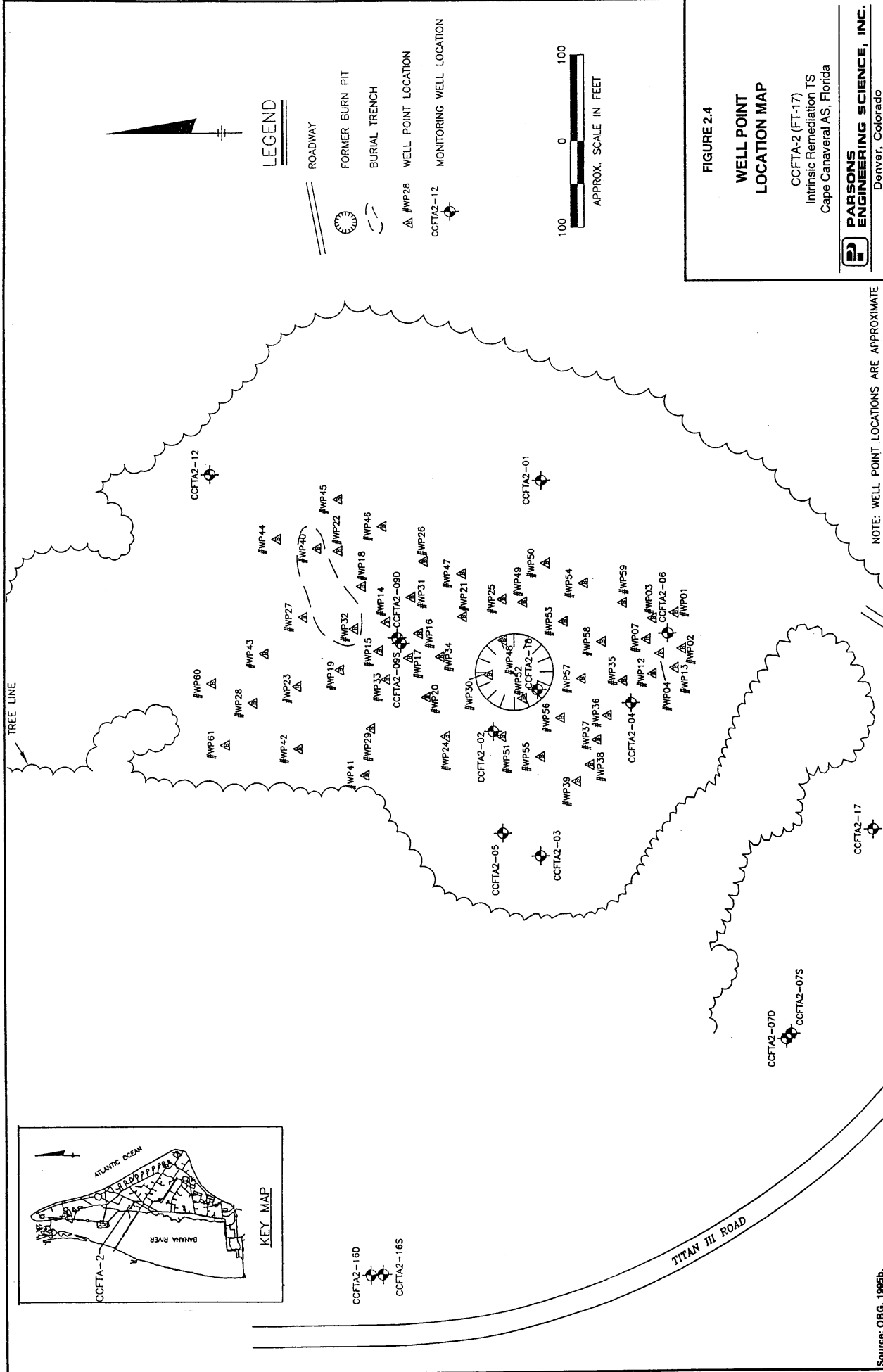


FIGURE 2.4
WELL POINT
LOCATION MAP
CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida
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NOTE: WELL POINT LOCATIONS ARE APPROXIMATE

clays. From the land surface to a depth of about 5 feet, the sediments are pale yellowish-brown, loose, well-sorted, fine to coarse quartz sand. Below 5 feet bgs, the sands grade to a light-olive-gray to medium-gray color. The unit contains variable amounts of fine, medium, and coarse sand with up to 35-percent shells and shell fragments and occasional interspersed clay lenses.

The Anastasia Formation was not encountered at this site, and the Caloosahatchee Marl, deposited during the Pleistocene Epoch, directly underlies the undifferentiated marine sand unit. The Caloosahatchee Marl is a medium-gray to greenish-gray unit of fine-grained calcareous sand, unconsolidated shells and shell fragments, and interbedded calcareous sand, silt, and clay units. Shells and shell fragments generally are from mollusks, including gastropods and bivalves. Boring logs from deeper monitoring wells at the site (e.g., CCFTA2-08D, CCFTA2-13D, and CCFTA2-16D) indicate that a clay layer is present within the Marl at a depth of about 60 feet bgs, but a few logs (e.g., CCFTA2-07D and CCFTA2-09D) show the presence of silty sand at about 55 to 60 feet bgs. A few clay lenses were found at about 20 to 22 feet bgs in the boreholes for wells CCFTA2-07D and CCFTA2-09D.

Hydrogeologic cross-sections of the CCFTA-2 (FT-17) site prepared by OBG (1995b) are presented as Figures 2.5 and 2.6. The locations of the cross-sections are indicated on Figure 2.3.

The shallow aquifer at the site consists of the undifferentiated marine sands, the Caloosahatchee Marl, and the Tamiami Formation, with the bottom of the aquifer at about 110 feet bgs. Recharge to the aquifer occurs through the infiltration of precipitation through the thin and sandy vadose zone. Assuming negligible runoff, the amount of recharge is approximately equal to the amount of precipitation less the

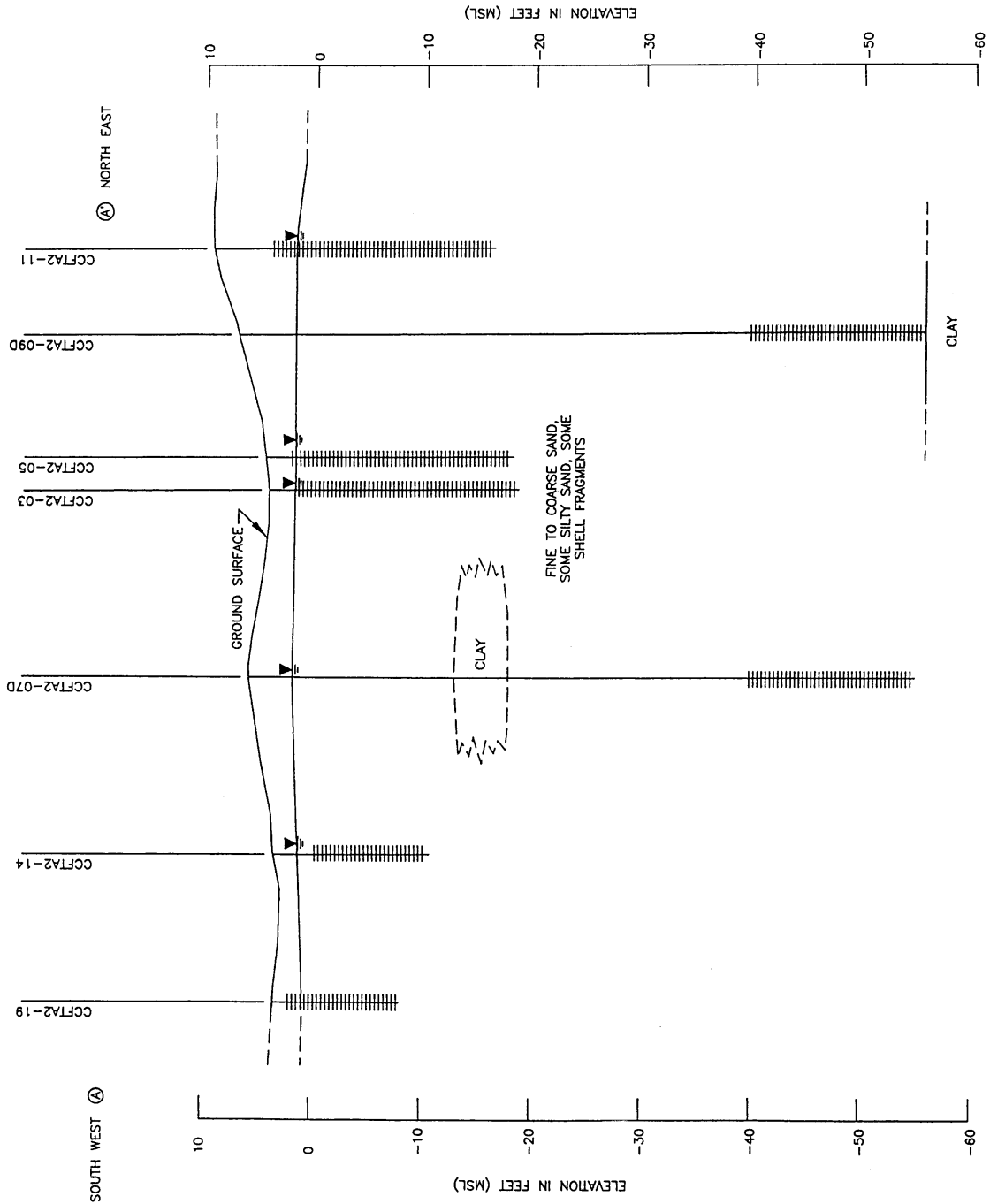
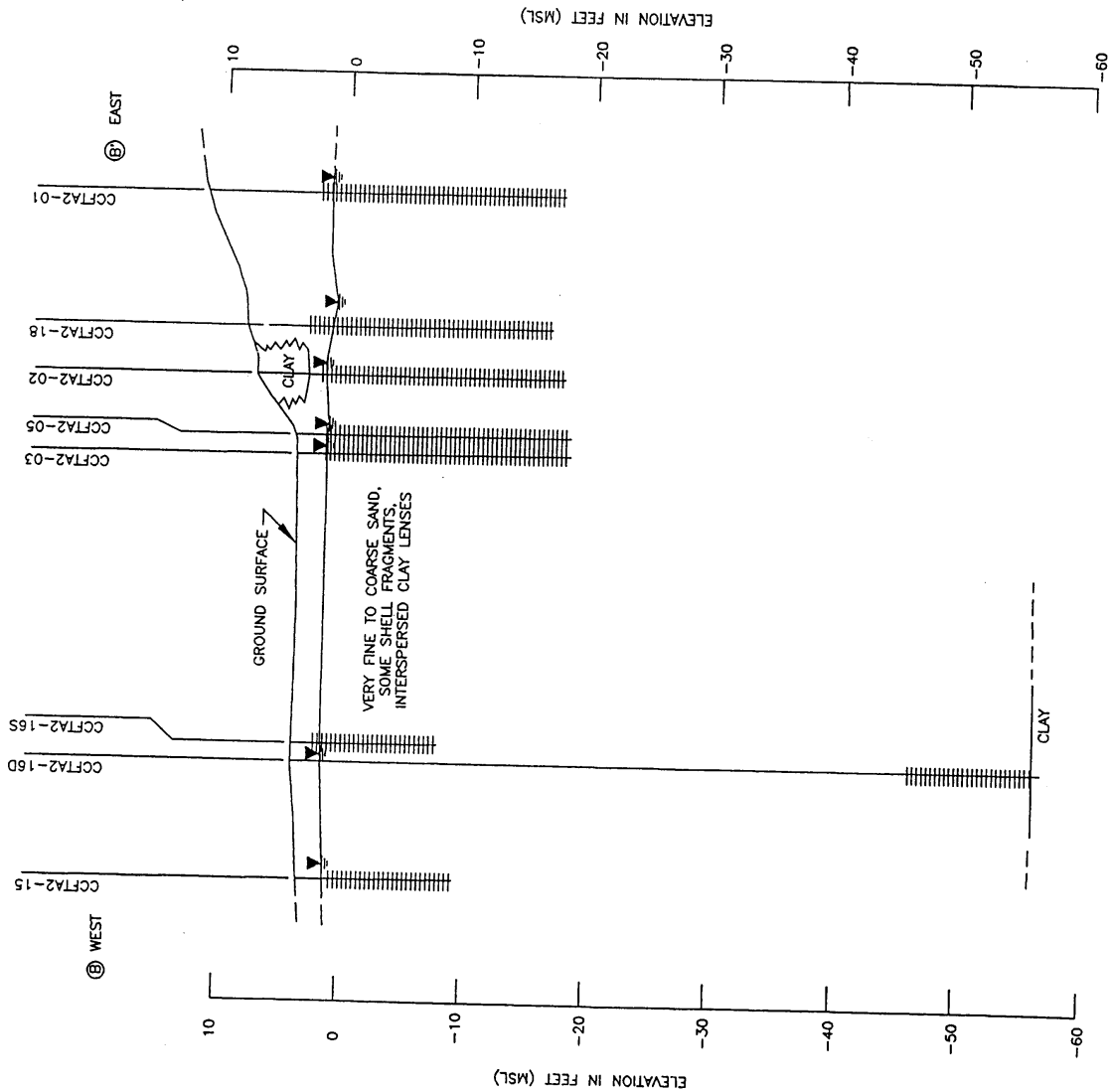


FIGURE 2.5
HYDROGEOLOGIC
CROSS-SECTION A-A'

CCFTA-2 (FT-17)
 Intrinsic Remediation TS
 Cape Canaveral AS, Florida



LEGEND

- SCREENED INTERVAL MONITORING WELL
- WATER TABLE (10/15/93)
- INTERPOLATION OF GEOLOGIC BOUNDARY

NOTE: VERTICAL EXAGGERATION = 20X

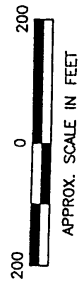


FIGURE 2.6

HYDROGEOLOGIC CROSS-SECTION B-B'

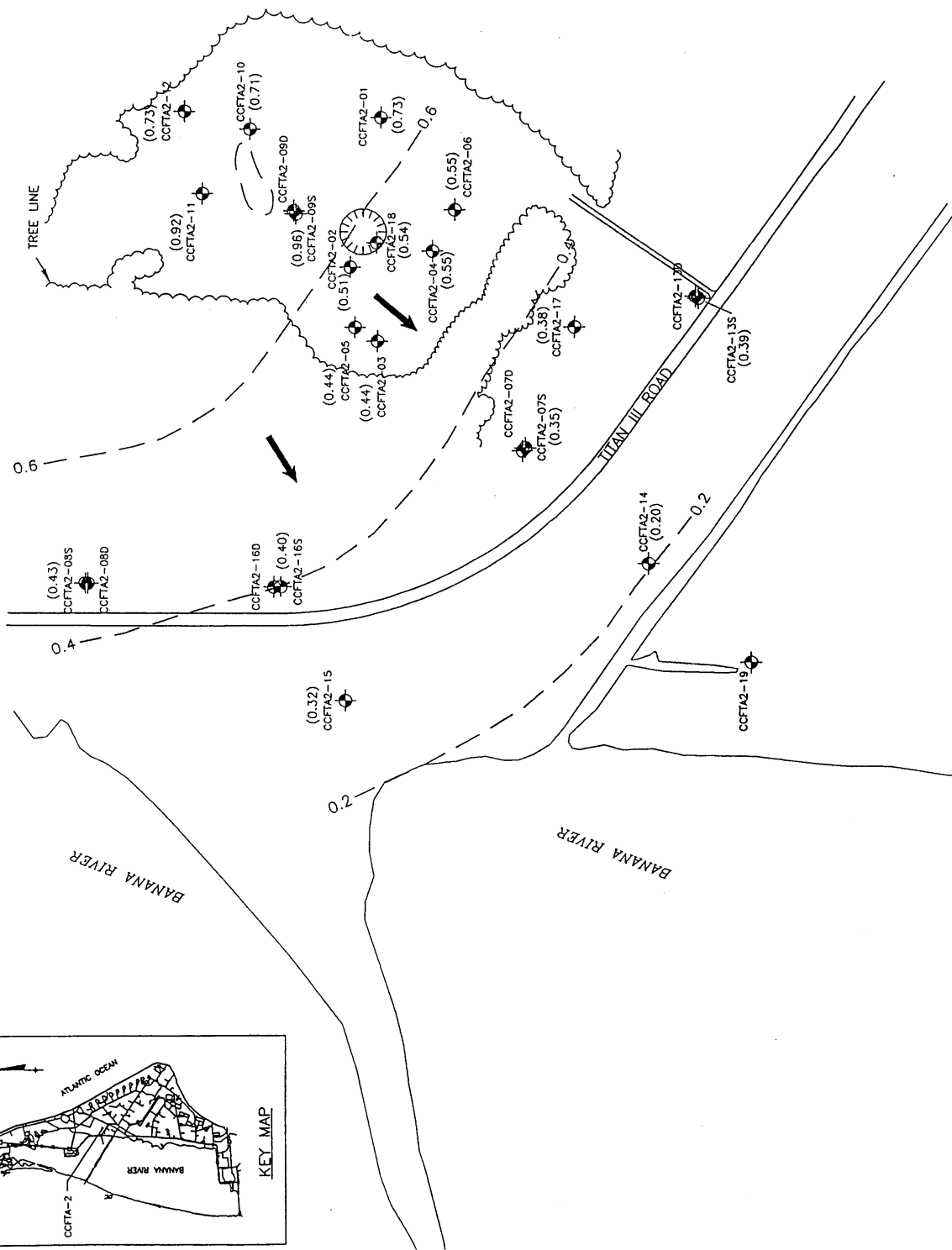
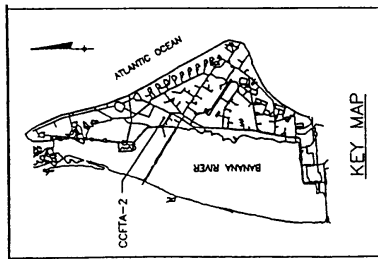
CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida

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amount returned to the atmosphere through evapotranspiration. Using data from Patrick AFB (ESE, 1991b), about 4.4 inches of precipitation may annually recharge the shallow aquifer near the site.

The water table at CCFTA-2 (FT-17) is present from about 2.1 to 11.4 feet bgs, corresponding to elevations of about 0.1 to 0.9 feet above msl (OBG, 1995b). Groundwater flow at the site is to the southwest, toward the Banana River and the drainage canal. Figure 2.7 shows the water table elevations and flow conditions on July 25, 1994. Flow in the deeper portion of the aquifer is similar. The horizontal hydraulic gradients measured on July 25, 1994 were 0.0004 foot per foot (ft/ft) in the shallow part of the aquifer and 0.0002 ft/ft in the deeper part of the aquifer (OBG, 1995b). Vertical gradients also were measured at well nests on the same date. These results indicated that the vertical component of groundwater flow within the shallow aquifer in the vicinity of the burn area and drum disposal trench was downward, while away from that area (toward the canal and the river) vertical gradients indicated that flow was upward. This suggests that flow from the shallow aquifer discharges to the canal and the Banana River.

During the RI field activities, OBG (1995b) performed *in situ* hydraulic conductivity tests at 19 monitoring wells. In the uppermost portion of the shallow aquifer, measured hydraulic conductivities ranged from 1.8×10^{-2} foot per minute (ft/min) to 8.1×10^{-2} ft/min. The geometric mean of these values is 3.6×10^{-2} ft/min (OBG, 1995b). In the deeper portion of the aquifer, measured hydraulic conductivities ranged from 1.7×10^{-2} ft/min to 4.9×10^{-2} ft/min, with a geometric mean of 2.9×10^{-2} ft/min. These results are summarized in Table 2.1.



LEGEND

- ROADWAY
- CANAL
- FORMER BURN PIT
- BURIAL TRENCH
- SHALLOW MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATION
- GROUND WATER FLOW DIRECTION
- GROUND WATER ELEVATION (FT-MSL) (07-25-94)
- GROUND WATER ELEVATION CONTOUR



FIGURE 2.7

WATER TABLE ELEVATION MAP (JULY 1994)

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral A.S., Florida



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TABLE 2.1
SUMMARY OF HYDRAULIC CONDUCTIVITY
TESTING RESULTS
CCFTA-2 (FT-17)
INTRINSIC REMEDIATION TS
CAPE CANAVERAL AS, FLORIDA

Well Name	Test Date	Well Diameter (inches)	Screen Length (feet)	Hydraulic Conductivity (ft/min)
CCFTA2-01	10/15/93	2	20	2.7E-02
CCFTA2-02	10/15/93	2	20	4.6E-02
CCFTA2-03	10/15/93	2	20	3.7E-02
CCFTA2-04	10/15/93	2	20	2.0E-02
CCFTA2-05	10/15/93	2	20	2.3E-02
CCFTA2-07D	10/18/93	2	15	3.4E-02
CCFTA2-07S	10/18/93	2	10	6.5E-02
CCFTA2-08D	10/18/93	2	15	1.7E-02
CCFTA2-08S	10/18/93	2	10	2.8E-02
CCFTA2-10	10/15/93	2	20	2.5E-02
CCFTA2-11	10/15/93	2	20	1.8E-02
CCFTA2-12	10/15/93	2	10	4.7E-02
CCFTA2-13D	10/18/93	2	10	4.9E-02
CCFTA2-13S	10/18/93	2	10	4.3E-02
CCFTA2-14	10/18/93	2	10	8.1E-02
CCFTA2-15	10/18/93	2	10	2.0E-02
CCFTA2-16D	10/18/93	2	10	2.4E-02
CCFTA2-16S	10/18/93	2	10	5.5E-02
CCFTA2-17	10/18/93	4	10	6.0E-02

Source: OBG, 1995b.

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

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

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

K = Hydraulic conductivity [L/T] (3.6×10^{-2} ft/min)

dH/dL = Gradient [L/L] (0.0004 ft/ft)

n_e = Effective porosity (assumed to be 0.25).

Using this relationship in conjunction with the site-specific data given above, the average advective groundwater velocity at the site is about 5.8×10^{-5} ft/min, or 30 feet per year (ft/yr).

2.1.3 Nature and Extent of Contamination at Site CCFTA-2 (FT-17)

The following sections are derived from information presented in the RI/FS report for Site CCFTA-3 (FT-17) (OBG, 1995b). Results summarized by OBG (1995b) are from three stages of investigations conducted at the site. In all three stages, samples were analyzed for constituents on the Superfund Target Compound List (TCL) and Target Analyte List (TAL); however, only in Stage 3 were all samples from all media analyzed for the full range of analytes on the TCL and TAL. Two rounds of sampling were conducted during Stage 3; the first round was in July 1993, and the second round was in October 1993.

Because this TS is directed at contamination dissolved in groundwater (as well as the source(s) of that contamination), and because source area soil excavation and treatment (including mobile LNAPL) is planned, the following discussion focuses primarily on

the nature of the groundwater contamination, with a secondary emphasis on subsurface soil and LNAPL data. For further information regarding site activities and sampling results from other media, the EE/CA and RI/FS (OBG, 1995a and 1995b) should be consulted.

2.1.3.1 Groundwater Contamination

Figures 2.3 and 2.4 show groundwater monitoring well and monitoring point locations at CCFTA-2 (FT-17). Sampling of groundwater monitoring wells and groundwater monitoring points at the site has indicated that concentrations of petroleum hydrocarbons and volatile organic halocarbons (VOHs, which include CAHs) were elevated in several monitoring wells at the site. Compounds detected include the BTEX compounds, TCE, 1,1-dichloroethane (1,1-DCA), 1,1-DCE, 1,2-DCE, VC, tetrachloroethene (PCE), and several other VOHs. With the exception of TCE, all of these compounds were detected only in shallow wells at the site. In the first and second sampling rounds, TCE was detected in samples from one deep well (CCFTA2-9D) at concentrations of 1.7 and 5 micrograms per liter ($\mu\text{g/L}$), respectively.

Figure 2.8 shows the distribution of total VOH concentrations in the shallow portion of the aquifer. Total VOH concentrations measured during Stage 3 ranged from 3 to 56,700 $\mu\text{g/L}$ in Round 1 and 1.7 to 7,600 $\mu\text{g/L}$ in Round 2 (OBG, 1995b). The highest concentrations were observed in CCFTA2-09S, which is just south of the drum burial trench. As noted in the RI/FS (OBG, 1995b), TCE and its degradation products make up the greatest fraction of the VOHs at CCFTA-2 (FT-17). The source of TCE is a mobile LNAPL body detected in well CCFTA2-09S. Analysis of this free product indicates that it contains TCE (cosolvenated with petroleum hydrocarbons) at a

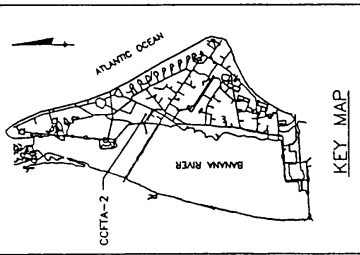
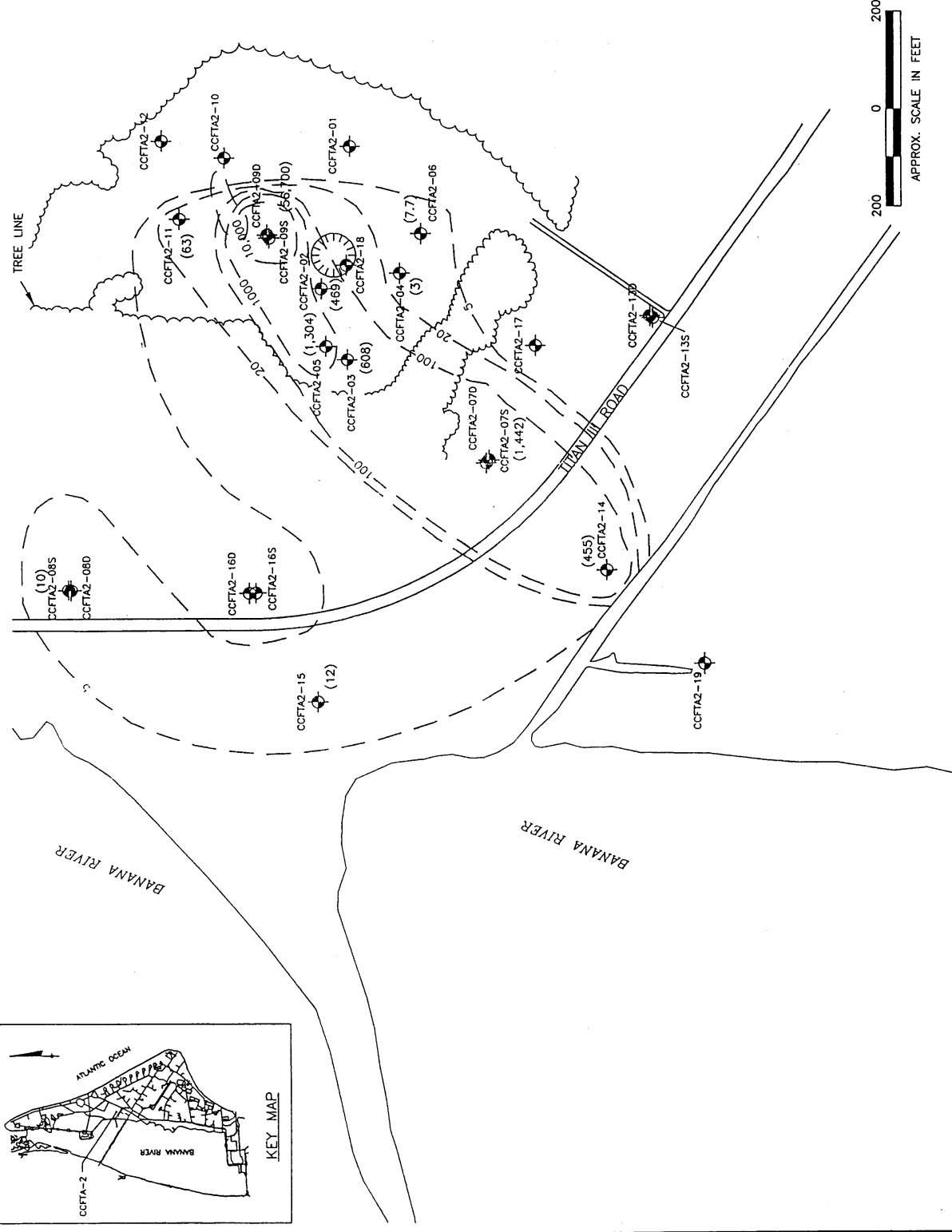


FIGURE 2.8

TOTAL VOH CONCENTRATIONS IN SHALLOW GROUNDWATER (JULY 1993)

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida

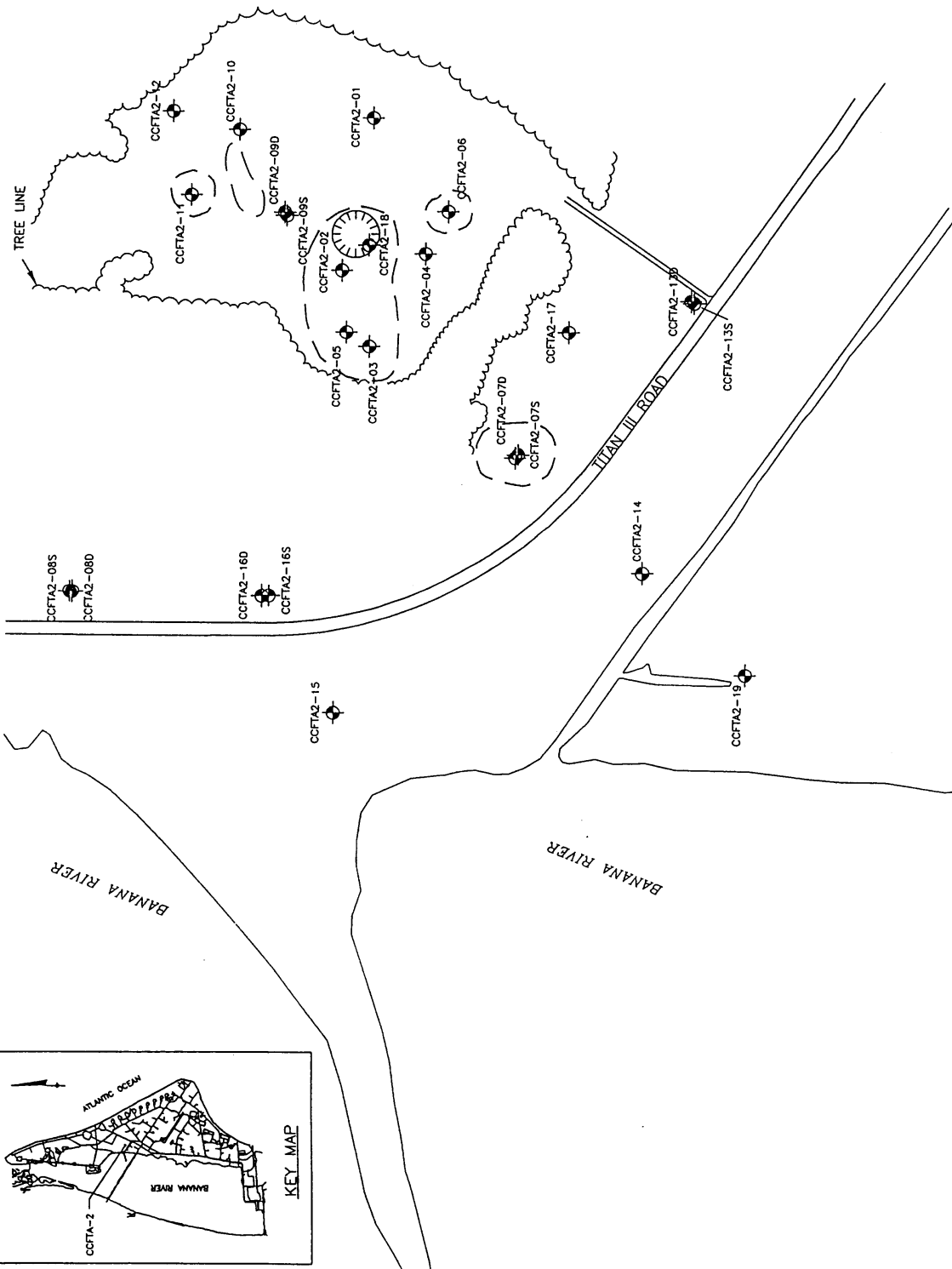
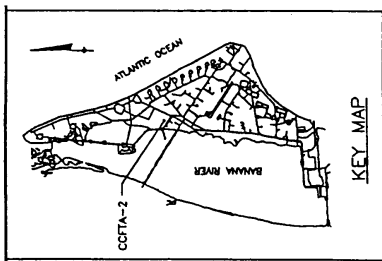
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concentration of 22,000 mg/kg. A more detailed discussion regarding this LNAPL body is presented in Section 2.1.3.3.

BTEX compounds were detected in seven monitoring wells, at concentrations ranging from 2 to 129 µg/L (OBG, 1995b). Figure 2.9 shows the interpreted limits of BTEX contamination in the shallow part of the aquifer. Most dissolved BTEX was detected beneath and east of the former burn pit. TPH compounds were detected in three monitoring wells (CCFTA2-06S, CCFTA2-09S, and CCFTA2-18). TPH concentrations at CCFTA2-06S were 3,900 milligrams per liter (mg/L) and 156 mg/L in Rounds 1 and 2, respectively. Round 1 and 2 TPH concentrations in CCFTA2-09S were 4,100 mg/L and 189 mg/L, respectively. One sample from CCFTA2-18 contained 1.9 mg/L of TPH. All three of these wells contained mobile LNAPL.

As indicated in the RI/FS (OBG, 1995b), concentrations of several volatile organic compounds (VOCs; this includes BTEX and the CAHs) detected in groundwater at the site exceeded GWQSSs. The observed concentrations of PCE, TCE, and VC exceeded the GWQSSs, as did benzene concentrations. However, PCE was detected in only one well (CCFTA2-2). In general, these compounds were all detected in the wells within the plume boundaries defined on Figure 2.8.

An additional investigation of the distribution of VOCs in groundwater was conducted at CCFTA-2 (FT-17) in May 1995. Using a Hydropunch[®] device, screening samples were collected at 12 locations parallel to and just south/southeast of Titan III Road, three locations along the canal, and two locations along the centerline of the VOH plume (Figure 2.8). These samples were analyzed for VOCs using USEPA Method SW8010. At most locations, samples were collected at multiple depths. Results of this sampling suggested that CAH contamination may extend further to the



LEGEND

- ROADWAY
- CANAL
- FORMER BURN PIT
- BURIAL TRENCH
- SHALLOW MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATION
- ESTIMATED LIMIT OF TOTAL DETECTED BTEX CONCENTRATION

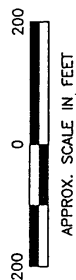


FIGURE 2.9

EXTENTS OF DISSOLVED BTEX IN GROUNDWATER

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida



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northwest than indicated by previous data, and that the full horizontal and vertical extent of groundwater contamination in this area may be uncertain (OBG, 1995b). Additional monitoring wells have been installed to confirm the results of this investigation.

2.1.3.2 Subsurface Soil Contamination

VOCs were detected in subsurface soil in four general areas: at the northeast corner of the burial trench, near the southwest edge of the burial trench, in and west of the burn pit, and southeast of well CCFTA2-06 (i.e., in soil boring #SB50). VOC concentrations were greatest [e.g., 6.76 mg/kg of total VOCs (Stage 3) and 8.5 mg/kg of TCE (Stage 2)] near the southwestern edge of the burial trench, and in general, contaminant concentrations were greatest in the vicinity of the water table. Pesticides and PCBs also were detected at several locations. TPH compounds were detected in locations similar to those for VOCs, with the greatest TPH concentrations observed beneath the burn pit and near the northeast end of the burial trench. OBG (1995b) noted that Stage 1 sample TPH concentrations are generally higher than those in samples collected in the later stages (Stages 2 and 3).

2.1.3.3 Mobile LNAPL

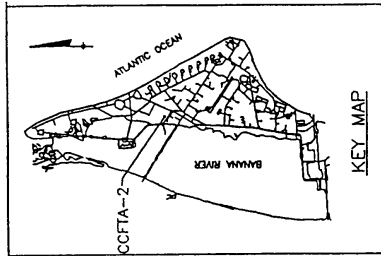
Free product (mobile LNAPL) has been observed in wells CCFTA2-06 and CCFTA2-09S). To further assess the extent of free product, OBG (1995b) installed 55 well points in November 1993 and August 1994. The locations of these points are shown on Figure 2.10, along with the measured mobile LNAPL thicknesses from September 1994. On the basis of several measurement events over a 1-year period, OBG (1995b) noted that the mobile LNAPL body is fairly static and maintains a fairly

constant thickness. The LNAPL body has been estimated to cover an area of about 1.3 acres, and has had a maximum observed thickness as great as 1.48 feet (OBG, 1995b).

Mobile LNAPL samples have been collected from wells CCFTA2-06 and CCFTA2-09S and submitted for laboratory analysis. In addition to containing petroleum compounds (e.g., xylenes, TPH, naphthalene, 2-methylnaphthalene, ethylbenzene, phenanthrene, and dichlorobenzene), the LNAPL samples from both wells contained cosolvenated PCBs, and the sample from CCFTA2-09S contained TCE (also cosolvenated) at a concentration of 22,000 mg/kg. On the basis of these LNAPL analyses, OBG (1995b) noted that the free product is a significant source of groundwater contamination at the CCFTA-2 (FT-17) site. The relatively low soil VOC concentrations (e.g., a maximum TCE concentration of 8.5 mg/kg) further support this interpretation. As noted previously, the mobile LNAPL sample data also suggested that there may have been two sources of LNAPL.

2.2 DEVELOPMENT OF CONCEPTUAL MODELS

A conceptual model is a three-dimensional representation of a site hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. A site conceptual model is developed to provide an understanding of the mechanisms controlling contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model also provides a foundation for formulating decisions regarding additional data collection and potential remedial actions. The conceptual model for CCFTA-2 (FT-17) will be used to aid in selecting additional data collection points and to identify



LEGEND

- ROADWAY
- CANAL
- FORMER BURN PIT
- BURIAL TRENCH
- WELL POINT LOCATION
- SHALLOW MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATION
- FREE PRODUCT THICKNESS CONTOURS (Sampled 9/9/94)

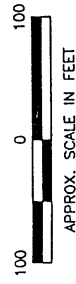
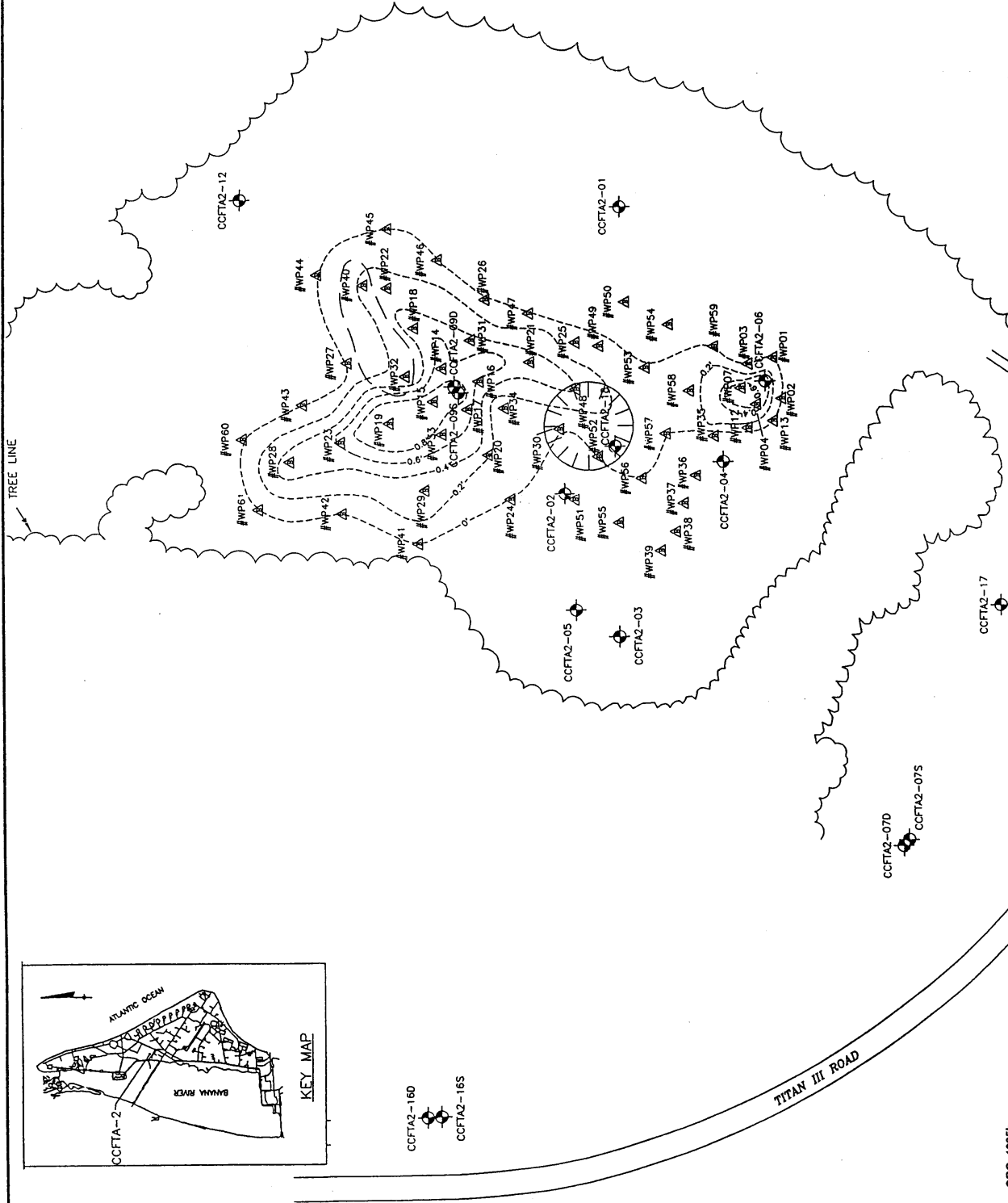


FIGURE 2.10
MOBILE LNAPL
THICKNESS
(SEPTEMBER 1994)

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida

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appropriate data needs for modeling chlorinated solvent and petroleum hydrocarbon attenuation using groundwater flow and solute transport models.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphic data, and
 - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors and exposure points; and
- Determining additional data requirements.

2.2.1 Intrinsic Remediation and Solute Transport Models

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any pathway for exposure of human or ecological receptors to site contaminants may be complete. Groundwater flow and solute transport models have proven useful for predicting plume migration and contaminant attenuation by natural biodegradation. For the BTEX compounds and other petroleum hydrocarbons, analytical solute transport models and the Bioplume II numerical model (Rifai *et al.*, 1988) can be used to evaluate critical groundwater fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. For CAHs, a wide variety of analytical and numerical models (e.g., the groundwater flow modeling code MODFLOW in conjunction with the transport code MT3D) are also available for evaluating solute fate and transport. Quantitative fate and transport analyses can be

used to determine what level and extent of remediation is required, as well as to evaluate the effects of additional remedial actions in conjunction with intrinsic remediation.

An accurate estimate of the potential for natural biodegradation of BTEX and chlorinated compounds in groundwater is important to consider when determining whether groundwater contamination presents a substantial threat to human health and the environment, and when deciding what type of remedial alternative will be most cost effective in eliminating or abating these threats. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons and chlorinated solvents (Lee, 1988; McCarty *et al.*, 1992).

The positive effects of natural attenuation (e.g., advection, dispersion, sorption, and biodegradation) processes on reducing the actual mass of fuel-related contamination dissolved in groundwater has been termed intrinsic remediation. Advantages of intrinsic remediation include: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide, ethene, or water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy-intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive and allows continuing use of infrastructure during remediation; (4) engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation (e.g., contaminants may be transferred into another medium during remediation activities); and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies.

2.2.2 Biodegradation of Dissolved BTEX Contamination

For BTEX compounds, biodegradation occurs naturally when sufficient oxygen (or other electron acceptors) and nutrients are available in the groundwater. The rate of natural biodegradation is generally limited by the lack of oxygen (or other electron acceptors) rather than by the lack of nutrients such as nitrogen or phosphorus. The supply of oxygen to unsaturated soil is constantly renewed by the vertical diffusion from the atmosphere. The supply of oxygen to a shallow, fuel-contaminated aquifer is constantly renewed by the influx of oxygenated, upgradient flow and the vertical diffusion of oxygen from the unsaturated soil zone into the groundwater (Borden and Bedient, 1986). The rate of natural biodegradation in unsaturated soil and shallow aquifers is largely dependent upon the rates at which oxygen and other electron acceptors enter the contaminated media.

To estimate the impact of natural attenuation on the fate and transport of BTEX compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminants at the field scale. Dissolved concentrations of biologically recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters such as groundwater seepage velocity and dilution to demonstrate that a reduction in contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass-balance calculations to show that areas with BTEX contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, groundwater flow and solute

transport models can be used to simulate the fate and transport of dissolved BTEX compounds under the influence of the process of natural attenuation.

Analytical and numerical models are available for modeling the fate and transport of fuel hydrocarbons under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. Analytical models derived from advection-dispersion equations and/or the Bioplume II numerical model will be used, as appropriate. The analytical solute transport models are derived from advection-dispersion equations given by Wexler (1992) and van Genuchten and Alves (1982). These models provide exact, closed-form solutions and are appropriately used for relatively simple hydrogeologic systems that are homogeneous and isotropic. Each model is capable of simulating advection, dispersion, sorption, and biodegradation (or any first-order decay process). These models can simulate continuous or decaying sources. A continuous-source model is useful for prediction of the worst-case distribution of the dissolved contaminant plume. A decaying-source model is useful for simulating scenarios including natural weathering processes or source removal via an engineered solution.

The Bioplume II numerical model is based upon the US Geological Survey (USGS) two-dimensional (2-D) solute transport model (Konikow and Bredehoeft, 1978), which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the groundwater and once for a dissolved oxygen plume. The two plumes are then combined using superimposition at every particle move to simulate biological reactions between fuel products and oxygen. If appropriate, biodegradation of contaminants by anaerobic processes is simulated using a first-order anaerobic decay rate.

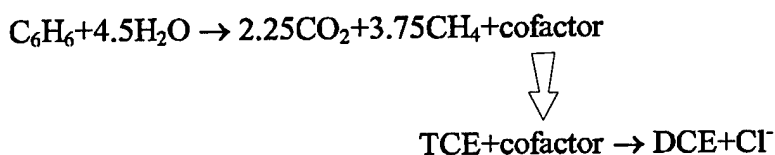
2.2.3 Biodegradation of CAHs

Chlorinated solvents can be transformed by biological processes (e.g., Bouwer *et al.*, 1981; Wilson and Wilson, 1985; Miller and Guengerich, 1982; Nelson *et al.*, 1986; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gosset, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; McCarty and Semprini, 1994; Vogel, 1994). However, the transformation differs from BTEX degradation because microorganisms typically do not obtain free energy from the transformation of chlorinated solvents. Instead, chlorinated solvent degradation is largely accomplished through cometabolism. Microorganisms in the groundwater produce enzymes or cofactors during the degradation of BTEX or other organic carbon sources. These enzymes and/or cofactors then participate in the degradation of the chlorinated solvents. Chlorinated solvents are usually only partially transformed during cometabolic processes (McCarty and Semprini, 1994). Either hydrolysis or dehalogenation is generally required to complete the transformation.

There also appears to be a correlation between cometabolism reaction rates and reducing conditions; the more reducing the conditions, the more quickly dechlorination of highly chlorinated compounds (e.g., PCE, TCE, and DCE) occurs. Bouwer and Wright (1988) documented that reaction rates of cometabolism tend to be faster under reducing conditions associated with methanogenesis than under less reducing conditions associated with denitrification. At CCFTA-2 (FT-17), the core of the plume is probably anaerobic and the principal BTEX biodegradation processes are likely to be both aerobic and anaerobic. Highly reducing (anaerobic) conditions will be favorable for cometabolism of highly chlorinated solvents (e.g., PCE, TCE, and DCE). If it is

occurring, aerobic respiration would have the greatest impact on the fringes and downgradient portions of the plume.

Studies have shown that TCE can be anaerobically reduced to either 1,1-, cis-1,2-, or trans-1,2-DCE (with cis-1,2-DCE acting as the primary pathway), all of which can be further transformed to VC (Miller and Guengerich, 1982; Wilson and Wilson, 1985; Mayer *et al.*, 1988; Nelson, *et al.*, 1986; Henson *et al.*, 1989; Tsien *et al.*, 1989; Henry, 1991; McCarty, 1994; Wilson *et al.*, 1994). VC may be subsequently reduced to innocuous products such as ethane or carbon dioxide. The reduction of VC occurs more readily under aerobic conditions, such as those encountered at the edge of the plume. VC may even be used as a primary substrate by aerobic organisms (McCarty and Semprini, 1994). Anaerobic and aerobic degradation pathways for CAHs are presented on Figures 2.11 and 2.12, respectively. The following equations demonstrate the cometabolic degradation of TCE to the first intermediate product (cis- or trans-1,2-DCE) using a cofactor derived from the methanogenesis of benzene as a catalyst:



Similar relationships can be developed for each of the intermediate products. TCE is indirectly transformed by hydrocarbon-degrading bacteria as BTEX or another substrate is used to meet their energy requirements. Therefore, TCE does not enhance the degradation of BTEX, nor will its cometabolism interfere with the use of electron acceptors involved in the oxidation of BTEX. It is possible, however, that the cometabolic degradation of high levels of TCE or one of the intermediate products

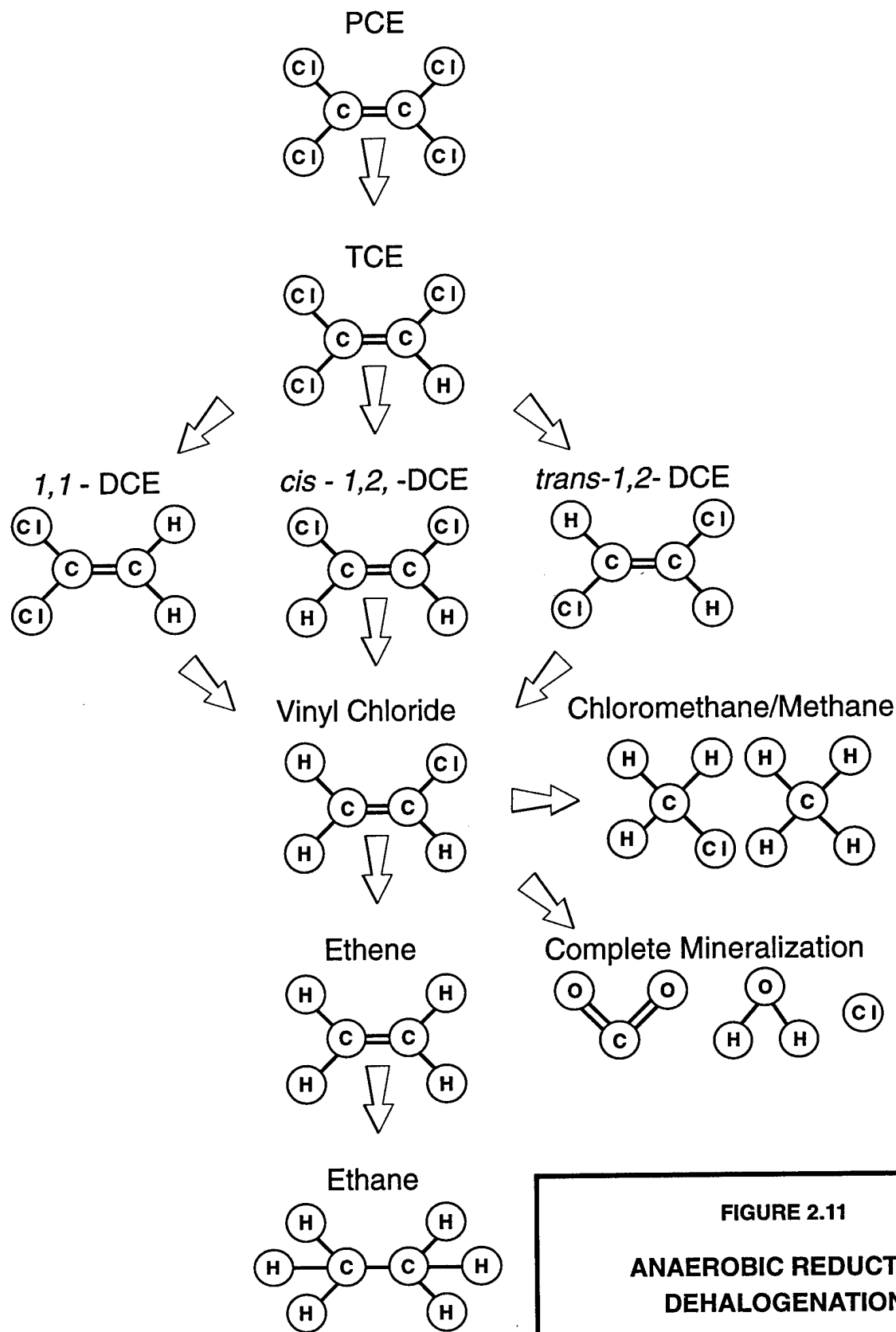


FIGURE 2.11

ANAEROBIC REDUCTIVE DEHALOGENATION

CCFTA-2 (FT-17)
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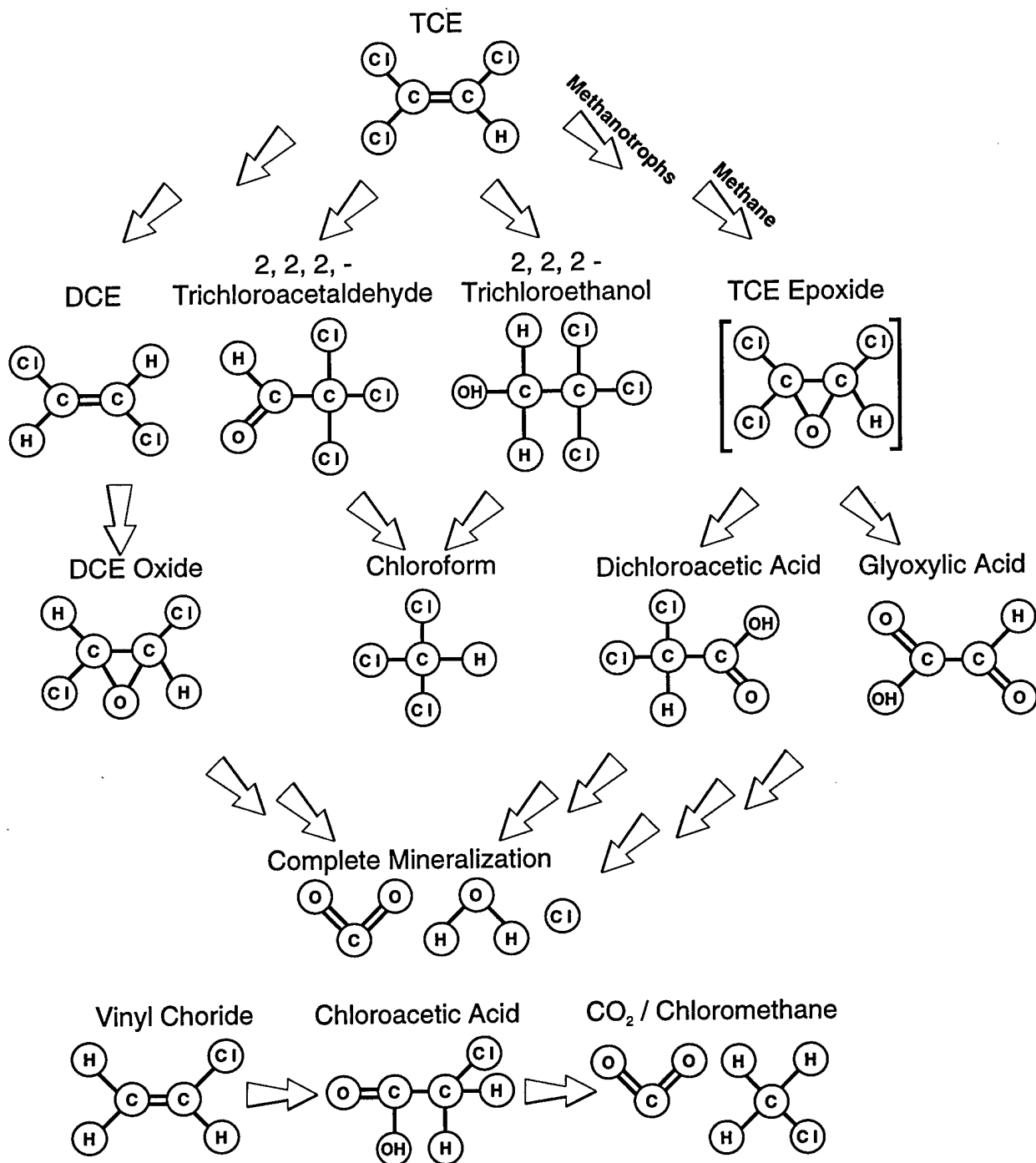


FIGURE 2.12

AEROBIC DEHALOGENATION

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canvaeral AS, Florida



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could have toxic side effects on the microorganisms involved in the BTEX degradation. In addition, depletion of suitable substrates (BTEX or other organic carbon sources) may limit cometabolism of CAHs.

Analytical and numerical models are available for modeling the fate and transport of CAHs under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation (cometabolism). Analytical models derived from advection-dispersion equations [e.g., the same models as used for BTEX compounds, such as Wexler (1992) and van Genuchten and Alves (1982)] may be useful. However, because CAH biodegradation may be the result of different processes in different locations, it may be necessary to be able to incorporate spatial variability in contaminant decay rates. A numerical solute fate and transport model code (such as MT3D) could be used in conjunction with a groundwater flow model code (such as MODFLOW) to evaluate the migration of CAHs dissolved in groundwater.

2.2.4 Initial Conceptual Model

Site CCFTA-2 (FT-17) geologic data were previously integrated to produce geologic cross-sections of the site. Cross-sections A - A' and B - B' (Figures 2.5 and 2.6) show that the site hydrogeology is relatively simple. Figure 2.7 is a groundwater surface map prepared using 1994 groundwater elevation data (OBG, 1995b).

Groundwater is present approximately 5 feet bgs in the sand and gravel deposits in the vicinity of the site, and it flows to the southwest. The relatively low hydraulic gradient inhibits groundwater movement. The deeper aquifers may not receive any vertical recharge due to the discharge of the shallow aquifer to the canal and the Banana River. On the basis of the available data, Parsons ES will model the site as an

unconfined, fine- to coarse-grained sand aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Mobile LNAPL is present at CCFTA-2 (FT-17). Because LNAPL is present, it may be necessary to use the NAPL/water partitioning models of Bruce *et al.* (1991), Cline *et al.* (1991), or Johnson and Pankow (1992) to provide a conservative source term to model the partitioning of solutes from the LNAPL into the groundwater. In order to use one of these models, samples of free product will be collected and analyzed for mass fraction of BTEX and CAHs. Parsons ES will also attempt to collect groundwater samples from immediately below the LNAPL layer, if possible.

The chemicals of concern in groundwater at CCFTA-2 (FT-17), BTEX and CAHs, will be the primary focus of this intrinsic remediation study because of their regulatory importance. The chemicals of concern for the site are expected to leach from contaminated soil or partition from mobile LNAPL containing fuel and chlorinated solvents into the groundwater, and to migrate downgradient as a dissolved contaminant plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption), these dissolved contaminants will likely be removed from the groundwater system by naturally occurring destructive attenuation mechanisms, such as biodegradation. The effects of these fate and transport processes on the dissolved groundwater plume will be investigated using quantitative groundwater analytical data and the solute-transport models. Data collection and analysis requirements are discussed in Section 3 of this work plan.

2.2.5 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater discharge points and subsurface utility corridors (artificial conduits) will be identified

during the field work phase of this project. The primary release mechanisms and potential migration path for contaminants at the site are from the mobile LNAPL and the remaining contaminated soils at the site into the groundwater, and from the groundwater to potential receptors via consumption, incidental contact, and discharge to surface waters.

Shallow groundwater beneath CCFTA-2 (FT-17) flows toward the southwest. There are no known operating potable or nonpotable water wells (other than monitoring wells) downgradient of the site. Surface drainage by overland flow from the site is to the southwest toward the canal, which flows west-northwest toward the Banana River. Because the site is relatively isolated in a low-use area of the Base, flora and fauna are the probable receptors of any soil, surface water, sediment, or groundwater contamination.

The potential for exposure to contaminated water originating at the site through ingestion is low because Base access is restricted, and Base drinking water does not come from wells located within the Base.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to demonstrate that intrinsic remediation of fuel-related contaminants and chlorinated solvents is occurring, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the groundwater surface in site monitoring wells;
- Locations of potential groundwater recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Measurement of extent and thickness of mobile LNAPL.

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentration;
- Specific conductance;
- pH;

- Reduction/oxidation (redox) potential;
- Total organic carbon (TOC);
- Chemical analysis of mobile LNAPL to determine mass fraction of BTEX and CAHs; and
- Additional chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

To obtain these data, soil, groundwater, and mobile LNAPL samples will be collected and analyzed. However, given the relatively thorough delineation of soil contamination during RI/FS activities, soil sampling for this demonstration may be minimized or omitted so that additional groundwater and LNAPL samples may be collected and analyzed. The following sections describe the procedures that will be followed when collecting additional site-specific data. Samples from CCFTA-2 (FT-17) will be collected from previously installed groundwater monitoring wells and monitoring points, and additional soil sampling, groundwater grab sampling, and well point installation at the site will be accomplished using the Geoprobe[®] system, which is described in Sections 3.1 and 3.2. Procedures to be used to collect soil core samples are described in Section 3.1. Procedures to be used for the installation of new monitoring points are described in Section 3.2. Procedures to be used to collect groundwater grab samples and to sample groundwater monitoring wells and newly installed groundwater monitoring points are described in Section 3.3. Sample handling procedures are described in Section 3.4, and procedures used to measure aquifer parameters (e.g. hydraulic conductivity) are described in Section 3.5.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUNDWATER AND SOIL SAMPLES
 CCFTA-2 (FT-17)
 INTRINSIC REMEDIATION TS
 CAPE CANAVERAL AS, FLORIDA

MATRIX Analyte	METHOD	FIELD (F) OR FIXED-BASE LABORATORY (L)
WATER		
Total Iron	Colorimetric, Hach Method 8008	F
Ferrous Iron (Fe ²⁺)	Colorimetric, Hach Method 8146	F
Ferric Iron (Fe ³⁺)	Difference between total and ferrous iron	F
Manganese	Colorimetric, Hach Method 8034	F
Sulfate	Colorimetric, Hach Method 8051	F
Nitrate	Titrimetric, Hach Method 8039	F
Nitrite	Titrimetric, Hach Method 8507	F
Redox Potential	A2580B, direct-reading meter	F
Oxygen	Direct-reading meter	F
pH	E150.1/SW9040, direct-reading meter	F
Conductivity	E120.1/SW9050, direct-reading meter	F
Temperature	E170.1, direct-reading meter	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Alkalinity (Carbonate [CO ₃ ²⁻] and Bicarbonate [HCO ₃ ⁻])	F = Titrimetric, Hach Method 8221 L = EPA M+B54ethod 310.1	F L
Nitrate + Nitrite	EPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147 ^{u/}	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs (BTEX + CAHs)	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
VOCs (BTEX + CAHs)	RSKSOP-124, modified	L
Total Hydrocarbons	RSKSOP-174	L
MOBILE LNAPL		
BTEX/CAH Mass Fraction	GC/MS, Direct Injection	L

^{u/} RSKSOP = Robert S. Kerr Laboratory(now NRMRL) Standard Operating Procedure.

NOTE: Additional analyses (as indicated in Appendix A) may also be performed at the discretion of Parsons ES and USEPA NRMRL personnel.

3.1 SOIL SAMPLING

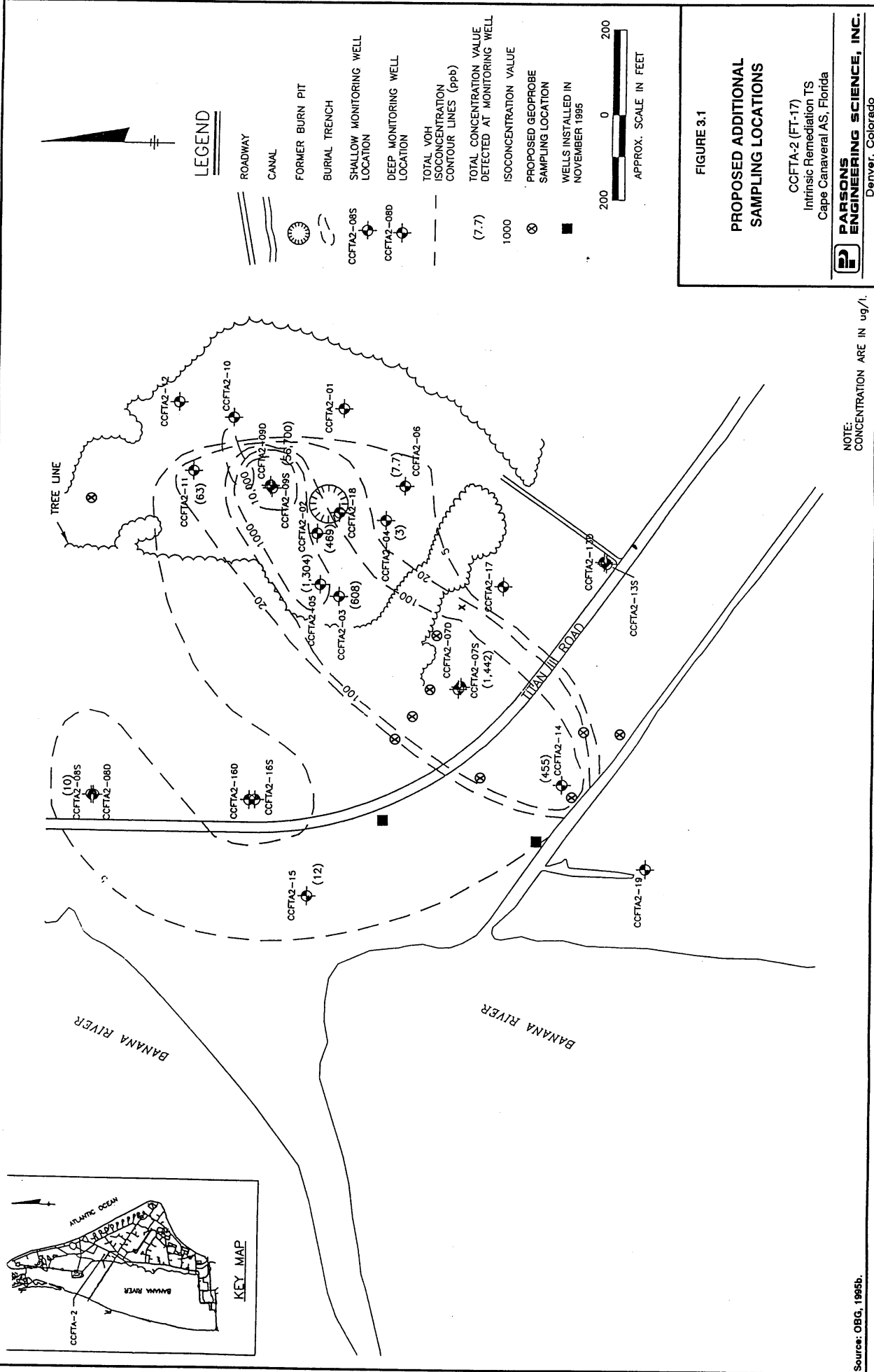
The following sections describe soil sampling locations, sample collection techniques, equipment decontamination procedures, site restoration, and management of investigation-derived waste materials.

3.1.1 Soil Sampling Locations and Required Analyses

Soil samples may be collected at all Geoprobe® and monitoring point installation locations. Figure 3.1 identifies the proposed locations of sample collection at CCFTA-2 (FT-17). Table 3.1 presents an analytical protocol for soil and groundwater samples, and Appendix A contains detailed information on the analyses and methods to be used during this sampling effort. Because of the number of wells present at the site and the relatively thorough soil characterization documented in the RI/FS, soil sampling may be minimized or omitted, depending on working conditions at the site.

Where soil samples are collected, a minimum of two samples will be collected from each hole location. One sample will be taken at the water table, and one will be taken at the depth of maximum BTEX contamination, as determined by soil headspace screening. Sampling locations for this study will generally be in the downgradient margins of the plume. Additional samples and sampling intervals may be selected at the discretion of the Parsons ES scientist.

A portion of each sample will be used to measure soil headspace, while another portion of selected samples will be sent to the laboratory for analytical analysis. Each laboratory soil sample will be placed in an analyte-appropriate sample container and hand-delivered to the USEPA field laboratory personnel for analysis of total hydrocarbons, aromatic hydrocarbons, CAHs, and moisture content using the



procedures presented in Table 3.1. If possible, at least two saturated soil samples from locations upgradient, crossgradient, or far downgradient of the contaminant source will be analyzed for TOC. Each headspace screening sample will be placed in a sealed plastic bag or mason jar and allowed to sit for at least 5 minutes. Soil headspace will then be determined using an organic vapor meter (OVM), and the results will be recorded in the field records by the Parsons ES field scientist.

3.1.2 Sample Collection Using the Geoprobe® System

Soil samples will be collected using a Geoprobe® system, which is a hydraulically powered percussion/probing machine capable of advancing sampling tools through unconsolidated soils. This system allows rapid collection of soil, soil gas, or groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.2 is a diagram of the Geoprobe® system.

Soil samples will be collected using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler is pushed or driven to the desired sampling depth, the drive point is retracted to open the sampling barrel, and the sampler is subsequently pushed into the undisturbed soils. The soil cores are retained within brass, stainless steel, or clear acetate liners inside the sampling barrel. The probe rods are then retracted, bringing the sampling device to the surface. The soil sample can then be extruded from the liners for lithologic logging, or the liners can be capped, and the undisturbed samples can be submitted to the analytical laboratory for testing.

If the probe-drive sampling technique described above is inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site,

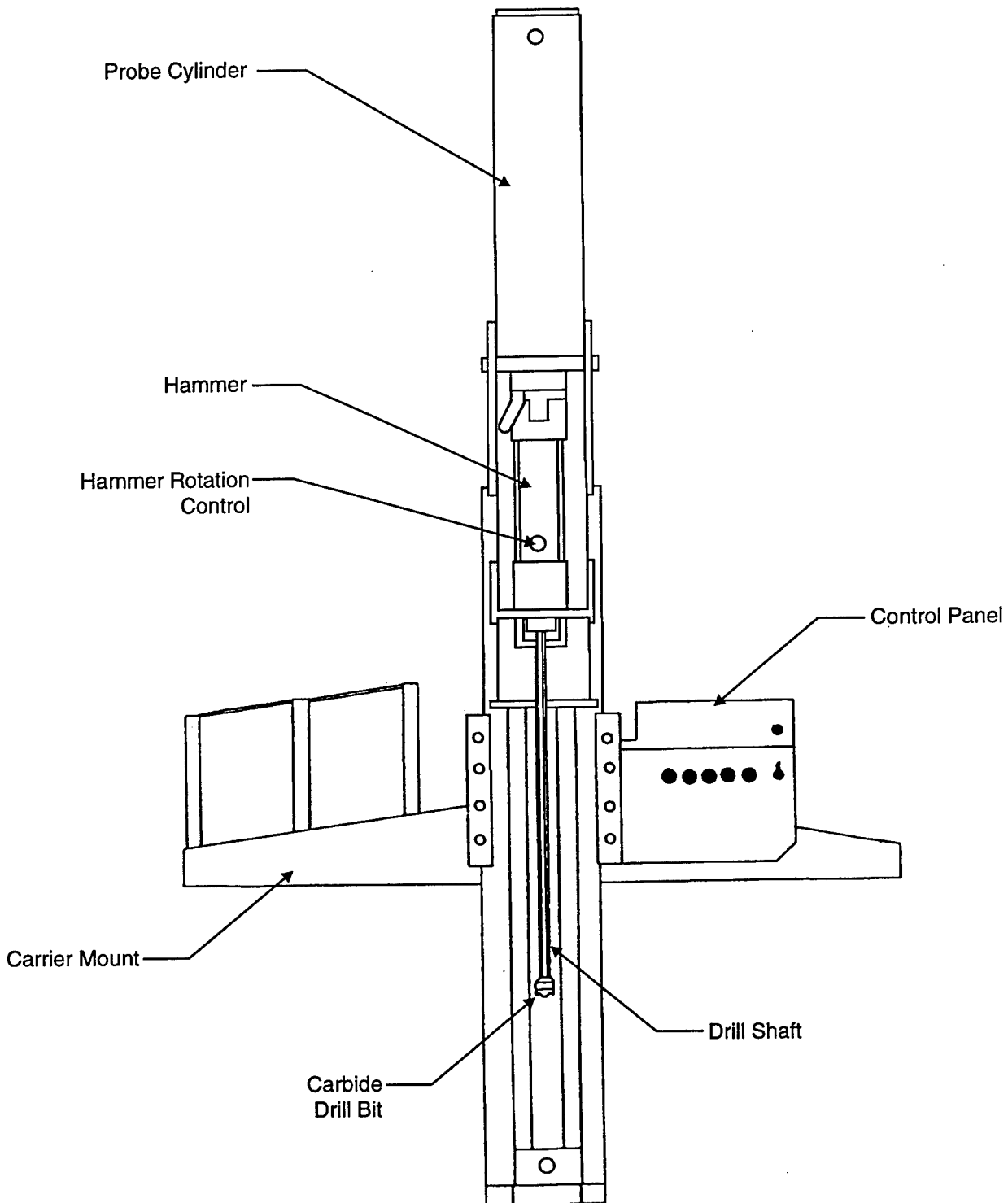


FIGURE 3.2

**CROSS-SECTION
OF GEOPROBE®**

CCFTA-2 (FT-17)
Intrinsic Remediation TS
Cape Canaveral AS, Florida



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continuous soil samples will be obtained from conventional soil boreholes using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example geologic boring log form is presented in Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination (as indicated by OVM readings);
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Base personnel will be responsible for identifying the location of all utility lines, fuel lines, or any other underground infrastructure prior to any sampling activities. All necessary digging permits will be obtained through Base personnel prior to mobilizing to the field. If necessary, base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations. Parsons ES and the USEPA NRMRL will provide trained operators for the Geoprobe®.

GEOLOGIC BORING LOG

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: _____ RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: _____ DRLG METHOD: _____ ELEVATION: _____
 LOCATION: _____ BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res				
					No.	Depth (ft)		PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1										
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

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

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

 Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

CCFTA-2 (FT-17)
 Intrinsic Remediation TS
 Cape Canaveral AS, Florida



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3.1.3 Datum Survey

The horizontal location of all soil sampling locations relative to established site coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface will also be measured to the nearest 0.1 foot relative to USGS msl data.

3.1.4 Site Restoration

After sampling is complete, each sampling location will be restored as closely to its original condition as possible. Holes created by the Geoprobe[®] in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive sampler. However, any test holes remaining open after extraction of the penetrometer rod will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Soil sampling using the Geoprobe[®] creates low volumes of soil waste. Soil not used for sampling will be placed in 55-gallon drums to await proper disposal. Alternate methods of soil waste disposal will be considered by the Parsons ES field scientist as recommended by Base personnel.

3.1.5 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination. All rinseate will be collected in 210-gallon purge tanks for transportation and proper disposal.

Between each soil sample, the sampling barrel will be disassembled and decontaminated with Alconox[®] and potable water. The barrel will then be rinsed with

deionized water and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination.

All rinseate will be collected in 210-gallon purge tanks for transportation and proper disposal. Alternate methods of rinseate disposal will be considered by the Parsons ES field scientist as recommended by Base personnel.

Potable water to be used during equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2 MONITORING POINT INSTALLATION

To further characterize site hydrogeologic conditions, up to 20 groundwater monitoring points may be installed at 10 locations at CCFTA-2 (FT-17) to supplement previously installed site monitoring wells. The following sections describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures. If site conditions prevent installation of monitoring points, groundwater grab samples will be collected using the Geoprobe® apparatus.

3.2.1 Monitoring Point Locations and Completion Intervals

The locations of the proposed additional soil and groundwater sampling locations are identified on Figure 3.1. The proposed locations for the new monitoring points were determined from a review of data gathered during previous site activities and from a

site visit, during which the locations of the most recently installed monitoring wells (not shown on Figure 3.1) were ascertained. Monitoring point locations were selected to provide hydrogeologic data necessary for successful implementation of a site-specific contaminant fate and transport model and to monitor potential fuel hydrocarbon and chlorinated solvent migration from the site. Monitoring point locations were selected to provide additional data on natural attenuation processes in the downgradient portions of the CAH plume. The proposed locations shown on Figure 3.1 may be modified in the field as a result of encountered field conditions and acquired field data.

Monitoring points may be installed singly, or in clusters of up to three points. Single monitoring points will be screened near the top of the saturated zone. All shallow monitoring points will have a screened interval of 3 feet, while deeper points will have 6-inch screens. Monitoring point clusters will include one point screened at the top of the saturated zone, with the exact depth of the remaining monitoring points to be determined by the Parsons ES field scientist on the basis of site conditions. The proposed screened intervals of 3 feet for shallow and deep monitoring points will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated groundwater in the monitoring point casing. Adjustments of the depth and length of the screened interval of the monitoring points may be necessary in response to actual aquifer conditions and contaminant distribution identified during Geoprobe[®] testing.

3.2.2 Monitoring Point Installation Procedures

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, and drilling permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed

drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.2.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Monitoring Point Materials Decontamination

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points and tubing will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

3.2.2.3 Installation and Materials

This section describes the procedures to be used for installation of monitoring points. Monitoring points will be installed using either 0.375-inch Teflon[®] tubing connected to a 0.5-inch-diameter stainless steel screen or a 0.5-inch inside-diameter (ID)/0.75-inch outside-diameter (OD) polyvinyl chloride (PVC) screen and casing.

3.2.2.3.1 Deep Monitoring Points

The deep monitoring points will be installed in boreholes punched using the Geoprobe[®]. The deep monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch-diameter stainless steel mesh that will function as the well screen, which in turn will be connected to 0.375-inch Teflon[®] tubing.

To install the deep monitoring points, the borehole is punched and sampled to several feet above the target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon[®] tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly, and tubing behind. The soil is likely to cave in around the screen and tube assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point, and the borehole annular space around the tubing above the sand pack will be filled with granular bentonite or grout to seal it. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4).

3.2.2.3.2 Shallow Monitoring Points

If subsurface conditions permit, shallow monitoring points will be constructed of 0.75-inch-OD/0.5-inch-ID PVC casing and well screen to provide additional water level information. Approximately 3 feet of factory-slotted screen will be installed for each shallow monitoring point. Effective installation of the shallow monitoring points requires that the boreholes remain open upon completion of drilling. Shallow 0.5-inch-ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe[®]. Upon removing the rods, the borehole depth will be measured to determine if the hole remains open. If the borehole is open, the 0.5-inch-ID PVC casing and screen will be placed at the appropriate depths. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing will be filled with grout or bentonite. Monitoring point construction details will be noted on a

Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

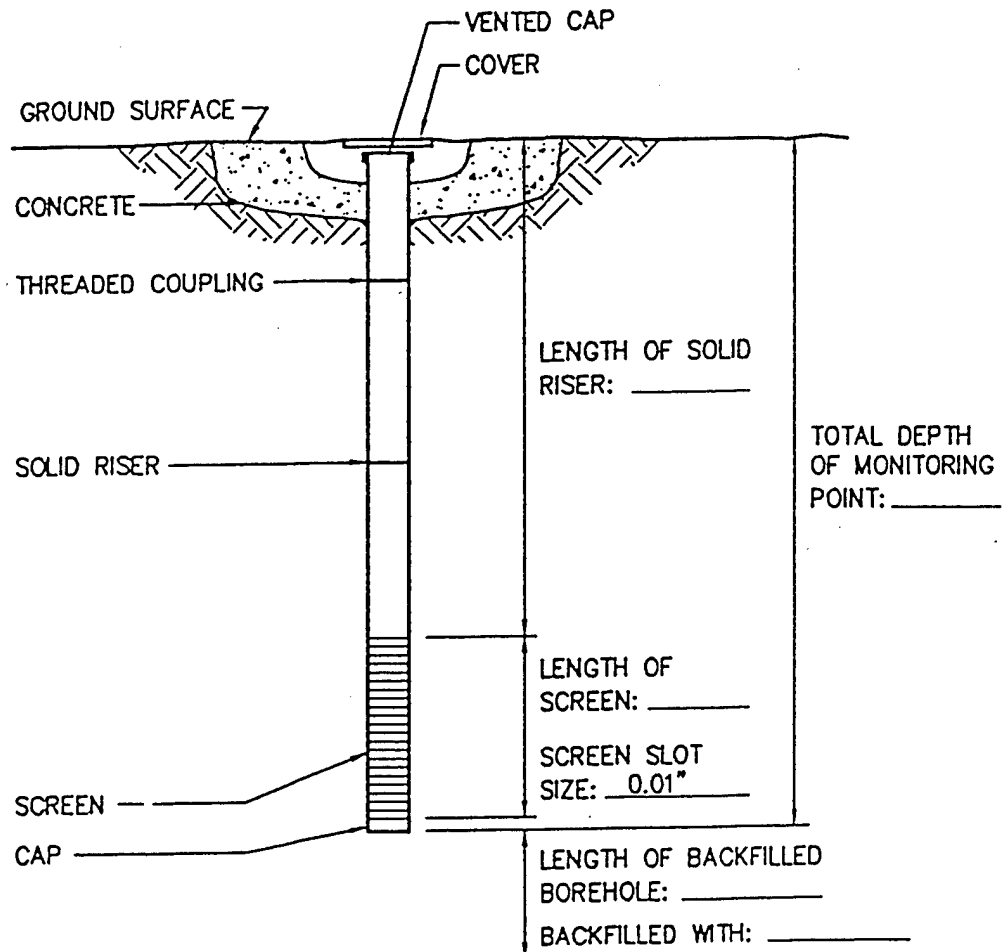
Monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch openings. Monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5 inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC.

If subsurface conditions do not permit the boreholes to stay open (i.e., if the formation collapses in the hole), shallow 0.5-inch-ID PVC monitoring points may be installed using the Geoprobe[®]. If the installation of 0.5-inch PVC monitoring points is not possible or is impractical using the Geoprobe[®], monitoring points constructed of 0.375-inch Teflon[®] described in Section 3.2.2.3.1 will be installed. Should 0.5-inch-ID PVC shallow monitoring points not be installed, the only resulting data gap will be the lack of water level information for that particular location. The decision to install 0.5-inch-ID PVC monitoring points will be made in the field once the open-hole stability of subsurface soils and Geoprobe[®] equipment can be evaluated.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

MONITORING POINT INSTALLATION RECORD

JOB NAME _____ MONITORING POINT NUMBER _____
 JOB NUMBER _____ INSTALLATION DATE _____ LOCATION _____
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL _____ SLOT SIZE _____
 RISER DIAMETER & MATERIAL _____ BOREHOLE DIAMETER _____
 CONE PENETROMETER CONTRACTOR _____ ES REPRESENTATIVE _____



(NOT TO SCALE)

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

CCFTA-2 (FT-17)
 Intrinsic Remediation TS
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STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 TOTAL MONITORING POINT DEPTH _____ FEET
 BELOW DATUM.
 GROUND SURFACE _____ FEET

3.2.2.4 Monitoring Point Completion or Abandonment

A number of the monitoring points will be completed above grade, and as needed, steel or PVC protective casing will be used to protect the well points from tampering and damage. The number of permanent monitoring points will be determined by the Parsons ES field scientist. The completion of the monitoring points will be similar to those protecting the existing monitoring wells unless otherwise specified by Base personnel.

Those monitoring points not completed with an external protective casing will be abandoned. The PVC casing and screen or Teflon[®] tubing will be extracted as far as possible and discarded. While holes created by the Geoprobe[®] in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive rod, any test holes remaining open after extraction of the casing will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. After monitoring point completion or abandonment, each site will be restored as closely as possible to its original condition.

3.2.3 Monitoring Point Development and Records

The monitoring points will be developed prior to sampling to remove fine sediments from the portion of the formation adjacent to the well point screen. Development will be accomplished using a peristaltic pump provided by USEPA NRMRL or Parsons ES. The pump will be inserted into or attached to the well point, and water will be removed until dissolved oxygen (DO) pH, temperature, and specific conductivity stabilize. Monitoring point development will occur a minimum of 24 hours prior to sampling.

A development record will be maintained for each monitoring point. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

Development waters will be collected in a 210-gallon tank for proper disposal.

3.2.4 Monitoring Point Location and Datum Survey

The location and elevation of the well points will be surveyed soon after completion. Horizontal coordinates will be measured to the nearest 0.1 foot relative to established Base coordinates. The elevation of the ground surface adjacent to the protective casing will be measured relative to the USGS msl datum. The ground surface elevation will be measured to the nearest 0.1 foot. A top of casing datum will be measured to the nearest 0.01 foot for all monitoring points constructed of 0.5-inch PVC casing and well screen. Because water levels cannot be measured through the well point tubing, no datum elevation, such as top of casing, will be measured for monitoring points constructed with Teflon[®] tubing.

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: 722450.29

Job Name: AFCEE Natural Attenuation

Location Cape Canaveral AS

By MS/MV

Date

Well Number

Measurement Datum

Pre-Development Information

Time (Start):

Water Level:

Total Depth of Well:

Water Characteristics

Color Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material
pH Temperature(°F °C)
Specific Conductance(μS/cm)

Interim Water Characteristics

Gallons Removed

pH

Temperature (°F °C)

Specific Conductance(μS/cm)

Post-Development Information

Time (Finish):

Water Level:

Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material
pH Temperature(°F °C)
Specific Conductance(μS/cm)

Comments:

I:\forms\develop.doc

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

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Cape Canaveral AS, Florida



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3.2.5 Water Level Measurements

Water levels at existing monitoring wells and monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe or an oil/water interface probe.

3.3 GROUNDWATER SAMPLING PROCEDURES

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from site monitoring wells (e.g., wells CCFTA2-1 through CCFTA2-19, and any new wells at the site), newly installed groundwater monitoring points, and at any grab-sample locations. A peristaltic pump or bladder pump with dedicated high-density polyethylene (HDPE) tubing will be used to collect groundwater samples at all wells and monitoring points. A Grundfos® Redi-Flow II® pump may be used for monitoring well purging prior to sampling. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parson ES and the USEPA NRMRL who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. Groundwater sampling includes the following activities:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
 - Protective cover, cap, and lock,

- External surface seal and pad,
- Monitoring point stick-up, cap, and datum reference, and
- Internal surface seal;
- Groundwater sampling, including:
 - Water level and product thickness measurements,
 - Visual inspection of sample water,
 - Monitoring point casing evacuation, and
 - Sample collection;
- Sample preservation and shipment, including:
 - Sample preparation,
 - Onsite measurement of physical parameters, and
 - Sample labeling;
- Completion of sampling records: and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Preparation for Sampling

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

3.3.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the Geoprobe[®] sampling tools, sampling pumps, nondisposable bailers, water level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Given the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the USEPA mobile laboratory's permanent record of the sampling event.

3.3.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of dissolved oxygen (DO), pH, electrical conductivity, temperature, redox potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.3.2 Well and Monitoring Point Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and through cross-contamination due to insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water

GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION _____

SAMPLING DATE(S) _____

MONITORING WELL _____

(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____

2 ☐ PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____

4 ☐ WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

FIGURE 3.6

GROUNDWATER SAMPLING RECORD

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MONITORING WELL

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Temp: _____ ° _____ Measured with: _____
pH: _____ Measured with: _____
Conductivity: _____ Measured with: _____
Dissolved Oxygen: _____ Measured with: _____
Redox Potential: _____ Measured with: _____
Salinity: _____ Measured with: _____
Nitrate: _____ Measured with: _____
Sulfate: _____ Measured with: _____
Ferrous Iron: _____ Measured with: _____
Other: _____

[] Filtration: Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

- [] Container Sides Labeled
- [] Container Lids Taped
- [] Containers Placed in Ice Chest

P

3-24

levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well or monitoring point developed, purged, and/or sampled with the sampling pump. Pumps and nondisposable bailers will be decontaminated according to procedures listed in Section 3.3.1.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different well or monitoring point is sampled.

The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring wells and monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook or on the groundwater sampling record.

3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point.

3.3.2.2 Water Level and Total Depth Measurements

Prior to removing water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe or oil/water interface probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly

lowered to the bottom of the monitoring well/point, and the depth will be measured to the nearest 0.01 foot. If free-phase product (mobile LNAPL) is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If mobile LNAPL is encountered, the thickness of the product will be measured with an oil/water interface probe.

3.3.2.3 Monitoring Well/Point Purging

The volume of water contained within the monitoring well/point casing at the time of sampling will be calculated, and at least three times the calculated volume will be removed from the well/point. A peristaltic pump will be used for monitoring well and monitoring point purging, depth and volume permitting, and a Grundfos Redi-Flo II[®] pump, Waterra[®] inertial pump, or bailer will be used to purge all monitoring wells or points in which a peristaltic pump cannot be used. All purge waters will be collected in 210-gallon tanks and disposed of properly.

If a monitoring well/point is evacuated to a dry state during purging, the monitoring well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well/point to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.2.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from monitoring wells/points whenever depth to groundwater permits;

otherwise, a bladder pump, a Waterra[®] inertial pump, or a bailer will be used. The tubing, pump, or bailer will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of in the same manner as purge water.

3.3.2.5 Grab Sampling

In the event monitoring points are not installed, groundwater grab samples will be collected using the Geoprobe[®] apparatus. To collect these samples, a properly decontaminated, screened probe tip will be driven to the desired sampling depth. As it is driven to depth, the screen will be inside the probe rods. After reaching the desired depth, the outer rods will be withdrawn to expose the screen. Purging and sampling procedures will be identical to those for monitoring points. After sampling, the rods and screen will be withdrawn, and the holes will be abandoned as described in Sections 3.1.4 and 3.2.2.4.

3.3.3 Onsite Groundwater Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA staff. Some of the measurements will be made with direct-reading meters, while others will be made using a Hach[®] portable colorimeter in

accordance with specific Hach[®] analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of laboratory-grade, phosphate-free detergent (e.g., Alconox[®]) and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric or colorimetric methods, the analysis will be repeated by diluting the groundwater sample with distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for proper disposal.

3.3.3.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before and immediately following groundwater sample acquisition. When DO measurements are taken in monitoring wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize. The lowest stable DO reading will be recorded.

3.3.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected using

the same technique as the samples taken for laboratory analyses. The measurements will be made in a flow-through cell or a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.6).

3.3.3.3 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced USEPA NRMRL scientists via titrimetric analysis using USEPA-approved Hach® Method 8221 (0 to 5,000 mg/L as calcium carbonate) or a similar method. Alkalinity of the groundwater sample will also be measured in the laboratory using USEPA Method 310.1.

3.3.3.4 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced USEPA NRMRL scientists via colorimetric analysis using a Hach® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with Hach® Method 8039 (0 to 30.0 mg/L NO₃). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved Hach® Method 8507 (0 to 0.35 mg/L NO₂) or a similar method.

3.3.3.5 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by USEPA NRMRL scientists via titrimetric analysis using Hach® Method 8223 (0 to 250 mg/L as CO₂). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.3.3.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. A USEPA NRMRL scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. EPA-approved Hach® Methods 8051 (0 to 70.0 mg/L SO₄) or similar and 8131 (0.60 mg/L S²⁻) or similar will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the redox potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. Hach® Method 8008 (or similar) for total soluble iron (0 to 3.0 mg/L Fe³⁺ + Fe²⁺) and Hach® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe²⁺) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a Hach[®] DR/700 Portable Colorimeter. USEPA approved Hach[®] Method 8034 (0 to 20.0 mg/L Mn) or similar will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.3.

3.3.3.9 Redox Potential

The redox potential of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potentials can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken in the upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis or in a flow through cell.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to USEPA field laboratory.

3.4.1 Sample Preservation

The USEPA laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of as close to 4 degrees centigrade (°C) as possible. Samples will be delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the NRMRL in Ada, Oklahoma for analysis.

3.4.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix A). The sample containers will be filled as described in Sections 3.1.2 and 3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite USEPA field laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the USEPA field laboratory. Delivery will occur as soon as possible after sample acquisition.

3.4.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA field laboratory to the NRMRL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA field personnel.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance, and
 - Sample odor;
- Weather conditions;

- Water level prior to purging (groundwater samples, only);
- Total monitoring well/point depth (groundwater samples, only);
- Sample depth (soil samples, only);
- Purge volume (groundwater samples, only);
- Water level after purging (groundwater samples, only);
- Monitoring well/point condition (groundwater samples, only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (groundwater samples, only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 shows an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples as well as the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, USEPA NRMRL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those listed in Appendix A of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory or USEPA NRMRL field personnel. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA NRMRL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

3.5 AQUIFER TESTING

Slug tests may be conducted on selected monitoring wells to estimate the hydraulic conductivity of unconsolidated deposits at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer 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 (ft²/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon®, PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data-recording instrument (such as the Hermit Environmental Data Logger®, In-Situ, Inc. Model SE1000B, or equivalent).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removing a slug or quantity of water (rising head) or introducing a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; in addition, slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be

decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.1.1.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:
 - Borehole/well number,
 - Project number,
 - Project name,
 - Aquifer testing team,
 - Climatic data,
 - Ground surface elevation,
 - Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Page number,
 - Static water level, and
 - Date.

Aquifer Slug Test Data Sheet

Location _____	Client _____	Well No. _____
Job No. _____	Field Scientist _____	Date _____
Water Level _____	Total Well Depth _____	
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]**FIGURE 3.7**

AQUIFER TEST DATA FORM

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4. Measure the static water level in the well to the nearest 0.01 foot.
5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
6. Lower the decontaminated slug into the well to just above the water level in the well.
7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.

3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ and the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions.

SECTION 4

REMEDIAL OPTION EVALUATION AND TS REPORT

Upon completion of field work, numerical and analytical groundwater models will be used to evaluate the fate and transport of fuel hydrocarbons and chlorinated solvents dissolved in groundwater at the site. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed. If it is shown that intrinsic remediation of CAHs and BTEX compounds at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare site-specific, long-term monitoring plans that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at the site, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, planned and potential remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate combination of remedial options will be recommended. Potential remedial options include, but are not limited to, groundwater pump-and-treat, enhanced biological treatment, bioventing, air sparging, and *in situ* reactive barrier walls. The reduction in dissolved contaminant concentrations that should result from remedial

activities will be used to produce new input files for the groundwater models. The models will then be used to predict the plume (and risk) reduction that should result from remedial actions.

Upon completion of modeling and remedial option selection, a TS report detailing the results of the modeling and remedial option evaluation will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site descriptions, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the suggested remedial approach for each site. This report will also contain the results of the site characterization activities described herein and a description of the models developed for each site.

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
CCFTA-2 (FT-17)
INTRINSIC REMEDIATION TS
CAPE CANAVERAL AS, FLORIDA

INTRODUCTION

Scope and Objectives
Site Background

SITE CHARACTERIZATION ACTIVITIES

Sampling and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Surface Features
Regional Geology and Hydrogeology
Site Geology and Hydrogeology
Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION

Source Characterization
Soil Chemistry
 Residual Contamination
 Total Organic Carbon
Groundwater Chemistry
 LNAPL Contamination
 Dissolved Contamination
 Groundwater Geochemistry
Discussion of Results
 Evidence of Biodegradation/Cometabolism
 Calculation of Biodegradation Rates
 Expressed Assimilative Capacity

GROUNDWATER MODEL

Model Description
Conceptual Model Design and Assumptions
Initial Model Setup
Model Calibration
Sensitivity Analysis
Model Results
Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Remedial Alternative Evaluation Criteria
 Long-Term Effectiveness
 Implementability (Technical, Administrative)
 Cost (Capital, Operating, Present Worth)
Factors Influencing Alternatives Development
 Program Objectives

TABLE 4.1 (concluded)
EXAMPLE TS REPORT OUTLINE
CCFTA-2 (FT-17)
INTRINSIC REMEDIATION TS
CAPE CANAVERAL AS, FLORIDA

Contaminant Properties
Site-Specific Conditions
Brief Description of Remedial Alternatives
Intrinsic Remediation with Long-Term Monitoring
Other Alternatives
Evaluation of Alternatives
Recommended Remedial Approach

LONG-TERM MONITORING PLAN

Overview
Monitoring Networks
Groundwater Sampling

CONCLUSIONS AND RECOMMENDATIONS

APPENDICES: Supporting Data and Documentation
Site-Specific Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the USEPA laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of as close to 4°C as possible.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate groundwater and replicate soil samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

TABLE 5.1
QA/QC SAMPLING PROGRAM
 CCFTA-2 (FT-17)
 INTRINSIC REMEDIATION TS
 CAPE CANAVERAL AS, FLORIDA

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	4 Groundwater and 2 Soil Samples (10%)	VOCs
Rinseate Blanks	2 Samples (5% of Groundwater Samples)	VOCs
Field Blanks	2 Samples (5% of Groundwater Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

Soil and groundwater samples collected with the Geoprobe[®] sampler should provide sufficient volume for some replicate/duplicate analyses. Refer to Table 3.1 and Appendix A for further details on sample volume requirements.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected from existing wells. Because disposable bailers may be used for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a new disposable bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

A field blank will be collected for every 20 or fewer groundwater samples (both from groundwater monitoring point and groundwater monitoring well sampling events) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs. LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used (see Table 3.1).

SECTION 6

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APPENDIX A

CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING

REQUIREMENTS FOR SOIL AND GROUNDWATER SAMPLES

APPENDIX A

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total volatile and extractable hydrocarbons,	Gas chromatography (GC) method SW/8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each soil sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Aromatic and Chlorinated hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]); Chlorinated Compounds	Purge and trap GC method SW/8240	Handbook method modified for field extraction of soil using methanol	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each soil sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the aquifer matrix.	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base

APPENDIX A (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic and chlorinated hydrocarbons (BTEX, trimethylbenzene isomers, chlorinated compounds)	Methods SW8010/8020 or SW8240	Handbook methods; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX & CAHs, which are the primary target analytes for monitoring natural attenuation; BTEX & CAH concentrations must also be measured for regulatory compliance; trimethylbenzenes are used to monitor BTEX plume dilution if degradation is primarily anaerobic.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only when required for regulatory compliance.	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	As required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base
Water	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	Each sampling round	Measure dissolved oxygen on site using a flow-through cell	Field

APPENDIX A (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Preservation	Field or Fixed-Base Laboratory
Water	Nitrate	IC method E300	Method E300 is a Handbook method.	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; add H ₂ SO ₄ to pH less than 2, cool to 4°C	Fixed-base
Water	Iron (II) (Fe ²⁺)	Colorimetric Hach Method # 8146	Filter if turbid.	May indicate an anaerobic degradation process due to depletion of oxygen, and nitrate	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Sulfate (SO ₄ ²⁻)	IC method E300	Method E300 is a Handbook method, if this method is used for sulfate analysis, do not use the field method.	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO ₄ ²⁻)	Hach method # 8051	Colorimetric, if this method is used for sulfate analysis, do not use the fixed-base laboratory method.	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Methane, ethane, and ethene	Kampbell <i>et al.</i> , 1989 or SW3810 Modified	Method published by researchers at the US Environmental Protection Agency.	The presence of CH ₄ suggests BTEX degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing anaerobic biological transformation.	Each sampling round	Collect water samples in 50 mL glass serum bottles with butyl gray/Teflon-lined caps; add H ₂ SO ₄ to pH less than 2, cool to 4°C	Fixed-base

APPENDIX A (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Carbon dioxide	Hach test kit model CA-23; Chemitrics Method R-1910	Titrimetric; alternate method	The presence of free CO ₂ dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the CO ₂ concentrations should be compared with background levels to determine if they are elevated; elevated concentrations of CO ₂ could indicate biodegradation of BTEX	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Alkalinity	Hach Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100 mL of water in glass container	Field
Water	Oxidation-reduction potential	A2580B	Measurements made with electrodes; results are displayed on a meter; protect samples from exposure to oxygen. Report results against a silver/silver chloride reference electrode	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 800 mV to less than -400 mV.	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

APPENDIX A (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	pH	Field probe with direct reading meter.	Field	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	Field probe with direct reading meter.	Field only	Well development	Each sampling round	Not Applicable	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system; elevated concentrations may also indicate biodegradation of CAHs	Each sampling round	Collect 250 mL of water in a glass container	Fixed-base
Water	Chloride (optional, see data use)	Hach Chloride test kit model 8-P	Silver nitrate titration	As above, and to guide selection of additional data points in real time while in the field.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Total Organic Carbon		Laboratory	Used to classify plume and to determine if cometabolism is possible in the absence of anthropogenic carbon	Each sampling round	Collect 100 mL of water in a glass container, cool	Laboratory

APPENDIX A (concluded)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Biochemical Oxygen Demand	EPA Method 405.1			Each sampling round	Collect 2 L of water in a glass container, cool	Laboratory
ADDITIONAL (OPTIONAL) ANALYSES							
Water	Hydrogen (H ₂)		Relatively new analysis; data useful for evaluating biodegradation processes operating at a given time	Indicator of terminal electron-accepting processes operating at a site.	Each sampling round	to be determined	
Water	Oxygenates (including methanol and acetone)	Optional; SW 8015 Modified			Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Laboratory
Water	Alcohols, ethers, and acetic acids	Optional; SW 8015 Modified		Optional carbon sources for biodegradation.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Laboratory
Water	Acetaldehydes	Optional; GC/MS method to be determined			Each sampling round	to be determined	Laboratory
Water	Aliphatic Fatty Acids	Optional; GC/MS method to be determined		Byproducts of biodegradation processes; indicators of biodegradation and cometabolism.	Each sampling round	to be determined	Laboratory
Water	Organic Acids	Optional; GC/MS method to be determined		Optional carbon sources and byproducts of biodegradation processes.	Each sampling round	to be determined	Laboratory

NOTES:

- * Analyses other than those listed in this table may be required for regulatory compliance.
- 1. "Hach" refers to the Hach Company catalog, 1990.
- 2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
- 3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, USEPA, 1983.
- 4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
- 5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
- 6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, USEPA, 3rd edition, 1986.
- 7. "ASTM" refers to the *American Society for Testing and Materials*.
- 8. "LUFT" refers to the State of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.