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**Work Plan for an
Engineering Evaluation/Cost Analysis
in Support of the Intrinsic Remediation
(Natural Attenuation) Option**



**Dover Air Force Base
Dover, Delaware**

Prepared For

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

and

**Dover Air Force Base
Dover, Delaware**

April 1994

ENGINEERING-SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

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SECTION 1

INTRODUCTION

This work plan, prepared by Engineering-Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct an engineering evaluation/cost analysis (EE/CA) for remediation of groundwater contaminated with JP-4 jet fuel at fuel pumping station 950 at site SS27/XYZ located at Dover Air Force Base (AFB), Delaware. Several remedial options will be evaluated during the EE/CA, including free product removal; groundwater extraction, treatment, and reinjection (i.e., pump and treat); air sparging; and natural contaminant attenuation (intrinsic remediation) with long-term monitoring. All hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options will be collected under this program; however, this work plan is oriented toward the collection of hydrogeologic data to be used as input into the Bioplume II[®] groundwater model in support of intrinsic remediation for restoration of fuel-hydrocarbon-contaminated groundwater.

In addition to the EE/CA to be conducted for site SS27/XYZ, limited data will be collected from sites ST04/AAFES (a military fuel station contaminated with gasoline) and D-7 (Zone D) (a former landfill contaminated with vinyl chloride). These data will be used in preliminary screening to determine the potential importance of intrinsic remediation at these sites; therefore, full site characterizations will not be performed. Data collected from these two sites will be used as part of a growing effort by the US Environmental Protection Agency (EPA) Kerr Research Laboratory, the Air Force Center for Environmental Excellence (AFCEE), and ES to document situations amenable to intrinsic remediation when contaminated with compounds other than JP-4 jet fuel.

As part of the EE/CA, the Bioplume II[®] modeling effort has three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to potential downgradient receptors; and 3) to provide technical

support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate.

This work plan was developed based on discussions among representatives from AFCEE, Dover AFB, and ES at a meeting at Dover AFB on November 23, 1993, on the statement of work (SOW) for this project, and on a review of existing site characterization data. The Bioplume II® modeling effort for this site involves completion of several tasks, which are described in the following sections.

All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II® Modeling Initiative* (ES, 1993) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and Dover AFB.

1.1 SCOPE OF CURRENT WORKPLAN

The ultimate objective of the work described herein is to provide an EE/CA for remediation of groundwater contamination at site SS27/XYZ located at Dover AFB, Delaware. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with EPA and ES to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in groundwater by indigenous microorganisms, and to model this degradation using the Bioplume II® numerical groundwater model. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. All data required to design an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities which will be performed in support of the EE/CA and the Bioplume II® modeling effort.

Proposed site characterization activities include cone penetrometer testing, monitoring point placement, soil and groundwater sampling, and aquifer testing. The materials and methodologies required for collection of these data are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II® model. 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 which are known to have the greatest influence on the results of Bioplume II® modeling, and where possible, the model will be calibrated to historical site data. Upon completion of the Bioplume II® model, 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 the most appropriate remedial option, ES will recommend the most appropriate groundwater remedial technology based on available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model 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 EE/CA 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 are two appendices to this work plan. Appendix A contains a listing of the containers, preservatives, packaging, and shipping requirements for groundwater samples. Appendix B contains a summary of existing soil and groundwater analytical data from previous field investigation work.

1.2 SITE BACKGROUND

Dover AFB is located in Kent County in the northern half of Delaware. It is situated 3.5 miles southeast of the center of Dover, Delaware (the state capitol), and is north of the St. Jones river and 2 miles west of Delaware Bay. Figure 1.1 is a regional location map showing the position of Dover AFB relative to the surrounding area. Dover AFB comprises approximately 4,000 acres of land including annexes, easements, and leased property. Most of the area surrounding Dover AFB is croplands and wetlands. The base has operated since 1941, and is currently a member of the Air Mobility Command (AMC) and hosts the 436th Support Group (SPTG), whose primary mission is to provide global strategic airlift capability. As a result, the base operates primarily C-5 Galaxy transport aircraft. Jet fuel leaks emanating from underground infrastructure have created the contamination present at site SS27/XYZ, which is located at the northwest end of the NW/SE runway (Figure 1.2). Building 950 is located at the northwest end of the NW/SE

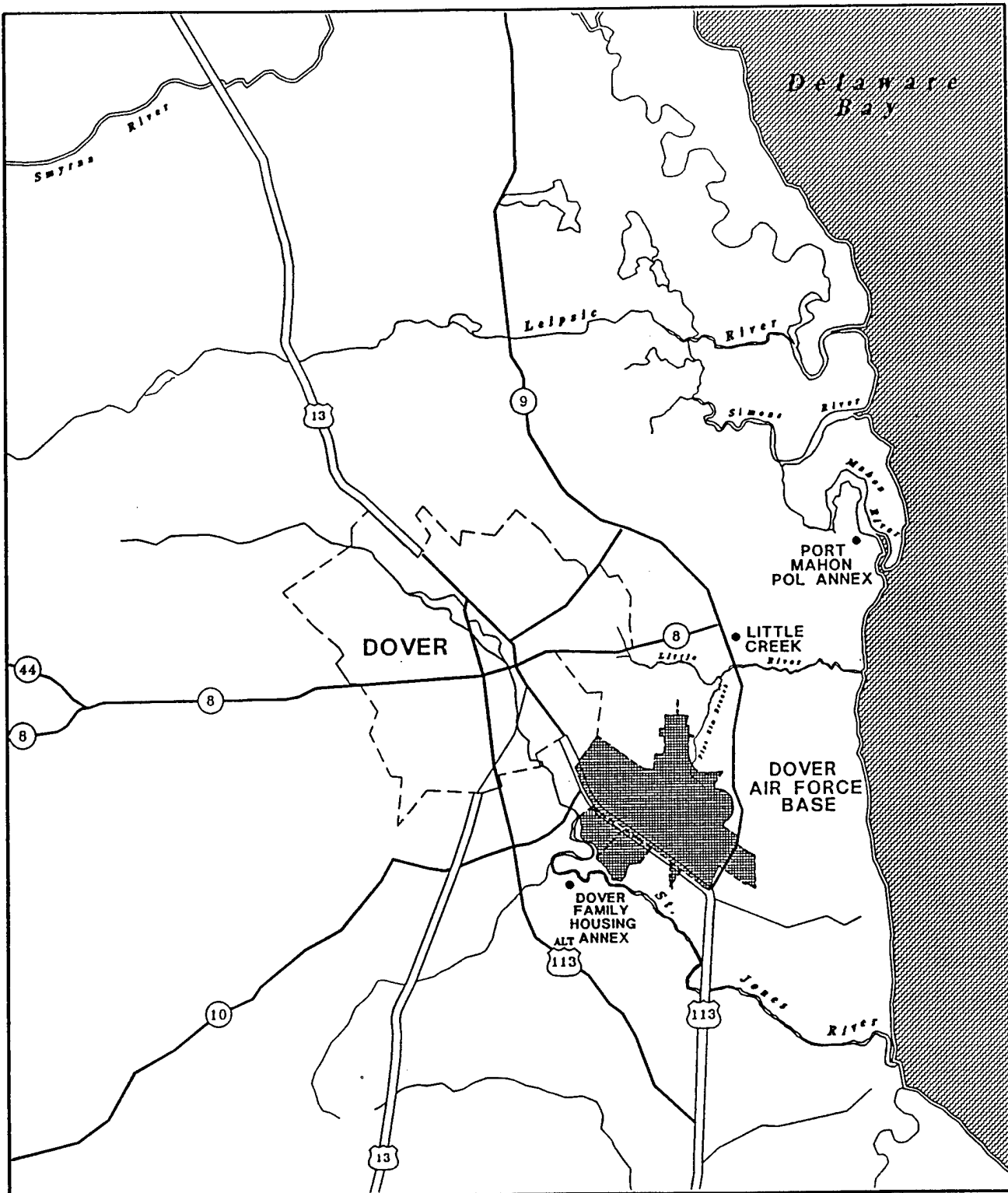


FIGURE 1.1

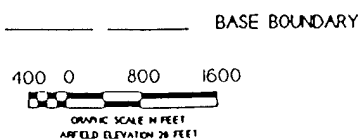
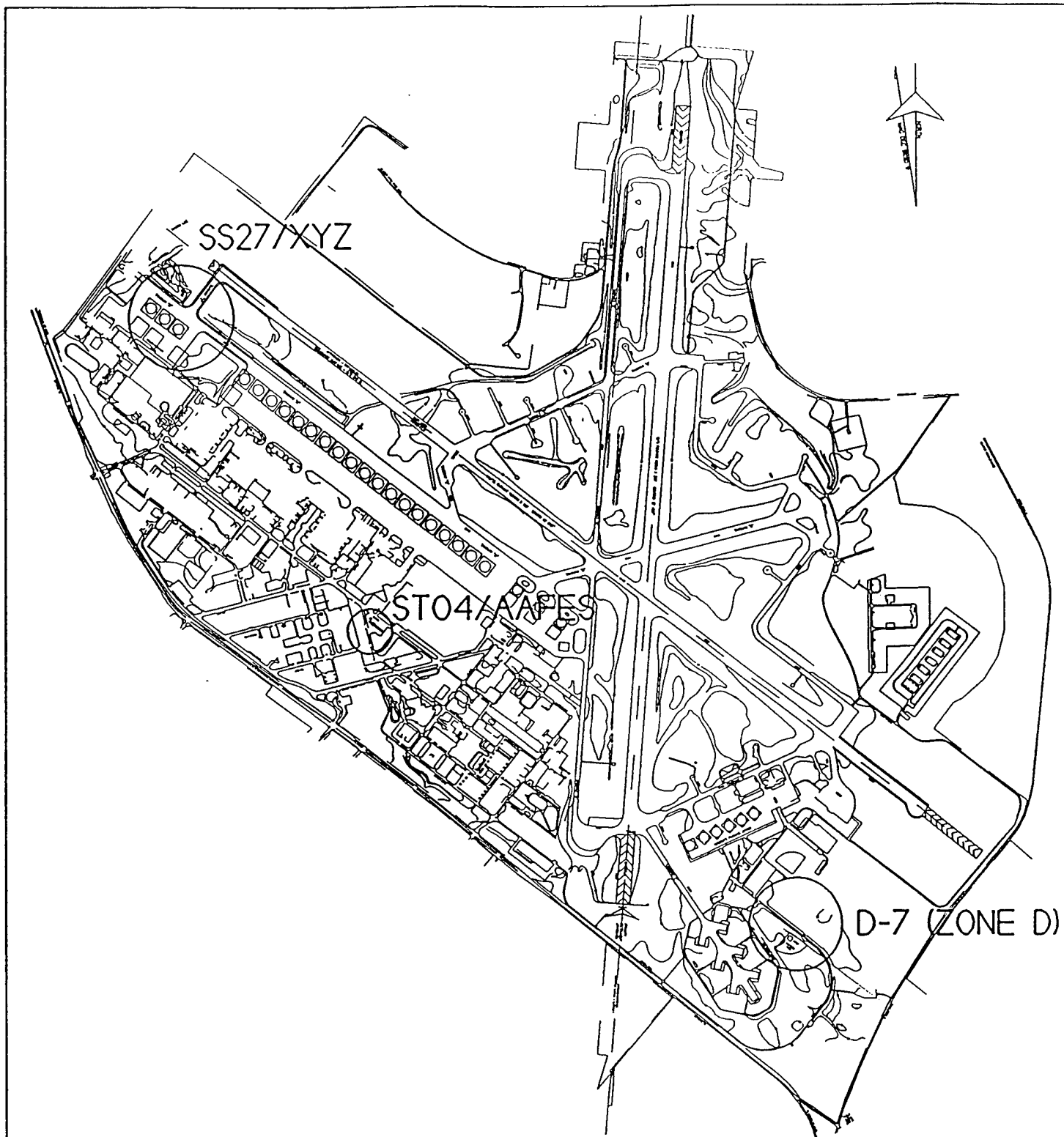
AREA LOCATION MAP OF DOVER AFB

EE/CA - DOVER AFB, DELAWARE

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: DAMES & MOORE, AND HAZWRAP, 1993.



SOURCES: DOVER AFB.

FIGURE 1.2

SITE MAP

EE/CA - DOVER AFB, DELAWARE

ENGINEERING-SCIENCE, INC.

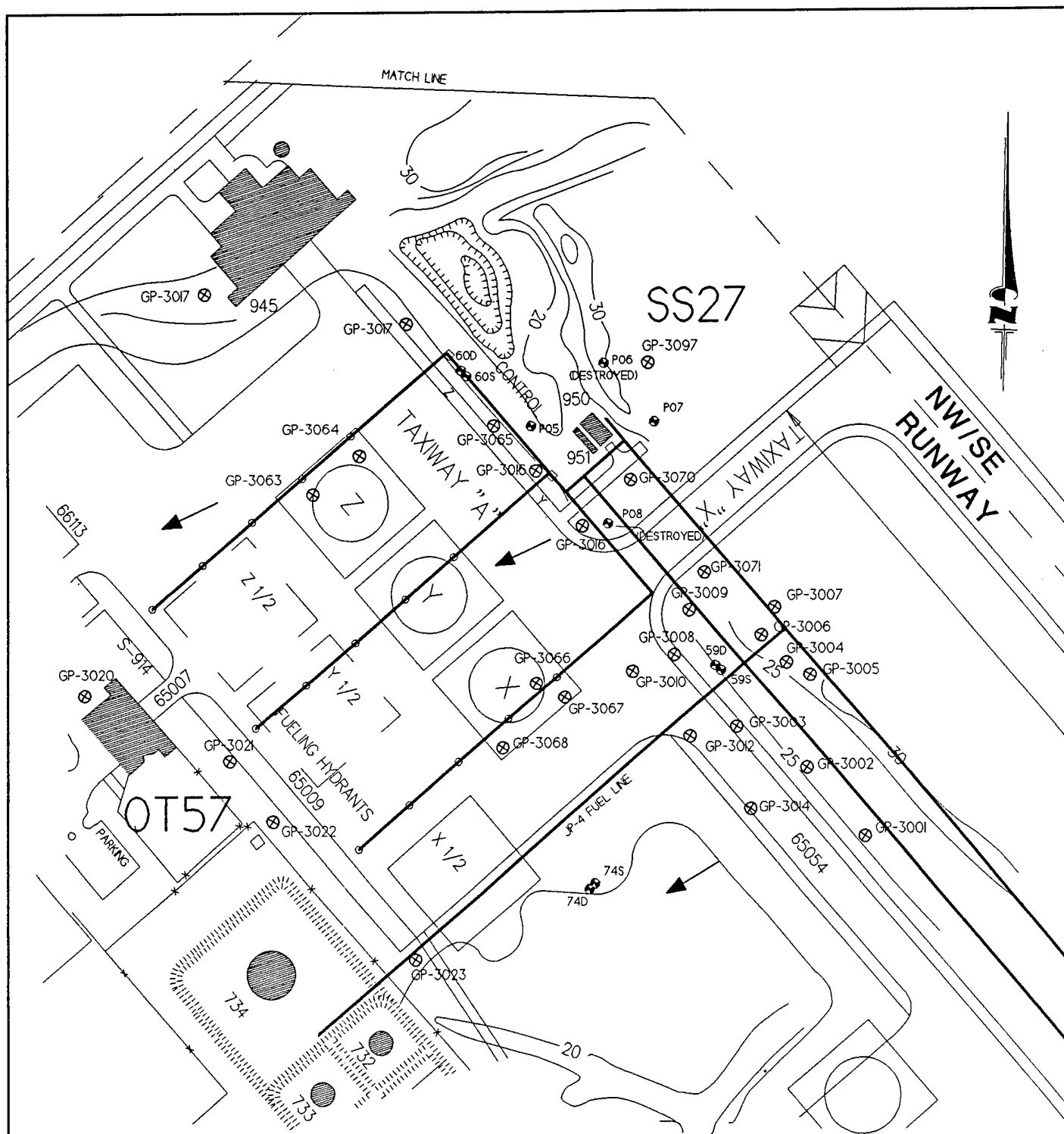
Denver, Colorado

runway and has served as a fuel-pumping station for pads X, Y, and Z since fueling operations began. Underground fuel lines are used to transfer JP-4 jet fuels from underground storage tanks (USTs) located beneath building 950 to the fuel hydrants at pads X, Y, and Z (Figure 1.3).

Soil and groundwater contamination was observed at site SS27/XYZ in June 1984 during preliminary site characterization activities conducted as part of the Phase II Installation Restoration Program (IRP) [Science Applications International Corporation (SAIC), 1986]. A second investigation of soil and groundwater was conducted in 1989 (SAIC, 1989). Recently, additional site characterization activities including a soil gas survey, soil borings, monitoring well installations, and soil and groundwater sampling was conducted at site SS27/XYZ [Dames & Moore and Hazardous Waste Remedial Actions Program (HAZWRAP), 1993]. The results of the most recent study revealed an area of elevated petroleum hydrocarbon concentrations predominantly along the fuel lines, though the distribution suggests that fuel constituents extend beneath the fueling pad (Figure 1-4). Other tests performed at the site as part of basewide remedial investigation program include: leak tests on all underground JP-4 pipelines in 1991 [Tracer Research Cooperation (TRC), 1991]; basewide ecological risk assessment conducted in 1993 (HAZWRAP, 1993a); Base-wide water level measurements taken at all accessible monitoring wells at Dover AFB quarterly for 24 months beginning in April 1991 (HAZWRAP, 1991a, b, c; 1992a, b, c, d; 1993b); and, an interpretation of the 2 years of water-level data was performed in 1993 (HAZWRAP, 1993c).

The site-specific data and conceptual model presented in Section 2 are based on a review these documents. A synopsis of site characterization activities conducted to date is provided in the 1993 Current Situation Report (Dames & Moore and HAZWRAP, 1993).

The two sites selected for preliminary screening of intrinsic remediation are contaminated with gasoline (site ST04/AFFES) and vinyl chloride (site D-7). Site locations are shown on Figure 1.2. Site ST04/AAFES (Army Air Force Exchange System), is an Air Force gas station. Gasoline contamination was discovered when one of five gasoline storage tanks located beneath and adjacent to Building 517 was removed after failing a leak test (Figure 1.5). It is not known how long the fuel tank had been



LEGEND

GP-300 ⊗ GROUNDWATER PROBE

50S ⊗ MONITORING WELL/PIEZOMETER

→ GROUNDWATER FLOW

--- BERM/FILL MATERIAL

--- FENCED AREA

— UNDERGROUND FUEL TRANSFER LINES

0 150 300
FEET

SOURCE: DOVER AFB

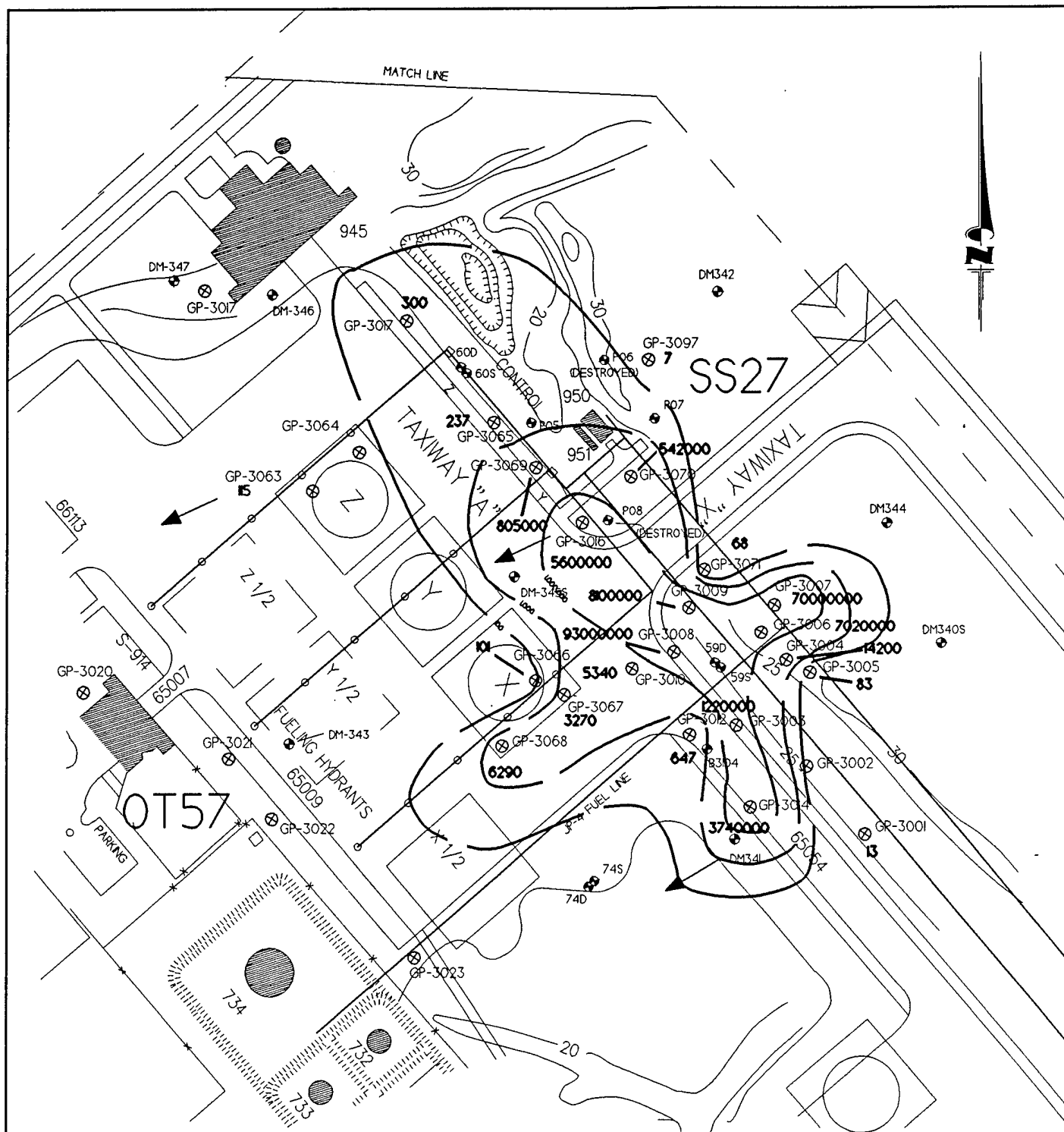
FIGURE 1.3

INFRASTRUCTURE MAP SITE SS27/XYZ

EE/CA -
DOVER AFB, DELAWARE

ENGINEERING-SCIENCE, INC.

Denver, Colorado



LEGEND

- | | |
|--|---------------------|
| GP-300 ⊗ GROUNDWATER PROBE | → GROUNDWATER FLOW |
| 50S ⊕ MONITORING WELL/PIEZOMETER | BERM/FILL MATERIAL |
| — 100 — CONTOUR OF BTEX CONCENTRATION (micrograms/Liter) | —+—+—+— FENCED AREA |
| — 20 — CONTOUR OF SURFACE ELEVATION (feet above MSL) | 0 150 300
FEET |

SOURCES: DOVER AFB, DAMES & MOORE, AND HAZWRAP, 1993.

FIGURE 1.4

BTEX CONCENTRATIONS IN GROUNDWATER AT SITE SS27/XYZ

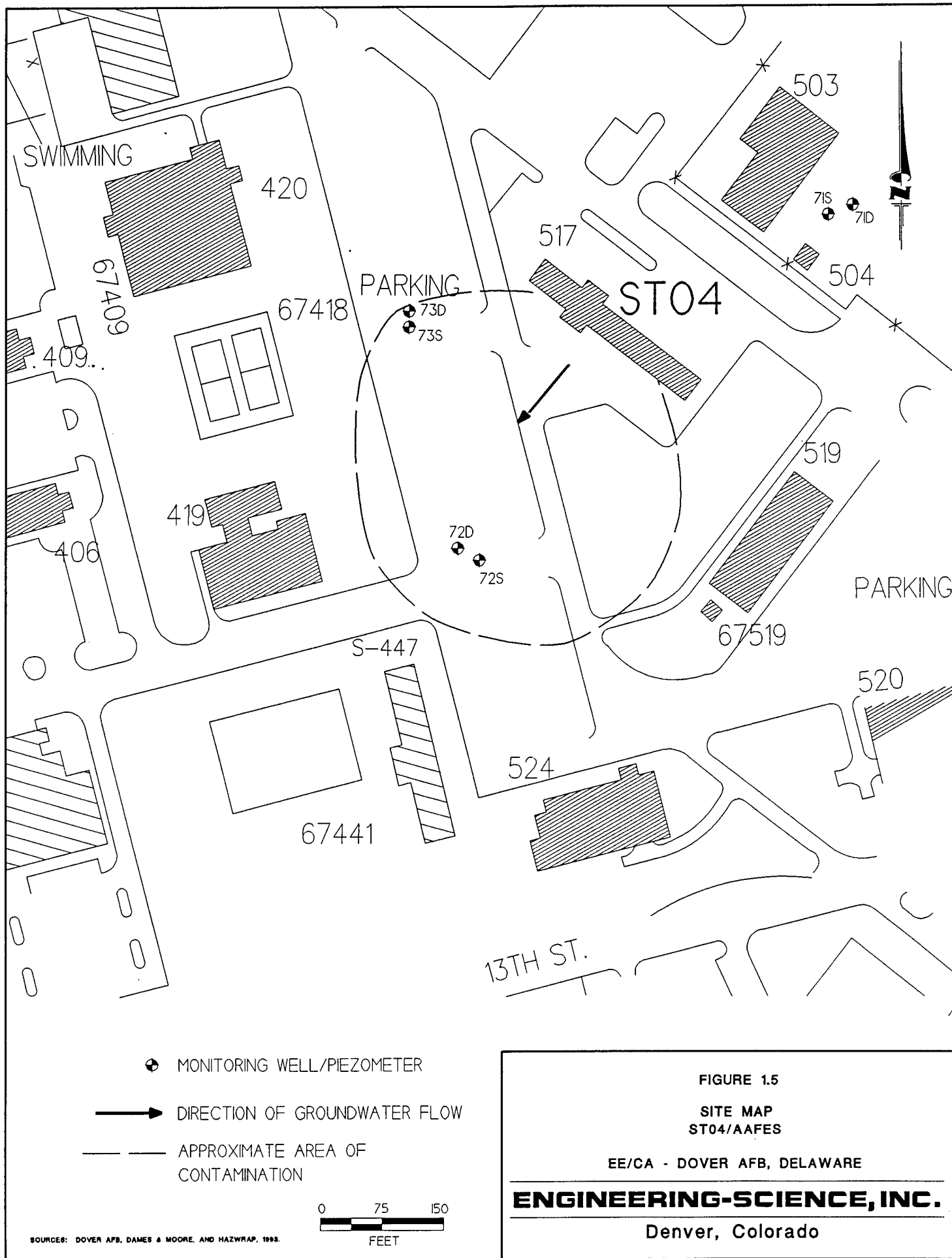
EE/CA -
DOVER AFB, DELAWARE

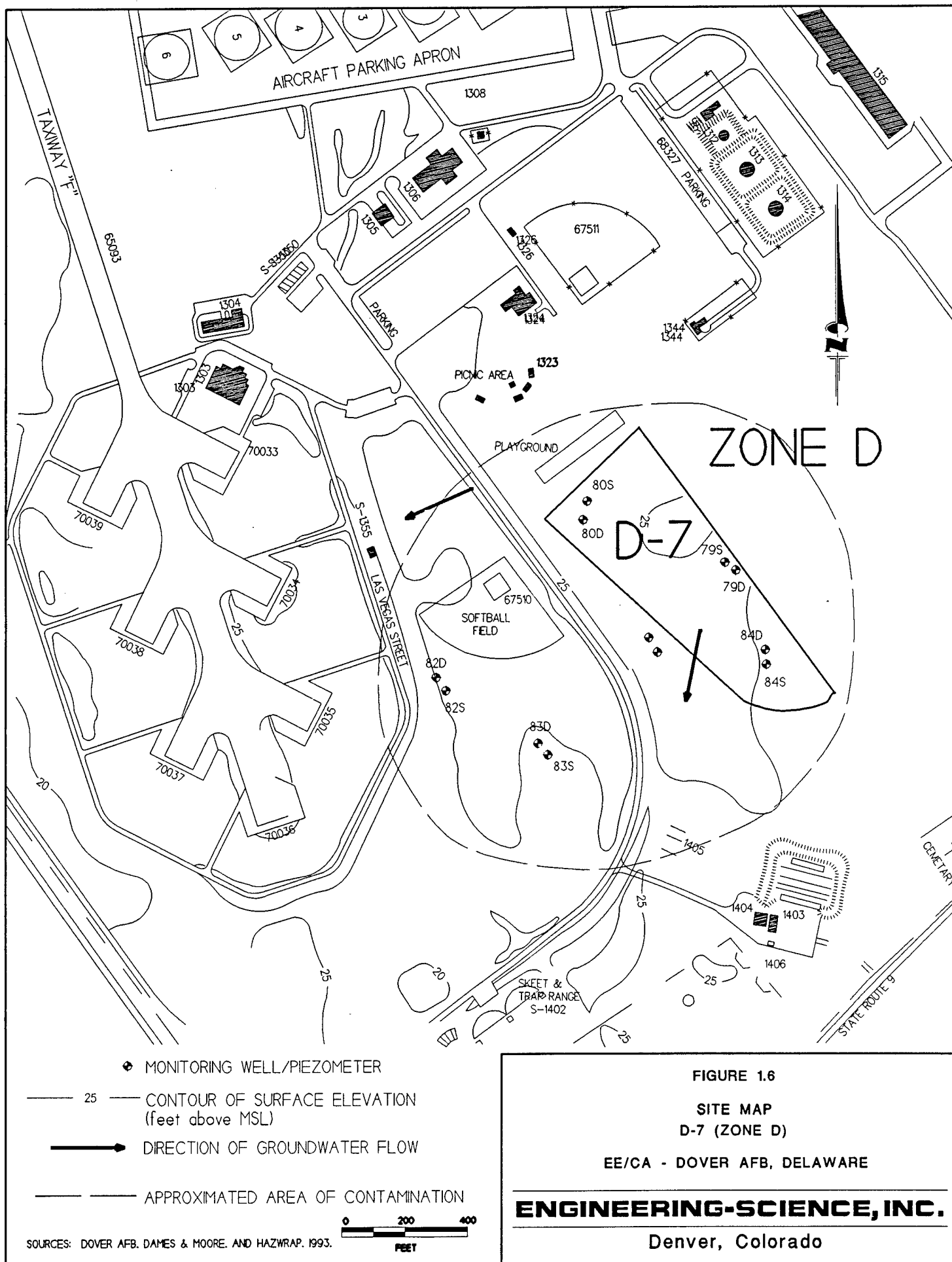
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leaking. The area impacted by the leak includes the service station parking lot, the road, and the parking lot adjacent to Building 419 (Figure 1.5). In 1989, a number of soil, soil gas, and groundwater measurements were taken as part of a remedial investigation (SAIC, 1989). Maximum benzene concentrations detected in groundwater and soil samples were 110 micrograms per liter ($\mu\text{g/L}$) and 7200 micrograms per kilogram ($\mu\text{g/Kg}$), respectively. In addition, a bioventing system was installed and is currently operating under the direction of the Air Force Civil Engineering Support Agency (AFCESA) to remediate residual fuel hydrocarbons in the unsaturated zone. Low concentrations of benzene, toluene, ethylbenzene, and xylene (BTEX) compounds dissolved in the groundwater suggest that this site is being biologically remediated.

Site D-7 (Zone D), is a former landfill site located at the southernmost portion of the base that was filled to a depth of 32 feet with general refuse disposed of during the late 1960's (ES, 1983) (Figure 1.6). The site has since been covered with soil and grass and is maintained as an empty field. A records search of previous site studies was conducted in 1983 (ES, 1983) and 12 monitoring wells were installed in 1989 as part of a site investigation (SAIC, 1989). Vinyl chloride was detected in groundwater at two locations at concentrations between 13 and 130 $\mu\text{g/L}$.





SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were reviewed and used to develop a conceptual model of the groundwater flow and contaminant transport system at site SS27/XYZ. This conceptual model will allow efficient collection of additional data which will be used to support the Bioplume II[®] modeling effort, and to evaluate potential remediation technologies, including intrinsic remediation. In addition, existing data for sites ST04/AAFES and D-7 (Zone D) was reviewed to develop a limited sampling strategy which will be used to document the occurrence of intrinsic remediation at sites not contaminated with jet fuels. Sections 2.1 and 2.2 present a synopsis of available site data. Section 2.3 presents the preliminary conceptual groundwater flow and solute transport model which was developed based on these data.

2.1 DATA REVIEW

The Current Situation Report prepared by Dames & Moore and HAZWRAP (1993) and available regional data were reviewed. Relevant data are summarized in the following sections.

2.1.1 Climate, Topography, and Surface Hydrology

The State of Delaware has a continental climate resulting from close geographic proximity to the Atlantic Ocean and from easterly atmospheric flow patterns. Spring and Fall are characterized by a succession of warm and cold periods associated with storm activity. Summers and winters are characterized as humid, making the winters more penetrating and the summers more sweltering than experienced in the drier climates of the central United States (Climates of the States, 1985). Average monthly precipitation ranges from 2.59 inches to 5.16 inches, and daily temperatures, on average, range from

25.3 to 88.9 degrees Fahrenheit (°F) (Dames & Moore and HAZWRAP, 1993). State-wide infiltration rates were previously estimated at 13 to 16 inches annually (ES, 1983).

Dover AFB exhibits little topographic variation with surface elevations varying from 10 feet above mean sea level (MSL) at the north end of the base to 30 feet MSL at the northwestern and western ends of the base. The eastern and southeastern portions of the base are typified by an average elevation of 20 feet MSL. Site SS27/XYZ has an average elevation of 30 feet MSL and is adjacent to the NW/SE runway which is well graded (average elevation of 28 feet MSL). Any significant elevation changes at Dover AFB and surrounding areas are mostly the result of erosional activity and/or stream channel development.

Drainage of surface waters at Dover AFB south of the NW/SE runway occurs in a southwestern direction where the waters then discharge into the St. Jones River. Most of the surface water is directed to the St. Jones River by diversion structures and area surface streams. The base is well drained and has not experience any disruptions due to flooding.

2.1.2 Site Geology and Hydrogeology

Dover AFB is located in the Atlantic Coastal Plain Physiographic Province, a wide wedge-shaped belt of Cretaceous to Recent sedimentary deposits of gravel, sand, silt, clay, limestone, chalk, and marl that dip to the southeast (Foster, 1950). Approximately 8 sedimentary formations exist under Dover AFB extending as much as 1400 feet below the ground surface. These formations are typified by various lithologies including; sand, gravel, fine to coarse sand, silt, clay, glauconitic sand, glauconitic silts, glauconitic-silty clay, interbedded clay, and variegated clay (Pickett and Benson, 1983). The Columbia Formation, which starts at grade and dominates the near surface geology in Delaware, was deposited under fluvial conditions, forming a broad sheet-like deposit of sand. This unconfined, water-bearing sand layer is characterized by reddish-brown to tan, yellow, or light-gray, poorly sorted coarse- to medium-grained sand and gravel, with interbedded silt and clay lenses. The thickness of the Columbia aquifer under Dover AFB typically ranges from 25 to over 70 feet.

Site SS27/XYZ is situated on a portion of the Columbia Formation that is characterized by fine- to medium-grained sand which coarsens into coarse, to very coarse

with depth. Laterally discontinuous lenses of clay and gravel are also present. The thickness of the Columbia Formation ranges from 25 to 35 feet under the fueling pads at site SS27/XYZ and groundwater elevations range from approximately 13.9 to 15.6 feet MSL. Estimates of the groundwater flow velocity at site SS27/XYZ were based on pump test data for site D-5, located about 2 miles east, and are approximately 0.29 foot/day, or 106 feet/year. A groundwater divide runs parallel to, and under, the NW/SE runway adjacent to site SS27/XYZ. This groundwater divide is apparently the result of extensive runway coverage, which inhibits surface water infiltration and of large volumes of fill material used in runway construction. Because of Site SS27's close proximity to the groundwater divide, it is possible that the direction of groundwater flow can switch during seasonal fluctuations in rainfall. However, the average flow of groundwater appears to be in a southwesterly direction with a gradient of 0.0022 foot/foot.

Site ST04/AAFES resides upon a portion of the Columbia Formation that consists of coarse- to very-coarse-grained sands with localized lenses of fine sand and gravel, thickening from 40 to 48 feet from east to west. The groundwater elevation at the site is approximately 10 feet above MSL, and groundwater appears to flow in a southwestward direction across the site, with a water table gradient of 0.0011 foot/foot. Estimated hydraulic conductivity at the site is based on a pump test conducted at site S-1, located 1.2 miles southeast of site ST04/AAFES, and is approximately 0.78 f/day or 285 feet/year.

Site D-7 (Zone D) resides upon a portion of the Columbia Formation that consists of fine sands, silts, and clays near the surface, and grades to coarse sands with occasional gravel toward the interface with the underlying Calvert Formation. The Columbia aquifer ranges in thickness from 50 to 75 feet at this site and groundwater elevations range from 8.3 to 9.6 feet above MSL. Groundwater flow is in a south and southwest direction with a gradient of 0.001 foot/foot. Hydraulic conductivity was derived from the pump tests performed at site S-1, and was estimated at 0.33 to 0.49 foot/day or 120 to 179 feet/year.

Tables 2.1 through 2.3 present available groundwater elevations for all three sites. Figure 2.1 shows transects of several hydrogeologic sections constructed for Dover AFB. Figure 2.2 is hydrogeologic section B-B' that transects site SS27/XYZ and shows the relationships between the groundwater surface and the stratigraphy at the site.

TABLE 2.1

**WATER LEVEL MEASUREMENTS
SITE SS27/(XYZ)
DOVER AFB, DELAWARE**

WELL ID	DATE	LAND ELEV. (FT MSL)	TOC ELEV. (FT MSL)	DEPTH TO WATER (FT)	REF. POINT	G. WATER ELEV. (FT MSL)
59D	12/4/89		24.67	11.10	TOC	13.57
59D	4/29/91		24.68	17.48	TOC	7.20
59D	8/7/91		24.68	18.66	TOC	6.02
59D	10/15/91		24.68	20.06	TOC	4.62
59D	1/13/92		24.68	21.42	TOC	3.26
59D	04/92		24.68	20.49	TOC	4.19
59D	07/92		24.68	20.97	TOC	3.71
59D	10/92		24.68	20.9	TOC	3.78
59S	12/4/89		24.99	17.28	TOC	7.71
59S	4/29/91		24.96	14.33	TOC	10.63
59S	8/7/91		24.96	14.17	TOC	10.79
59S	10/15/91		24.96	15.06	TOC	9.90
59S	04/92		24.96	17.29	TOC	7.67
59S	07/92		24.96	14.75	TOC	10.21
59S	10/92		24.96	14.29	TOC	10.67
60D	12/4/89		25.14	7.28	TOC	17.86
60D	4/29/91		25.14	8.42	TOC	16.72
60D	8/7/91		25.14	10.63	TOC	14.51
60D	10/15/91		25.14	12.00	TOC	13.14
60D	1/13/92		25.14	12.84	TOC	12.30
60D	04/92		25.14	11.93	TOC	13.21
60D	07/92		25.14	11.83	TOC	13.31
60D	10/92		25.14	12.00	TOC	13.14
60D	01/93		25.14	12.00	TOC	13.14
60S	12/4/89		25.16	7.28	TOC	17.88
60S	4/29/91		25.16	8.46	TOC	16.70
60S	8/7/91		25.16	10.60	TOC	14.56
60S	10/15/91		25.16	11.99	TOC	13.17
60S	1/13/92		25.16	12.85	TOC	12.31
60S	04/92		25.16	12.07	TOC	13.09
60S	07/92		25.16	11.74	TOC	13.42
60S	10/92		25.16	11.95	TOC	13.21
60S	01/93		25.16	12.26	TOC	12.90
74D	12/04/89		23.99	6.42	TOC	17.57
74S	12/04/89		24.19	6.40	TOC	17.79
p05	11/7/84	22.87		7.60	BLS	15.27
p05	11/16/84		24.87	8.84	TOC	16.03
p05	12/5/84		24.87	9.22	TOC	15.65
p05	1/9/85		24.87	10.60	TOC	14.27
p05	12/4/89		24.86	6.71	TOC	18.15
p05	4/29/91		24.87	7.05	TOC	17.82
p05	8/7/91		24.87	9.45	TOC	15.42
p05	10/15/91		24.87	10.91	TOC	13.96
p05	1/13/92		24.87	11.75	TOC	13.12
p05	04/92		24.87	10.23	TOC	14.64
p05	07/92		24.87	10.69	TOC	14.18
p05	10/92		24.87	10.69	TOC	14.18
p05	01/93		24.87	10.42	TOC	14.45
p06	11/7/84	26.87		12.00	BLS	14.87
p06	11/16/84		28.87	14.10	TOC	14.77
p06	12/5/84		28.87	13.20	TOC	15.67
p06	1/9/85		28.87	13.53	TOC	15.34

TABLE 2.1 (CONTINUED)
WATER LEVEL MEASUREMENTS
SITE SS27 (XYZ)
DOVER AFB, DELAWARE

WELL ID	DATE	LAND ELEV. (FT MSL)	TOC ELEV. (FT MSL)	DEPTH TO WATER (FT)	REF. POINT	G. WATER ELEV. (FT MSL)
p07	11/14/84	23.61		7.15	BLS	16.46
p07	11/16/84		26.18	9.91	TOC	16.27
p07	12/5/84		26.18	10.26	TOC	15.92
p07	1/9/85		26.18	10.55	TOC	15.63
p07	12/4/89		26.17	8.05	TOC	18.12
p07	4/29/91		26.18	8.33	TOC	17.85
p07	8/7/91		26.18	10.46	TOC	15.72
p07	10/15/91		26.18	11.68	TOC	14.50
p07	1/13/92		26.18	12.88	TOC	13.30
p07	04/92		26.18	11.25	TOC	14.93
p07	07/92		26.18	11.73	TOC	14.45
p07	10/92		26.18	11.72	TOC	14.46
p07	01/93		26.18	11.03	TOC	15.15
p08	11/7/84	24.84		9.20	BLS	15.64
p08	11/16/84		26.84	11.01	TOC	15.83
p08	12/5/84		26.84	11.39	TOC	15.45
p08	1/9/85		26.84	11.83	TOC	15.01

FT MSL- Feet above mean sea level

BLS- Measured from land surface (feet)

TOC- Top of PVC casing (feet)

Sources: Dames & Moore and HAZWRAP, 1993.

TABLE 2.2

**WATER LEVEL MEASUREMENTS
SITE ST04/AAFES
DOVER AFB, DELAWARE**

WELL ID	DATE	LAND ELEV. (FT MSL)	TOC ELEV. (FT MSL)	DEPTH TO WATER (FT)	REF. POINT	G. WATER ELEV. (FT MSL)
71D	12/4/89	22.69	22.49	10.33	TOC	12.16
71D	4/29/91		22.49	10.85	TOC	11.64
71D	8/7/91		22.49	11.66	TOC	10.83
71D	10/15/91		22.49	12.18	TOC	10.31
71D	1/13/92		22.49	12.50	TOC	9.99
71D	04/92		22.49	12.00	TOC	10.49
71D	07/92		22.49	11.92	TOC	10.57
71D	10/92		22.49	11.99	TOC	10.50
71D	01/93		22.49	11.96	TOC	10.53
71S	12/4/89	22.68	22.59	10.43	TOC	12.16
71S	4/29/91		22.59	10.93	TOC	11.66
71S	8/7/91		22.59	11.75	TOC	10.84
71S	10/15/91		22.59	12.28	TOC	10.31
71S	1/13/92		22.59	12.6	TOC	9.99
71S	04/92		22.59	12.11	TOC	10.48
71S	07/92		22.59	12.02	TOC	10.57
71S	10/92		22.59	12.09	TOC	10.50
71S	01/93		22.59	12.00	TOC	10.59
72D	12/4/89	22.90	22.69	10.78	TOC	11.91
72D	4/29/91		22.69	12.22	TOC	10.47
72D	8/7/91		22.69	12.06	TOC	10.63
72D	10/15/91		22.69	12.61	TOC	10.08
72D	1/13/92		22.69	12.95	TOC	9.74
72D	04/92		22.69	12.34	TOC	10.35
72D	07/92		22.69	12.33	TOC	10.36
72D	10/92		22.69	12.37	TOC	10.32
72D	01/93		22.69	12.41	TOC	10.28
72S	12/4/89	22.92	22.55	10.64	TOC	11.91
72S	4/29/91		22.55	12.10	TOC	10.45
72S	8/7/91		22.55	11.92	TOC	10.63
72S	10/15/91		22.55	12.47	TOC	10.08
72S	1/13/92		22.55	12.81	TOC	9.74
72S	04/92		22.55	12.2	TOC	10.35
72S	07/92		22.55	12.18	TOC	10.37
72S	10/92		22.55	12.23	TOC	10.32
72S	01/93		22.55	12.27	TOC	10.28
73D	12/4/89	22.53	22.55	10.18	TOC	12.37
73D	4/29/91		22.55	10.70	TOC	11.85
73D	8/7/91		22.55	11.5	TOC	11.05
73D	10/15/91		22.55	12.05	TOC	10.50
73D	1/13/92		22.55	12.38	TOC	10.17
73D	04/92		22.55	11.88	TOC	10.67
73D	07/92		22.55	11.82	TOC	10.73
73D	10/92		22.55	11.86	TOC	10.69
73D	01/93		22.55	11.8	TOC	10.75
73S	12/4/89	22.57	22.43	10.06	TOC	12.37
73S	4/29/91		22.43	10.56	TOC	11.87
73S	8/7/91		22.43	11.40	TOC	11.03
73S	10/15/91		22.43	11.95	TOC	10.48
73S	1/13/92		22.43	12.29	TOC	10.14
73S	04/92		22.43	11.76	TOC	10.67
73S	07/92		22.43	11.71	TOC	10.72
73S	10/92		22.43	11.75	TOC	10.68
73S	01/93		22.43	11.77	TOC	10.66

TOC- Top of PVC casing.

Source: Dames & Moore & HAZWRAP, 1993.

FT MSL- Feet Above Mean Sea Level.

TABLE 2.3

**WATER LEVEL MEASUREMENTS
SITE D-7 (ZONE D)
DOVER AIR FORCE BASE**

WELL ID	DATE	LAND	TOC	DEPTH TO	REF.	G. WATER
		ELEV. (FT MSL)	ELEV. (FT MSL)	WATER (FT)		ELEV. (FT MSL)
79D	4/29/91		26.65	14.42	TOC	12.23
79D	8/7/91		26.65	16.86	TOC	9.79
79D	10/15/91		26.65	17.65	TOC	9.00
79D	1/13/92		26.65	18.03	TOC	8.62
79D	04/92		26.65	16.05	TOC	10.60
79D	07/92		26.65	16.86	TOC	9.79
79D	10/92		26.65	17.92	TOC	8.73
79D	01/93		26.65	17.76	TOC	8.89
79S	12/4/89		27.43	15.04	TOC	12.39
79S	4/29/91		27.43	15.18	TOC	12.25
79S	8/7/91		27.43	17.65	TOC	9.78
79S	10/15/91		27.43	18.4	TOC	9.03
79S	1/13/92		27.43	18.82	TOC	8.61
79S	04/92		27.43	18.84	TOC	8.59
79S	07/92		27.43	17.59	TOC	9.84
79S	10/92		27.43	18.70	TOC	8.73
79S	01/93		27.43	18.55	TOC	8.88
80D	4/29/91		29.81	17.67	TOC	12.14
80D	8/7/91		29.81	20.04	TOC	9.77
80D	10/15/91		29.81	20.78	TOC	9.03
80D	1/13/92		29.81	21.20	TOC	8.61
80D	04/92		29.81	20.28	TOC	9.53
80D	07/92		29.81	20.02	TOC	9.79
80D	10/92		29.81	21.06	TOC	8.75
80D	01/93		29.81	20.91	TOC	8.90
80S	12/4/89		29.54	17.29	TOC	12.25
80S	4/29/91		29.54	17.36	TOC	12.18
80S	8/7/91		29.54	19.78	TOC	9.76
80S	10/15/91		29.54	20.52	TOC	9.02
80S	1/13/92		29.54	20.93	TOC	8.61
80S	04/92		29.54	20	TOC	9.54
80S	07/92		29.54	19.71	TOC	9.83
80S	10/92		29.54	20.81	TOC	8.73
80S	01/93		29.54	20.40	TOC	9.14
81D	12/4/89		28.54	16.46	TOC	12.08
81D	4/29/91		28.54	16.59	TOC	11.95
81D	8/7/91		28.54	18.96	TOC	9.58
81D	10/15/91		28.54	19.75	TOC	8.79
81D	1/13/92		28.54	20.15	TOC	8.39
81D	04/92		28.54	19.22	TOC	9.32
81D	07/92		28.54	19.02	TOC	9.52
81D	10/92		28.54	20.04	TOC	8.50
81D	01/93		28.54	19.91	TOC	8.63
81S	4/29/91		29.15	17.17	TOC	11.98
81S	8/7/91		29.15	19.55	TOC	9.60
81S	10/15/91		29.15	20.37	TOC	8.78
81S	1/13/92		29.15	20.76	TOC	8.39
81S	04/92		29.15	19.83	TOC	9.32
81S	07/92		29.15	19.63	TOC	9.52
81S	10/92		29.15	20.66	TOC	8.49
81S	01/93		29.15	20.51	TOC	8.64

TABLE 2.3 (Continued)

WATER LEVEL MEASUREMENTS

SITE D-7 (ZONE D)

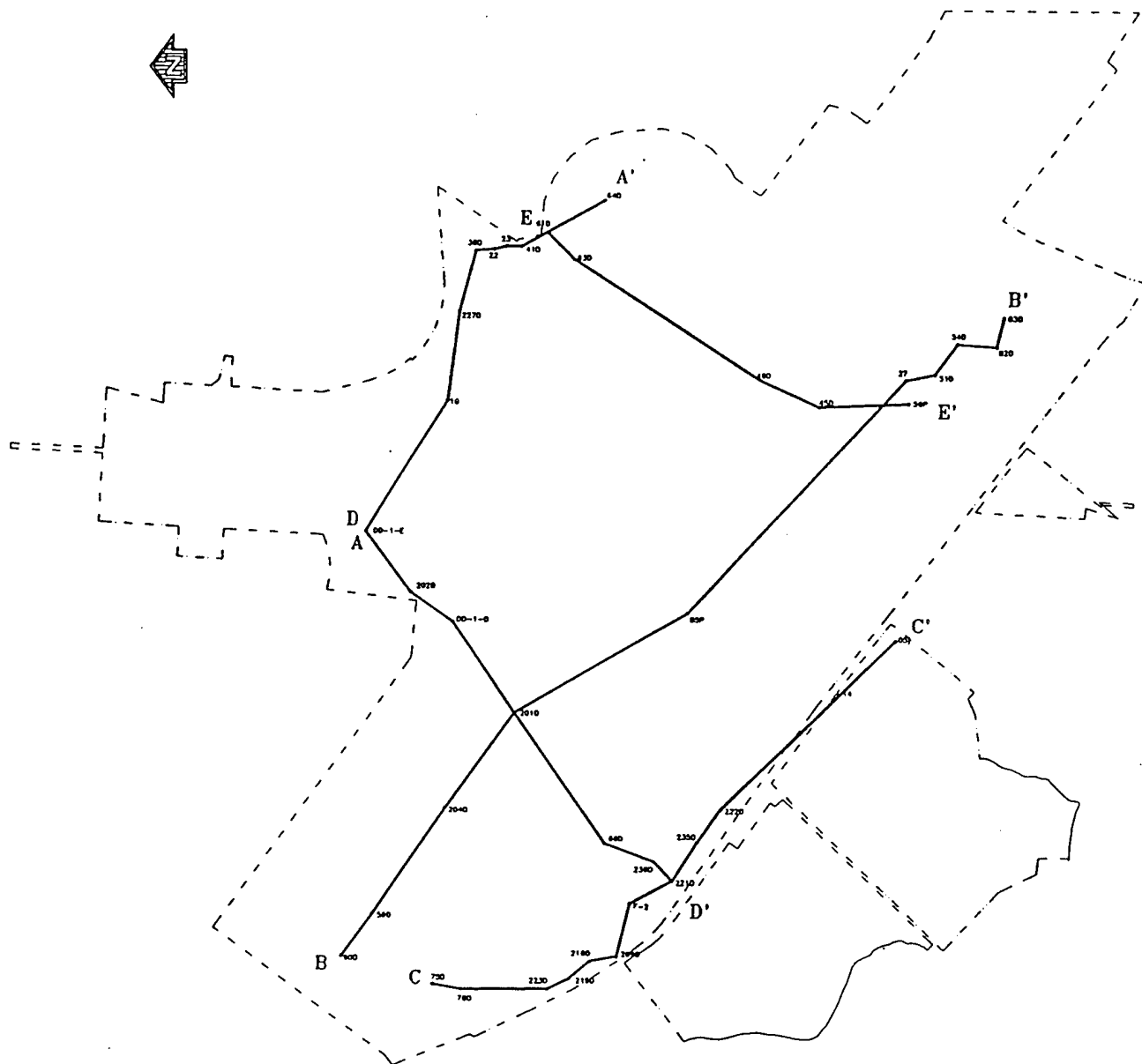
DOVER AIR FORCE BASE

WELL ID	DATE	LAND ELEV. (FT MSL)	TOC ELEV. (FT MSL)	DEPTH TO WATER (FT)	REF. POINT	G. WATER ELEV. (FT MSL)
82D	12/4/89		27.29	16.17	TOC	11.12
82D	4/29/91		27.29	16.37	TOC	10.92
82D	8/7/91		27.29	18.11	TOC	9.18
82D	10/15/91		27.29	19.06	TOC	8.23
82D	1/13/92		27.29	19.43	TOC	7.86
82D	04/92		27.29	18.43	TOC	8.86
82D	07/92		27.29	18.58	TOC	8.71
82D	10/92		27.29	19.39	TOC	7.90
82D	01/93		27.29	19.2	TOC	8.09
82S	4/29/91		27.56	16.67	TOC	10.89
82S	8/7/91		27.56	18.65	TOC	8.91
82S	10/15/91		27.56	19.25	TOC	8.31
82S	1/13/92		27.56	19.71	TOC	7.85
82S	04/92		27.56	18.85	TOC	8.71
82S	07/92		27.56	18.87	TOC	8.69
82S	10/92		27.56	19.66	TOC	7.90
82S	01/93		27.56	19.49	TOC	8.07
83D	12/4/89		25.45	13.96	TOC	11.49
83D	4/29/91		25.45	14.24	TOC	11.21
83D	8/7/91		25.45	16.37	TOC	9.08
83D	10/15/91		25.45	17.11	TOC	8.34
83D	1/13/92		25.45	17.45	TOC	8.00
83D	04/92		25.45	16.55	TOC	8.90
83D	07/92		25.45	16.56	TOC	8.89
83D	10/92		25.45	17.42	TOC	8.03
83D	01/93		25.45	17.17	TOC	8.28
83S	12/4/89		25.49	14.17	TOC	11.32
83S	4/29/91		25.49	14.26	TOC	11.23
83S	8/7/91		25.49	16.54	TOC	8.95
83S	10/15/91		25.49	17.18	TOC	8.31
83S	1/13/92		25.49	17.52	TOC	7.97
83S	04/92		25.49	16.61	TOC	8.88
83S	07/92		25.49	16.63	TOC	8.86
83S	10/92		25.49	17.47	TOC	8.02
83S	01/93		25.49	17.25	TOC	8.24
84D	4/29/91		26.22	14.26	TOC	11.96
84D	8/7/91		26.22	16.68	TOC	9.54
84D	10/15/91		26.22	17.5	TOC	8.72
84D	1/13/92		26.22	17.88	TOC	8.34
84D	04/92		26.22	16.62	TOC	9.60
84D	07/92		26.22	16.5	TOC	9.72
84D	10/92		26.22	17.54	TOC	8.68
84D	01/93		26.22	17.35	TOC	8.87
84S	4/29/91		25.99	13.49	TOC	12.50
84S	8/7/91		25.99	16.47	TOC	9.52
84S	10/15/91		25.99	17.25	TOC	8.74
84S	1/13/92		25.99	17.61	TOC	8.38
84S	04/92		25.99	16.93	TOC	9.06
84S	07/92		25.99	16.78	TOC	9.21
84S	10/92		25.99	17.79	TOC	8.20
84S	01/93		25.99	17.61	TOC	8.38

TOC- Top of PVC casing

Sources: Dames & Moore and HAZWRAP, 1993.

FT MSL- Feet above mean sea level



LEGEND:

--- BASE BOUNDARY

LOCATION OF CROSS
SECTION LINES AND
INTERSECTED WELLS

0 2500
SCALE IN FEET

SOURCE: DAMES & MOORE, AND HAZWRAP, 1993.

FIGURE 2.1

HYDROGEOLOGIC SECTION LOCATION MAP

EE/CA - DOVER AFB, DELAWARE

ENGINEERING-SCIENCE, INC.

Denver, Colorado

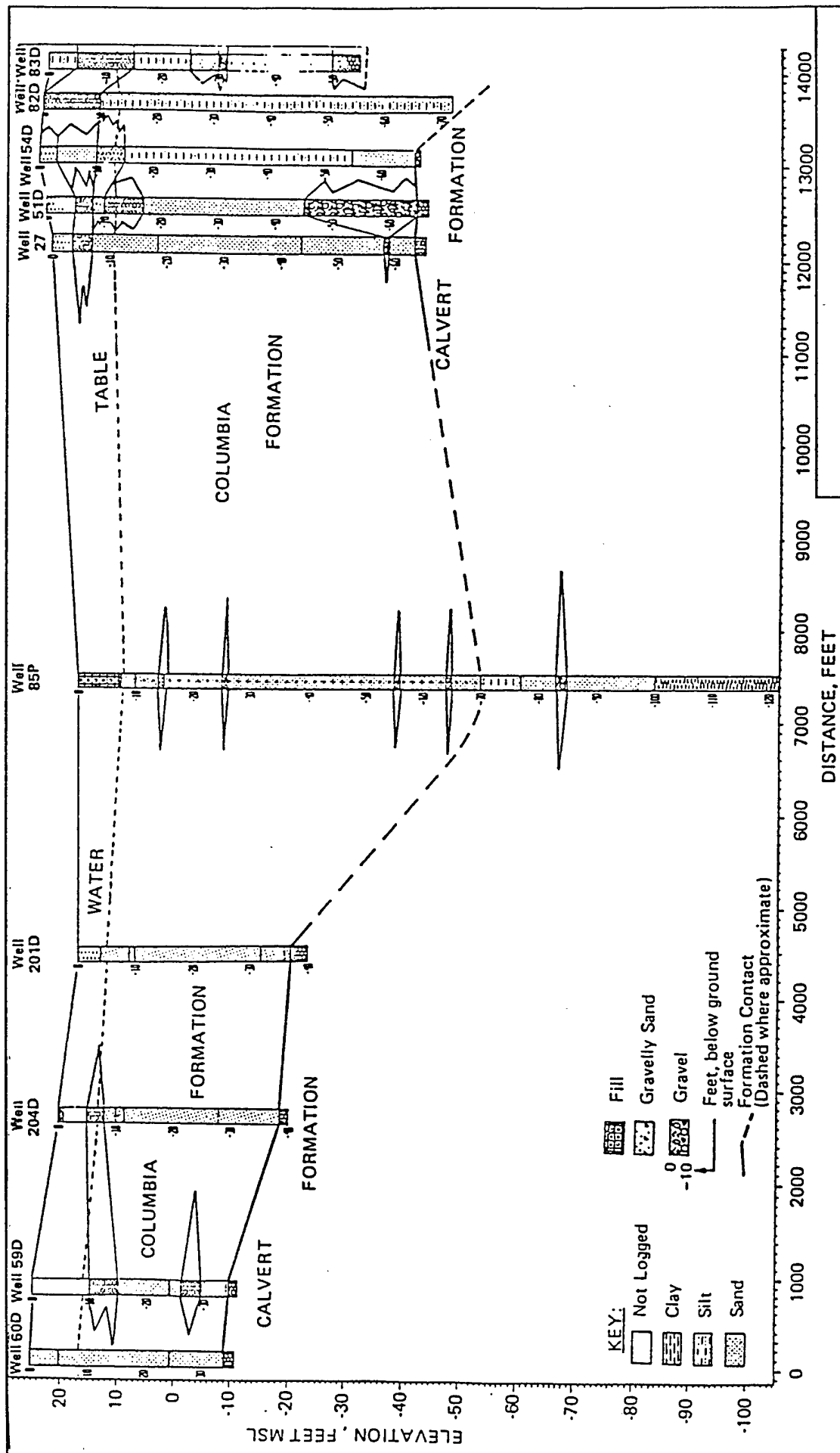


FIGURE 2.2

HYDROGEOLOGIC SECTION B-B'

EE/CA - DOVER AFB, DELAWARE

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: DAVES & MOORE AND HAZWRAP, 1993.

2.1.3 Soil Quality

Characterization of the vadose zone and shallow Columbia aquifer system at site SS27/XYZ has been the objective of several site investigations. To date, 4 sediment samples have been taken by SAIC (1986, 1989). A soil gas survey completed by SAIC in 1989 (SAIC, 1989) included 32 measurements across the site. An additional soil gas survey was performed by Dames & Moore in 1993 (Dames & Moore and HAZWRAP, 1993) which included a grid of sampling points covering an area approximately 400 by 2,400 feet between the NW/SE runway and the fueling pads. An estimated 75 measurements of soil gas were taken.

The results of the second soil gas study revealed that the majority of petroleum hydrocarbon contamination at site SS27/XYZ is along the fuel lines, though the isocontours for total volatile organic compounds (VOCs) appear to extend beneath the fuel pad. Soil gas study results also indicate that hydrocarbon contamination at the site is high, though not as spatially extensive as reported in previous studies (SAIC, 1989). Oil and grease concentrations in the soil at the site ranged from 2.5 to 65 mg/kg (SAIC, 1986), and soils also contained minor amounts of lead (5 mg/kg).

Site ST04/AAFES has been characterized in previous field investigations. Toluene, ethylbenzene, and total xylene concentrations were detected in soil borings (SAIC, 1989). Total recoverable lead was within the background levels for Delaware (10 to 20 mg/kg) in all soil samples. Current bioventing operations at the site have probably decreased levels of BTEX in the soil at this site to concentrations below those shown in Table 2.4.

No soil data are available for site D-7 (Zone D).

2.1.4 Groundwater Quality and Chemistry

Previous investigations of site SS27/XYZ detected plumes of benzene (1.4 to 7,000 µg/L), 1,4,-dichlorobenzene (2 to 290 µg/L), ethylbenzene (1.3 to 2,200 µg/L), toluene (0.3 to 680 µg/L), and o-xylene (11 to 870 µg /L) originating at the JP-4 fuel pipelines extending from Building 950. The most recent investigation of VOCs in the groundwater was conducted by Dames & Moore and HAZWRAP (1993). Results

TABLE 2.4
SUMMARY OF SOIL ANALYTICAL DATA
SITE ST04/AAFES
DOVER AFB, DELAWARE

ANALYTE	SAMPLE ID	DATE	MAXIMUM CONCENTRATION (micrograms/Kg)	MINIMUM CONCENTRATION (micrograms/Kg)	MEAN (micrograms/Kg)	NUMBER OF DETECTS	NUMBER OF SAMPLES
LEAD	SB-66-11.5	05/27/88	9.2*	1.700	4.729	7	7
ACETONE	SB-66-11.5	05/27/88	3600.000	7.600	1657.933	6	7
BENZENE	SB-66-11.5-5	05/27/88	7200.000	170.000	2513.333	3	7
ETHYLBENZENE	SB-66-11.5-R	05/27/88	640.000	640.000	640.000	2	7
METHYL ETHYL KETONE	SB-66-11.5	05/27/88	8000.000	4.600	3902.920	5	7
METHYLENE CHLORIDE	SB-66-5-7	05/27/88	26.000	2.000	10.067	3	7
TOLUENE	SB-66-11.5	05/27/88	2200.000	1000.000	1466.667	3	7
XYLENE (TOTAL)	SB-66-11.5-R	05/27/88	4300.000	4200.000	4250.000	2	7

*milligrams/Kg

Source: Dames & Moore and HAZWRAP, 1993.

TABLE 2.5
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE SS27/XYZ
DOVER AFB, DELAWARE

SITE I.D.	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27
LOCATION I.D.	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
SAMPLE I.D.	GP3001	GP3002	GP3003	GP3004	GP3005	GP3006	GP3007	GP3008	GP3009	GP3010	GP3012	GP3014	GP3016	GP3017			
SAMPLE DATE	04/21/93	04/21/93	04/21/93	04/21/93	04/21/93	04/20/93	04/20/93	04/21/93	04/20/93	04/21/93	04/22/93	04/22/93	04/20/93	04/20/93			
DEPTH (feet)	11.5	8.5	10	11.5	10	11	10	11	11.5	11.5	14.5	14.5	9	11.5			
TCE (ug/L)	<0.5	<0.5	<1500	<0.5	<0.5	<150	<1500	<3000	<150	<0.5	<0.5	<1500	<150	<0.5			
PCE (ug/L)	<0.5	<0.5	<1500	<0.5	<0.5	<150	<1500	<3000	<150	<0.5	<0.5	<1500	<150	<0.5			
BENZENE (ug/L)	2.3	<2.0	670000	6000	32	2600000	26000000	38000000	3000000	1200	240	1800000	2300000	210			
TOLUENE (ug/L)	2.9	<2.0	270000	2000	11	1700000	13000000	19000000	1800000	740	140	830000	1400000	20			
ETHYLBENZENE (ug/L)	2.3	<2.0	130000	<2.0	<2.0	920000	16000000	16000000	1600000	<2.0	220	560000	900000	<2.0			
TOTAL XYLENES (ug/L)	5.3	<2.0	150000	6200	40	1800000	15000000	20000000	1700000	2200	47	1000000	1000000	70			
TOTAL VOLATILES (ug/L)	650	57	7800000	110000	1000	49000000	490000000	740000000	490000000	18000	2600	20000000	34000000	4100			

SITE ID.	SS27	SS27	SS27	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB
LOCATION ID.	XYZ	XYZ	XYZ										
SAMPLE I.D.	GP3018	GP3021	GP3023	GP3063	GP3064	GP3065	GP3066	GP3067	GP3068	GP3069	GP3070	GP3071	GP3097
SAMPLE DATE	03/22/93	04/19/93	03/26/93	04/13/93	04/13/93	04/20/93	04/13/93	04/13/93	04/13/93	04/20/93	04/20/93	04/20/93	04/20/93
DEPTH (feet)	20.5	8.5	17.5	14.5	14.5	11.5	14.5	14.5	14.5	11.5	11.5	8.5	8.5
TCE (ug/L)	<0.5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<1.5	<150	<150	<0.5	<0.5
PCE (ug/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.5	<150	<150	<0.5	<0.5
BENZENE (ug/L)	<2.0	<2.0	<2.0	5.6	<2.0	1.50	70	2700	2600	430000	280000	22	6.8
TOLUENE (ug/L)	<2.0	<2.0	<2.0	5.5	<2.0	17	5.2	380	2800	200000	47000	10	<2.0
ETHYL BENZENE (ug/L)	<2.0	<2.0	<2.0	4.3	<2.0	61	26	<2.0	<2.0	76000	45000	<2.0	700
TOTAL XYLENES (ug/L)	<2.0	<2.0	<2.0	<2.0	<2.0	9.2	<2.0	190	890	99000	170000	36	<2.0
TOTAL VOLATILES (ug/L)	49	<45	34	67	<45	3000	2000	7100	18000	7300000	9400000	480	13000

Source: Dames & Moore and HAZWRAP, 1993.

indicate that areas of groundwater contamination coincide with earlier detections of fuel contamination in soil gas.

The highest measured levels of VOC contamination in the groundwater seem to parallel both the runway and the JP-4 fuel lines in a direction extending from the pump stations (Building 950) to the groundwater probe location, GP-3014, approximately 1000 feet southeast (Figure 1.4). Samples were collected at depths ranging from 8.5 to 14.5 bgs and analyzed at an onsite laboratory (Table 2.5). The highest concentrations of BTEX and total VOCs were detected in samples GP3003, GP3006, GP3007, GP3008, GP3009, GP3014, GP3016, GP3069, and GP3070. Floating product thicknesses of 4, 59, and 38 inches were measured at probes GP3003, GP3007, and GP3008, respectively. Sample GP3009 contained a trace amount of free product. The shape of the contaminant plume does not follow the "tear-drop" pattern extending in the typical direction of groundwater flow, but instead has a "halo" shape; edges of the plume stretch toward the NW/SE runway and toward the fueling pads. This "halo" shape is believed to be the result of the groundwater divide adjacent to the site. Contaminants seem to be temporarily contained in the immediate vicinity near the fuel lines, and under fuel pads X, Y, & Z and the taxiways near the site. Background levels of BTEX contamination at wells GP3022, GP3021, and GP3020 (located approximately 1,000 feet southwest of Building 950) were below EPA maximum contaminant levels (MCLs). Detections of chlorinated hydrocarbons were limited to methylene chloride in only three isolated samples: GP3018, (21 µg /L), GP3065 (2.9 µg/L), and GP3066 (2.9 µg /L)

Contaminants identified in the groundwater at site ST04/AAFES included benzene, toluene, and ethylbenzene at three wells, although only benzene exceeded MCLs in a shallow downgradient well (SAIC, 1989) (Table 2.6). Samples from some Site D-7 (Zone D) wells contain quantities of vinyl chloride and tetrachloroethene (PCE) that exceed MCLs (Table 2.7). Some PCE contamination detected upgradient from site D-7 and is believed a result of the adjacent groundwater divide rather than a upgradient contaminant source (Dames & Moore & HAZWRAP, 1993).

TABLE 2.6

**SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE ST04/AAFES
DOVER AFB, DELAWARE**

ANALYTE	SAMPLE ID	DATE	MAXIMUM CONCENTRATION	MINIMUM CONCENTRATION	MEAN	NUMBER OF DETECTS	NUMBER OF SAMPLES
ALKALINITY	72D	08/04/88	270.000	25.000	85.857	7	7
pH	71S	08/04/88	6.400	4.500	5.150	6	6
SPECIFIC CONDUCTIVITY	72D	08/04/88	410.000	88.000	201.167	6	6
TEMPERATURE	72S	08/04/88	28.000	21.000	23.000	6	6
TOTAL DISSOLVED SOLIDS - (micrograms/L)	71S	08/04/88	220000.000	58000.000	126428.571	7	7
LEAD (micrograms/L)	73SD	08/04/88	760.000	2.000	114.286	7	7
CHLORIDE (micrograms/L)	71S	08/04/88	69000.000	6900.000	19500.000	7	7
NITRATE-NITRITE (micrograms/L)	71D	08/04/88	3800.000	500.000	2082.857	7	7
SULFATE (micrograms/L)	72S	08/04/88	36000.000	8600.000	22920.000	5	7
BENZENE (micrograms/L)	110	08/04/88	110.000	0.200	36.867	3	7
ETHYLBENZENE (micrograms/L)	1.3	08/04/88	1.300	0.500	0.900	2	7
P-XYLENE (micrograms/L)	1.7	08/04/88	1.700	1.400	1.550	2	8
TOLUENE (micrograms/L)	0.6	08/04/88	0.600	0.400	0.500	2	7

SOURCE: Dames & Moore and HAZWRAP, 1993.

TABLE 2.7

**SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE D-7 (ZONE D)
DOVER AFB, DELAWARE**

ANALYTE	SAMPLE ID	UNITS	DATE	MAXIMUM CONC.	MINIMUM CONC.	MEAN	NUMBER OF DETECTS	NUMBER OF SAMPLES
ALKALINITY	81S	milligrams/L	07/26/88	170.000	17.000	75.455	11	11
pH	79D	standard units	07/26/88	6.700	5.300	5.740	10	10
SPECIFIC CONDUCTIVITY	79S	micro-mhos	07/25/88	420.000	22.000	214.727	11	11
TEMPERATURE	79S	degrees centigrade	07/25/88	17.000	14.000	15.727	11	11
TOTAL DISSOLVED SOLIDS	79S	milligrams/L	07/25/88	250.000	52.000	113.385	13	13
ALUMINUM	82SD	micrograms/L	07/26/88	4100.000	120.000	965.385	13	13
BARIUM	82SD	micrograms/L	07/26/88	190.000	30.000	75.385	13	13
BORON	79D	micrograms/L	07/26/88	410.000	12.000	68.188	8	13
CALCIUM	79S	micrograms/L	07/25/88	34000.000	4900.000	13153.846	13	13
CHROMIUM	79S	micrograms/L	07/25/88	8.000	8.000	8.000	1	13
COPPER	79S	micrograms/L	07/25/88	11.000	7.000	8.000	6	13
IRON	81S	micrograms/L	07/26/88	19000.000	61.000	4254.250	12	13
LEAD	83S	micrograms/L	07/26/88	37.000	2.000	8.615	13	13
MAGNESIUM	81S	micrograms/L	07/26/88	9000.000	57.000	3950.538	13	13
MANGANESE	81S	micrograms/L	07/26/88	810.000	18.000	154.833	12	13
MERCURY	79S	micrograms/L	07/25/88	1.000	1.000	1.000	1	13
POTASSIUM	79S	micrograms/L	07/25/88	17000.000	14000.000	15500.000	2	13
SILICON	80D	micrograms/L	07/25/88	15000.000	5500.000	11407.692	13	13
SODIUM	80S	micrograms/L	07/25/88	38000.000	6800.000	14023.077	13	13
VANADIUM	82SD	micrograms/L	07/26/88	12.000	11.000	11.500	2	13
ZINC	79D	micrograms/L	07/26/88	50.000	21.000	34.769	13	13
CHLORIDE	79S	micrograms/L	07/25/88	27000.000	3500.000	14450.000	8	8
FLUORIDE	79D	micrograms/L	07/26/88	740.000	390.000	565.000	2	8
NITRATE-NITRITE	79S	micrograms/L	07/25/88	45000.000	50.000	6757.500	8	8
SULFATE	79S	micrograms/L	07/25/88	90000.000	340.000	23017.500	8	8
1,4-DICHLOROBENZENE	81S	micrograms/L	07/26/88	3.500	0.900	2.200	2	13
2-METHYLNAPHTHALENE	83S	micrograms/L	07/26/88	10.000	1.100	5.550	2	13

TABLE 2.7 (Continued)
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE D-7 (ZONE D)
DOVER AFB, DELAWARE

ANALYTE	SAMPLE ID	UNITS	DATE	MAXIMUM CONC.	MINIMUM CONC.	MEAN	QUANTITY OF HITS	QUANTITY OF SAMPLES
BIS(2-ETHYLHEXYL)PHTHALATE	80D	micrograms/L	07/25/88	4.500	1.700	2.967	3	13
DI-N-BUTYL PHTHALATE	84D	micrograms/L	07/26/88	6.000	1.900	3.809	11	12
N-NITROSODIMETHYLAMINE	83S	micrograms/L	07/26/88	10.000	10.000	10.000	2	13
NAPHTHALENE	81S	micrograms/L	07/26/88	1.600	1.600	1.600	1	13
O-XYLENE	81S	micrograms/L	07/26/88	10.000	0.300	4.933	3	14
1,1-DICHLOROETHANE	81S	micrograms/L	07/26/88	1.600	0.500	1.050	2	13
1,2-DICHLOROETHENE	83S	micrograms/L	07/26/88	3.400	3.400	3.400	1	13
ACETONE	80S	micrograms/L	07/25/88	3600.000	3.100	479.456	9	13
BENZENE	81S	micrograms/L	07/26/88	6.300	1.200	3.750	2	13
CHLOROETHANE	83S	micrograms/L	07/26/88	1.400	0.900	1.150	2	13
CHLOROFORM	79D	micrograms/L	07/26/88	1.100	0.070	0.493	4	13
ETHYLBENZENE	81S	micrograms/L	07/26/88	3.600	0.400	2.000	2	13
M-XYLENE	79D	micrograms/L	07/26/88	0.900	0.900	0.900	1	13
METHYL CHLORIDE	81S	micrograms/L	07/26/88	3.000	3.000	3.000	1	13
TETRACHLOROETHENE	79D	micrograms/L	07/26/88	0.900	0.030	0.279	8	13
TOLUENE	81S	micrograms/L	07/26/88	40.000	0.200	20.100	2	13
TRICHLOROFLUOROMETHANE	82SD	micrograms/L	07/26/88	0.300	0.200	0.250	2	13
VINYL CHLORIDE	81S	micrograms/L	07/26/88	130.000	13.000	71.500	2	13
XYLENE (TOTAL)	81S	micrograms/L	07/26/88	5.800	5.800	5.800	1	13

Source: Dames & Moore and HAZWRAP, 1993.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

The Site SS27/XYZ conceptual model is a three-dimensional representation of the hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose of the conceptual model is to integrate available data so that a coherent representation of the groundwater flow and contaminant transport system can be developed. The conceptual model will be used to aid in locating additional data collection points and to help develop the Bioplume II® model.

Successful conceptual model development involves:

- Definition of the problem to be solved;
- Model selection;
- Designing the conceptual model;
- Integrating available data, including:
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphy,
 - Contaminant concentration and distribution data; and
- Determining additional data requirements.

2.2.1 Conceptual Model Design Components

Site hydrogeologic data were previously integrated to produce hydrogeologic cross-sections of Dover AFB (Dames & Moore and HAZWRAP, 1993). Section B-B' shows, in limited detail, the relationships between hydrostratigraphic units (i.e., transmissive units and aquitards), and visual definition of approximate groundwater levels and locations of the lower Calvert Formation. Figure 2.1 depicts the locations of hydrogeologic sections for Dover AFB. Figure 2.2 represents hydrogeologic section B-B', which is oriented roughly parallel to the NW/SE runway. This section shows that the alluvial groundwater regime changes from unconfined to confined or semiconfined from northwest to southeast across site SS27/XYZ located in the western most portion of section B-B'.

Because free product is present at the site, it may be necessary to use the fuel/water partitioning model of Bruce et al. (1991) to provide a conservative source term to model

the partitioning of BTEX compounds from the free-product phase into the groundwater. In order to use this model, samples of free product must be collected and analyzed for mass fraction of BTEX compounds.

Based on available data, ES will model the site as an unconfined to semi-confined fine- to coarse-grained sandy aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

2.2.2 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater surface discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. Such information can be obtained from Dover AFB maps which delineate areas that may facilitate rapid subsurface transport and/or surface discharge. Pathways to potential receptors may include discharge of contaminated groundwater into downgradient surface water bodies (e.g., drainageways and surface stream), and migration of the contaminant plume toward downgradient potable and nonpotable water wells.

Potential human and/or ecological receptors of BTEX contamination in groundwater will be identified. Three jurisdictional wetlands are delineated on Dover AFB, but are not located within or down-gradient to site XYZ. No designated ecologically sensitive habitat has been identified at the site, and Dover AFB is characterized as having limited habitat due to the extent of surface coverage by roadways, buildings, etc. An ecological assessment (EA) describing base ecology was performed in 1991 to identify sensitive habitats and potential impacts on these habitats from base activities (HAZWRAP, 1993a). No groundwater wells for potable water supplies are known to exist at Dover AFB or in adjacent lands. Up to 80 percent of the groundwater used by surrounding Kent County and Dover AFB is extracted from the Cheswold and Piney Point aquifers, located beneath the Columbia Aquifer and separated by several confining beds of clay. Hence, the potential contamination of potable groundwater supplies is low. Because the groundwater at site SS27/XYZ is hydrogeologically connected to the St. Jones River southwest of the site (approximately 4,000 feet from the edge of the plume to the river), it may be necessary to survey the area outside the immediate vicinity of the site to identify any river marshes or other possible receptors.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To accurately complete the EE/CA and to demonstrate that intrinsic remediation of site-related contaminants is occurring at Site SS27/XYZ, 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 EE/CA.

Hydrogeologic characteristics to be determined for Site SS27/XYZ include:

- Depth from measurement datum to the groundwater surface in existing monitoring wells.
- Depth from measurement datum to the base of the shallow saturated zone (where feasible).
- 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.
- Determination of extent and thickness of free-phase product.

Chemical and physical hydrogeologic characteristics to be determined for Site SS27/XYZ include:

- Dissolved oxygen (DO) concentration.
- Temperature.
- Specific conductance.
- pH.

- Chemical analysis of free product to determine mass fraction BTEX.
- Additional chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

To document the potential for intrinsic remediation at Sites ST04/AAFES and D-7 (Zone D), limited site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined after the field work phase of the EE/CA for Site SS27/XYZ is completed.

Hydrogeologic characteristics to be determined for Sites ST04/AAFES and D-7 (Zone D) include:

- Depth from measurement datum to the groundwater surface in existing monitoring wells.
- Depth from measurement datum to the base of the shallow saturated zone (where feasible).
- Locations of potential groundwater recharge and discharge areas.
- Locations of downgradient wells and their uses.
- Stratigraphic analysis of subsurface media.
- Determination of extent and thickness of free-phase product.

Chemical and physical hydrogeologic characteristics to be determined for Sites ST04/AAFES and D-7 (Zone D) include:

- DO concentration.
- Temperature.
- Specific conductance.
- pH.
- Additional chemical analysis of groundwater and soil for some of the parameters listed in Table 3.1.

In order to obtain these data, cone penetrometer testing (CPT) in conjunction with laser-induced fluorometry (LIF) and groundwater, free product, and soil sampling will be completed at site SS27/XYZ in support of the EE/CA. New groundwater monitoring points will be installed, as needed, to support the intrinsic remediation option. The following

TABLE 3.1
LABORATORY ANALYTICAL PROTOCOL FOR
GROUND WATER AND SOIL ANALYSIS
SITES SS27/XYZ, ST04/AAFES, and D-7 (ZONE D)
DOVER AFB, DELAWARE

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric	F
Ferrous Iron (Fe2+)	Colorimetric	F
Ferric Iron (Fe+3)	Difference between total and ferrous iron	F
Manganese	Colorimetric	F
Sulfate	Colorimetric	F
Sulfide	Colorimetric	F
Nitrate-Nitrogen	Colorimetric	F
Nitrite-Nitrogen	Colorimetric	F
Oxygen	Direct Reading Meter	F
pH	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
Carbon Dioxide	Titrimetric	F
Alkalinity (Carbonate [CO3-2] and Bicarbonate [HCO3-1])	Titrimetric	F
Nitrate	E300 or SW9056	L
Nitrite	E300 or SW9056	L
Chloride	E300 or SW9056	L
Sulfate	E300 or SW9056	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015	L
Vinyl Chloride	SW8021	L
SOIL		
Aromatic Hydrocarbons	SW8020	L
Total Organic Carbon	Method 415.1	L
Moisture	Dry @ 105 degrees Centigrade for 24 Hours	L
Total Petroleum Hydrocarbons	Method 418.1, Modified 8015	L
Grain Size Distribution	Sieve Analysis	L

sections describe the procedures that will be followed when collecting additional site-specific data. CPT and CPT/LIF testing are described in Section 3.1. Procedures to be used for the installation of permanent monitoring points and temporary sampling points are described in Section 3.2. Procedures to be used to sample existing groundwater monitoring wells and newly installed permanent monitoring points and temporary sampling points are described in Section 3.3. Procedures used to measure aquifer parameters (i.e., hydraulic conductivity) are described in Section 3.4.

3.1 CONE PENETROMETRY

Subsurface conditions at sites SS27/XYZ, ST04/AFFES, and D-7 (Zone D) will be characterized with CPT coupled with LIF. Cone penetrometry is an expeditious and effective means of analyzing the stratigraphy of a site by measuring the resistance of different soil types against the conical probe of the penetrometer as it is pushed into the subsurface. The resistance on the pressure tip and friction sleeves on the side of the cone are then correlated to soil cores collected to calibrate the CPT readings to the lithologies present at the site. Methodologies for the collection of soil core data are described in Section 3.1.2. Depending on the type of soil, site conditions, and experience of the crew operating the equipment, CPT can provide large amounts of data for a minimum of the cost of actual soil borings.

CPT will be conducted using the Applied Research Associates, Inc. (ARA) cone penetrometer truck, which consists of an instrumented probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is mounted inside an 18-foot van body attached to a 10-wheel truck chassis with a turbo-charged diesel engine. Ballast in the form of metal weights and a steel water tank, which can hold 5,000 pounds of water, are added to the truck to achieve an overall push capability of 45,000 pounds. This push capacity may be limited in tight soils by the structural bending capacity of the 1.7-inch outside-diameter (OD) pushrods, rather than by the weight of the truck. The current 45,000-pound limitation is intended to minimize the possibility of pushrod buckling. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe is of standard dimensions, having a 1.7-inch-OD, 60-degree conical tip, and a 1.7-inch OD by 5.27-inch-long friction sleeve. A pressure gauge located above the cone tip monitors the pore water pressure so that corrected estimates of water depth and

permeability can be made. Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell inside the probe is a cylinder of uniform cross section which is instrumented with four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data is digitized, recorded, and plotted by computer in the penetrometry truck. The penetrometer is normally advanced vertically into the soil at a constant rate of 48 inches per minute, although this rate must sometimes be reduced, such as when hard layers are encountered. The magnitude of the penetration pore pressure is a function of compressibility and, most importantly, permeability. Penetration, dissipation, and resistivity data will be used to determine potential site layering as it is encountered in the field.

The CPT apparatus is capable of placing a variety of well types to collect groundwater samples. Permanent monitoring points and temporary sampling points can be installed by the pushrod of the CPT as it descends into the subsurface. Placement of such points is useful because groundwater samples can be taken at several depths very quickly. Polyvinyl chloride (PVC) casing is inserted into the hollow center of each section of the pushrod and lowered into the subsurface to construct a fully cased well. A sacrificial tip on the end of the pushrod anchors the PVC screen and casing into the soil as the pushrod is extracted. Groundwater samples are collected with a peristaltic pump and Teflon[®]-lined tubing. Such sampling points are constructed with 1 meter of slotted PVC screen. Grab-samples of water can also be collected with the CPT equipment without placement of screens by extracting water from the center of the penetrometer rod itself. The penetrometer rod is lowered to the desired depth, and then withdrawn 2 to 3 feet to allow water to enter the vacated space left by the penetrometer tip. A tube or a bailer inserted to the bottom of the rod is then used to extract the groundwater.

The known ability of aromatic or chlorinated hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology in conjunction with CPT technology to detect soil characteristics and hydrocarbon contamination simultaneously. The CPT/LIF system has a sapphire window in the side of the CPT pressure cone that allows a laser to scan the soil for fluorescent compounds as the CPT/LIF penetrometer rod pushes through soil. Assuming that aromatic hydrocarbons are co-solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. A fiber optic cable connected to the laser spectrometer, and a

6-pair electrical conductor connected to the CPT data acquisition system, are routed through the interior of the push tubes to the CPT probe.

The basic laser system components of the LIF CPT are a Nd:YAG[®] pump laser, two separate and independent dye lasers, frequency-doubling crystals which convert the visible dye laser output to ultraviolet, a fiber optic probe, a monochromator for wavelength resolution of the return fluorescence, a photomultiplier tube to convert photons into an electrical signal, a digital oscilloscope for waveform capture, and a control computer. The fiber optic probe for the cone penetrometer consists of a delivery and collection fiber, a protective sheath, a fiber optic mount within the cone, and a sapphire window. The up-hole portion of the system is adaptable to either groundwater monitoring fiber optic probes or an optical cone penetrometer probe. Optimal wavelengths to be used during a continuous CPT push will be determined from initial data. Wavelength is selected to give the strongest fluorescence signal, which can be attributed to the presence of contamination. Past experience suggests that a short wavelength of less than 275 nanometers (nm) may be appropriate for detecting the fluorescence of BTEX.

The purpose of the CPT/LIF sampling at Site SS27/XYZ is to determine subsurface stratigraphy, to help delineate the areal extent of the free- and residual-phase BTEX plumes, and to place permanent monitoring points and temporary sampling points. The purpose of CPT sampling is determination of subsurface stratigraphy and placement of permanent monitoring points and temporary sampling points for delineation of the dissolved-phase plume. Limited sampling at Sites ST04/AFFES and D-7 (Zone D) will be conducted with CPT or CPT/LIF to confirm the presence of subsurface contaminants (gasoline and vinyl chloride, respectively) and to provide a general delineation of subsurface stratigraphy.

3.1.1 Sampling Strategy

CPT/LIF data will be used to better define the areal and vertical extent of free- and residual-phase fuel hydrocarbons in the unsaturated zone at site SS27/XYZ. The cone penetrometer with the LIF assembly will be pushed from ground surface to below visible contamination, or up to 40 feet bgs, depending on contaminant distribution. The cone penetrometer without the LIF assembly will be used to better define the areal and vertical extent of dissolved-phase hydrocarbons after the free-phase plume has been delineated with CPT/LIF. It is anticipated that data from a total of 24 temporary sampling locations will be collected with both CPT/LIF and CPT equipment with two depths punched per location, or up

to 48 punches, to define the edges of the free- and dissolved-phase plumes (Figure 3.1). Grab-samples may also be taken to collect additional groundwater data near proposed CPT/LIF or CPT locations. In addition to the 24 temporary sampling locations, up to 6 new permanent monitoring locations will be installed, or 12 permanent points (shallow and deep), to help monitor the long-term biodegradation and migration of the dissolved-phase hydrocarbon plume. Table 3.2 shows the total quantity of permanent and temporary points to be placed.

The general area to be sampled was determined from information provided at the November 23, 1993 meeting at Dover AFB. Sample locations will emanate radially from the estimated centroid of the plume at 45-degree intervals, with a total of eight radial sampling arms completing a 360-degree scan. The estimated centroid of the plume is located approximately 200 feet northwest of monitoring well 59D (Figure 3.1) at the middle of the fillet defining the corner of the taxiway and the edge of the grassy median. An iterative, forward and backward sampling strategy will be used to define the leading edge of the free-phase plume along the radial arms. Once the downgradient edge of the free-phase plume has been identified, cone penetrometer sampling will continue to define the lateral, vertical, and horizontal extent of the dissolved-phase plume.

Site SS27/XYZ is located in an area of significant aircraft traffic and paved taxiway and fuel pad coverage. In addition, the concrete beginning 300 feet southeast of fuel pad X has been replaced recently (May 1993) and is covered by a warranty that may preclude any drilling operations for 1 year. A majority of the CPT/LIF samples will be located in the areas northeast of the NW/SE taxiway and will not require drilling into paved taxiways and fuel pads, except possibly in sidewalk or driveway areas around the fuel pump station (Building 950). At least a third of the CPT punches must be placed in the tarmac around fuel pads X, Y, and Z, and in the new concrete area southeast of fuel pad X. As many as four CPT/LIF samples may need to be collected in the vicinity of the new concrete to define the contaminant plume. ES proposes to conduct CPT operations in these areas by drilling and punching during periods of low activity (e.g., weekends, late afternoon, or early morning), as recommended by Dover AFB. An anticipated CPT sampling layout is shown in Figure 3.1.

CPT sampling at Sites ST04/AFFES and D-7 (Zone D) will consist of up to three pushes at each site along the approximate centerline of the plume in the general direction of groundwater flow and plume migration. These samples are designed to verify the existence

TABLE 3.2

**SUMMARY OF WELL TYPES TO BE PLACED
AT SITE SS27/XYZ
DOVER AFB, DELAWARE**

SAMPLE TYPE	NUMBER OF LOCATIONS	SCREENED INTERVALS PER LOCATION	NUMBER OF SCREENS	ID (inches)
Temporary Sampling Points	24	2	48	0.5
Permanent Monitoring Points	6	2	12	1.5
Grab Samples	A*	N/A	N/A	N/A

A* - To be determined in the field.

N/A - Not applicable, samples to be collected directly from the CPT apparatus.



**PROPOSED CONE PENETROMETER
AND GROUNDWATER SAMPLING
LOCATIONS AT SITE SS27/XYZ**

Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.

Denver, Colorado

LEGEND

-
- GP-300
 - MONITORING WELL/PIEZOMETER
 - CONTOUR OF BTEX CONCENTRATION
(micrograms/Liter)
 - CONTOUR OF SURFACE ELEVATION
(feet above MSL)
 - PROPOSED MONITORING WELL LOCATION
 - PROPOSED CONE PENETROMETER (CPT) LOCATION
AND/OR PROPOSED GROUNDWATER SAMPLE FROM
CPT PUNCH USING A PERISTALTIC PUMP
 - GROUNDWATER FLOW
 - BURM/FILL MATERIAL
 - FENCED AREA

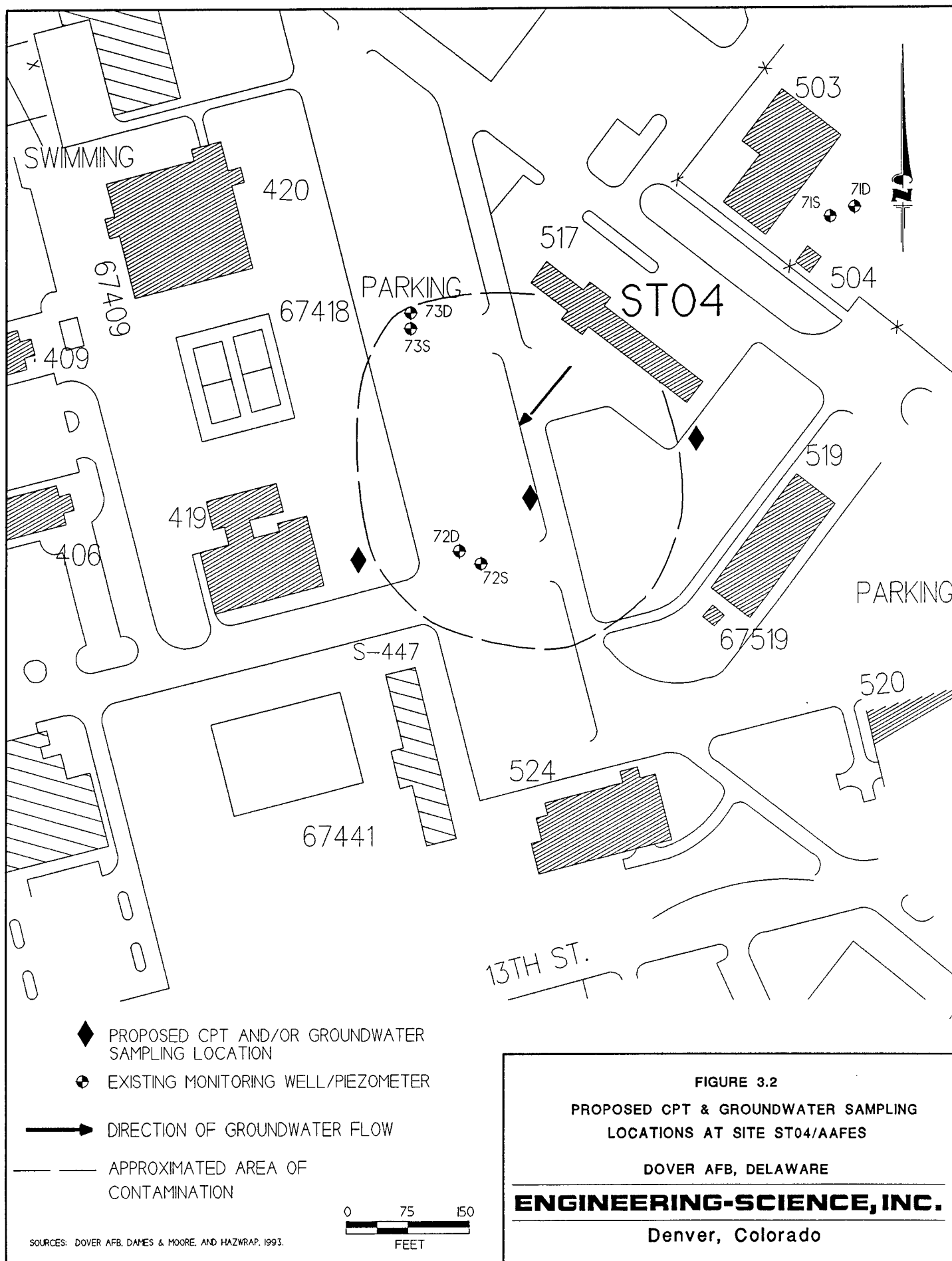
of contamination and to document the possibility of any natural biodegradation occurring at three distinct locations within the plumes. Anticipated sampling locations are shown in Figures 3.2 and 3.3.

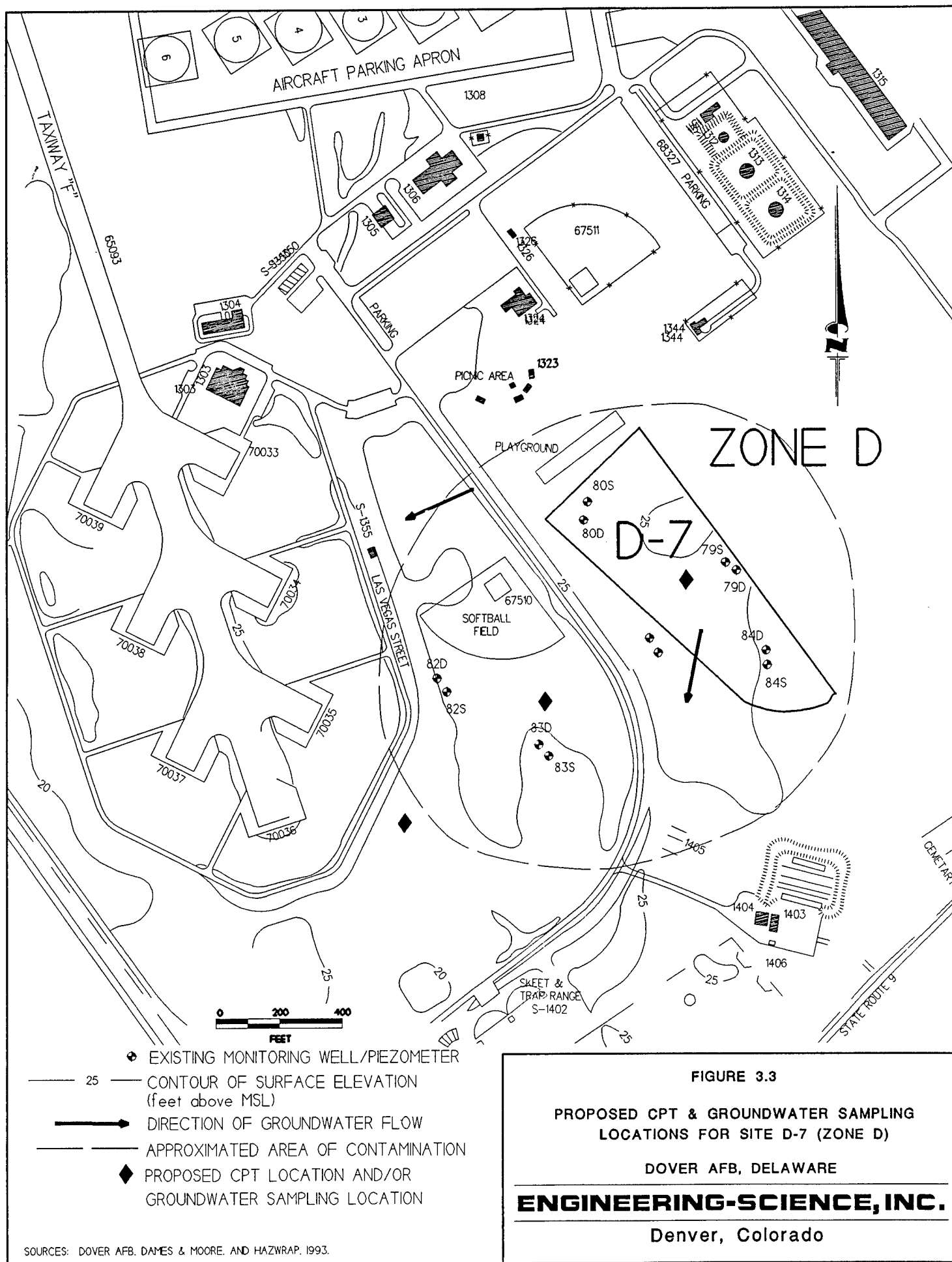
All necessary digging and access permits will be obtained by Dover AFB personnel prior to ES mobilizing to the field. This will include the identification of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any CPT operations. ARA will be responsible for supplying a certified Delaware driller and acquiring the necessary state drilling and well installation (CPT) permits.

3.1.2 Soil Core Sampling and Analysis

To calibrate CPT/LIF data, soil cores will be collected during CPT/LIF activities at Sites SS27/XYZ, ST04/AAFES, and D-7 (Zone D). It is anticipated that five soil samples will be required. Soil coring will involve coring the suspected area of the free-phase plume from approximately 4 feet above the free-phase plume to approximately 4 feet below the free-phase plume until CPT/LIF data are sufficiently verified/validated. Most of these soil cores will be located near the CPT sampling locations in the suspected free-phase plume to allow data comparison and verification. ARA will provide the equipment and personnel necessary to complete this activity during the period from April 11 through April 22, 1994. One-foot resolution of soil cores for verification purposes will be considered sufficient for the intrinsic remediation demonstration at Site SS27/XYZ.

A Mostap-35[®] sampler generally can be used to collect "complete" soil samples at any desired depth within the range of the driving apparatus. The sampler is coupled to the penetrometer rod and pushed into the soil with equipment used for CPT/LIF. While the Mostap-35[®] cone is in position, soil is prevented from entering the sampling tube until the desired depth is achieved. When the sampler has been pushed to the depth at which the soil sample is to be taken, the sampling unit is raised a few inches and the Mostap apparatus is then unlocked. After unlocking the Mostap attachment, a soil section is cut and the sampling apparatus is then pulled from the ground as quickly as possible. Soil sections of 2 feet will be used as optimal sample lengths in the sandy soils of the Columbia Aquifer. Recovery efficiencies for samples in saturated soils are often reduced or the samples are compromised because of spillage of the soil from the device after extraction. To mitigate this problem, soil samples will be compressed *in situ* with the penetrometer and Mostap assembly to drain much





of the pore water before extraction. Compressed soil samples can then be extracted and measured to give a description of the soil stratigraphy accurate for the length of soil core taken. If the Mostap-35[®] sampling techniques described above is not appropriate for the characterization of any of the sites, continuous soil samples will be obtained from other conventional methods as deemed appropriate by the ES field hydrogeologist.

Soil samples will be collected continuously over the full depth of the soil borehole unless an alternative sampling frequency is requested by the ES field hydrogeologist. Procedures will be modified, if necessary, to ensure good sample recovery. The soil samples collected will be removed from the continuous sampler and split lengthwise. One-half of the sample will be placed on clean aluminum foil for lithologic logging. The other half of the sample will be placed in analyte-appropriate sample containers (Appendix A) and shipped to the analytical laboratory for analysis of BTEX, total organic carbon (TOC), moisture content, total petroleum hydrocarbons (TPH), and grain size distribution.

The ES field hydrogeologist 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 of the proposed geologic boring log form is presented in Figure 3.4. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- 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.

The purpose of the soil corings are to verify/validate the CPT/LIF data. Limited site hydrogeologic characterization of Sites SS27/XYZ, ST04/AAFES, and D-7 (Zone D) has already been accomplished.

BOREHOLE LOG

SITE NAME AND LOCATION	DRILLING METHOD:					BORING NO.	
						SHEET	
	SAMPLING METHOD:					OF	
						DRILLING	
						START	FINISH
	WATER LEVEL					TIME	TIME
	TIME						
	DATE					DATE	DATE
	CASING DEPTH						

DRILL RIG					SURFACE CONDITIONS								
ANGLE					BEARING								
SAMPLE HAMMER TORQUE					FT.-LBS								
DEPTH IN FEET (ELEVATION)	BLOWS/ MIN. ON SAMPLER (RECOVERY)	CORES			SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS		
		RUN NO.	NO. AND SIZE OF CORE PIECES	% RECOVERY							ROD	FROM	TO

DRILLING CONTR.

LOGGED BY:

DATE _____ CHK'D BY _____

18

FIGURE 3.4
GEOLOGIC BORING LOG

3.1.3 Boring Location and Datum Survey

The locations of and other relevant site information for the soil corings collected for verification purposes will be recorded by the ES field hydrogeologist. The horizontal location will be measured relative to established Dover AFB coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface relative to the measurement datum will also be measured relative to US Geological Survey (USGS) mean sea level data. The ground surface elevation will be measured to the nearest 0.1 foot, and the measurement datum will be measured to the nearest 0.01 foot.

3.1.4 Site Restoration

After sampling is complete, each CPT and soil sampling location will be restored as close by to its original condition as possible. Holes created by CPT in sandy soils similar to those found at the Dover AFB sites tend to cave in soon after extraction of the penetrometer rod. However, any test holes remaining open after extraction of the penetrometer rod will be sealed with hydrated bentonite pellets to eliminate any contaminant migration pathway to the groundwater.

Holes bored into concrete runways, taxiways, fuel pads, and other paved surfaces will be patched to grade upon completion of the CPT soundings and well installations. If requested by Dover AFB personnel, ARA will provide temporary hole covers for protection of aircraft and vehicular traffic that may pass over the hole. These hole covers will be constructed of a steel plate no less than 1/8" thick and large enough to fully cover the hole. The plate will be sufficiently anchored to the hole to prevent potential dislodgment by jet engine operation and aircraft tires.

3.1.5 Decontamination Procedures

The CPT push rods will be cleaned with ARA's CPT steam-cleaning system as the rods are withdrawn from the ground. A vacuum recovery system will be implemented to capture nearly 100 percent of steam-cleaning rinseate from the rod cleaner located beneath the truck. Rinseate is generated only as the rods move past the cleaner, thereby minimizing liquid waste generation. Care will be taken not to apply the pressurized steam to the LIF module. Rinseate will be collected in 55 gallon drums provided by ARA. Filled drums will be

transported by ARA to Dover AFB's industrial waste collection drains located at Building 583 or to another disposal location identified by authorized Dover AFB personnel.

Potable water to be used in CPT equipment cleaning, decontamination, or grouting will be obtained from one of the onsite base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for the activities listed above. The field hydrogeologist 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. Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices.

3.2 PERMANENT MONITORING POINT AND TEMPORARY SAMPLING POINT INSTALLATION

To further characterize the hydrogeologic conditions of the shallow subsurface, up to 12 permanent monitoring points (6 locations with shallow and deep points) and 48 temporary sampling points (24 locations with shallow and deep points) will be installed at Site SS27/XYZ. Some of the temporary sampling points may be completed as permanent monitoring points, as necessary, to monitor plume migration. The following sections describe the proposed permanent monitoring point and temporary sampling point locations and completion intervals, point installation, point development, and equipment decontamination procedures. Grab-sampling of groundwater through bailing or pumping of water through the penetrometer rod requires no installation of materials and is described in Section 3.3.1.

3.2.1 Locations and Completion Intervals

Permanent monitoring points will be placed in locations requiring long-term monitoring to track potential migration of dissolved- or free- phase hydrocarbons from Site SS27/XYZ. Temporary monitoring points will be interspersed throughout the suspected area of contamination to describe horizontal and vertical concentrations of free- and dissolved-phase hydrocarbons in support of the natural attenuation remedial option. A more detailed description of the locations and completion intervals is described in the following sections.

3.2.1.1 Permanent Monitoring Points

At a minimum, six permanent monitoring points locations will be installed to further characterize and monitor groundwater quality at the site. Proposed locations for these points were determined from a review of existing data compiled in a *Current Situation Report* prepared in May 1993 (Dames & Moore and HAZWRAP, 1993). Final monitoring point locations will be based on the results of the proposed field work. These additional monitoring points are needed to provide downgradient and upgradient monitoring points at the site.

Installation of five of the six permanent monitoring points is anticipated to occur at the suspected boundaries of the plume along the southwestern edge and due south of fueling pads Z and X, respectively; at the northwestern corner of the plume by Building 945; at the northeastern edge of the plume in the grassy area; and south of the plume (Figure 3.1). These locations were selected to provide useful hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. The other monitoring point location will be selected in the field pending the collection of additional data. Each monitoring point will consist of a pair of nested points: a shallow point intended to sample the shallow portion of the aquifer, and a deep point intended to sample the groundwater at depth. These two screened depths, with 1 meter of screen each, will provide discrete information on the nature of hydraulic gradients in the area and on vertical contaminant distribution. Monitoring point completion depths to the bottom of the screened interval are expected to range between approximately 12 and 35 feet bgs.

3.2.1.2 Temporary Sampling Points

In addition to the 6 permanent monitoring points to be installed at Site SS27/XYZ, up to 24 temporary sampling point locations will be installed to fully identify the extent of hydrocarbon contamination. The proposed locations for the temporary sampling points were determined from the *Current Situation Report* prepared in May 1993 (Dames & Moore and HAZWRAP, 1993), and may change based on the results of proposed field work. Figure 3.1 shows the 24 proposed temporary sampling locations, which coincide with anticipated CPT/LIF or CPT activities. These locations were selected to provide geochemical and hydrogeologic data necessary for successful implementation of the Bioplume II model. Two screened depths, with 1 meter of screen each, will allow groundwater samples to be collected. These groundwater samples will provide information on the vertical and horizontal

contaminant distribution. Temporary sampling point completion depths are expected to range from between approximately 12 and 35 feet bgs.

3.2.2 Permanent Monitoring Point and Temporary Sampling Point Installation Procedures

This subsection addresses the procedures for installing new permanent monitoring points and temporary sampling points. All new monitoring points will be constructed with 1.9/1.5-inch OD/inside-diameter (ID) PVC casing for both deep and shallow intervals placed with a CPT pushrod using equipment described in Section 3.1. All screened sections of temporary sampling points will be constructed of 0.75/0.5-inch OD/ID PVC casing with either a tube (3/8-inch Teflon[®] or high-density polyethylene [HDPE]) or PVC casing extending to the surface. Screened intervals of both permanent monitoring points and temporary sampling points will be a maximum of 1 meter. The permanent monitoring points will be fitted with vented caps provided by ARA.

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, drilling, and groundwater monitoring and sampling point installation 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.

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

3.2.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling site, instrumented probes, tips, sleeves, pushrods, samplers, tools, and other down-hole 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 55-gallon drums provided by ARA and

later transported by ARA to the industrial waste collections drains at the oil/water separator in Building 583 or to another location designated by base personnel.

All sampling tools will be cleaned onsite, prior to use and between each sampling event, with a clean water/phosphate-free detergent mix and a clean water rinse. All permanent monitoring and temporary sampling point completion materials that are not factory sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used. All decontamination activities must be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

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

Surface runoff of miscellaneous spills and leaks and precipitation will not be allowed to enter any penetrometer hole either during or after monitoring point construction. Starter casing, recirculation tanks, berms around the boreholes, and surficial bentonite packs, as appropriate, will be used to prevent runoff.

3.2.2.3 Permanent Monitoring Point and Temporary Sampling Point Installation

Permanent groundwater monitoring points and temporary sampling points will be installed by attaching 1.9- or 0.75-inch OD PVC casing, respectively, inside the pushrod of the penetrometer device and then inserting it into the subsurface. As the pushrod descends, new PVC tubing will be continuously attached until the desired depth and screened interval are reached. Data collection devices such as CPT and LIF will not be used during monitoring point placement. More detailed monitoring point installation procedures are described in the following paragraphs.

3.2.2.3.1 Permanent Monitoring Point and Temporary Sampling Point Materials Decontamination

Point completion materials will be inspected by the field hydrogeologist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned with a high-pressure, steam/hot water cleaner using approved water

prior to use. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used.

3.2.2.3.2 Permanent Monitoring Point and Temporary Sampling Point Casing

Pushing the penetrometer rod to the desired depth will install the casing for each point. Construction details will be noted on a Monitoring/Sampling Point Installation Record form (Figure 3.5). This information will become part of the permanent field record for the site.

Blank permanent monitoring or temporary sampling point casing will be constructed of Schedule 40 PVC with an ID of 1.5 inches and 0.5 inches, respectively. All casing sections will be flush-threaded; glued joints will not be used. The casing at each monitoring point will be connected to the disposable penetrometer tip on the bottom and fitted with a top cap constructed of the same type of material as the monitoring point casing. The top caps of the permanent monitoring points will be vented to maintain ambient atmospheric pressure within the monitoring point casing.

The field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all permanent monitoring and temporary sampling point completion materials placed in the annulus between the casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

3.2.2.3.3 Permanent Monitoring Point and Temporary Sampling Point Screen

Permanent monitoring and temporary sampling point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 1.5 inches and 0.5 inches, respectively. The screens will be factory slotted with 0.01-inch openings. The positions of the screens will be selected by the field hydrogeologist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the point will be screened. The shallow wells will be placed across the water table to sample the free product layer, and the deep wells will be placed to sample below the free product layer.

3.2.2.3.4 Flush-Mount Protective Cover

Each of the permanent monitoring points will be completed with an at-grade protective cover supplied by ARA. In areas where pavement is present, the at-grade cover will be

Well No. _____
Boring No. X-Ref: _____

MONITORING/SAMPLING POINT CONSTRUCTION SUMMARY

Survey Coords: _____ Elevation Ground Level _____
Top of Casing _____

Drilling Summary:

Total Depth _____
Borehole Diameter _____
Casing Stick-up Height: _____
Driller _____
Rig _____
Bit(s) _____
Drilling Fluid _____
Protective Casing _____

Well Design & Specifications

Basis: Geologic Log _____ Geophysical Log _____
Casing String (s): C = Casing S = Screen.

Depth	String(s)	Elevation
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Casing: C1 _____
C2 _____
Screen: S1 _____
S2 _____

Filter Pack: _____
Grout Seal: _____
Bentonite Seal: _____

Comments: _____

Construction Time Log:

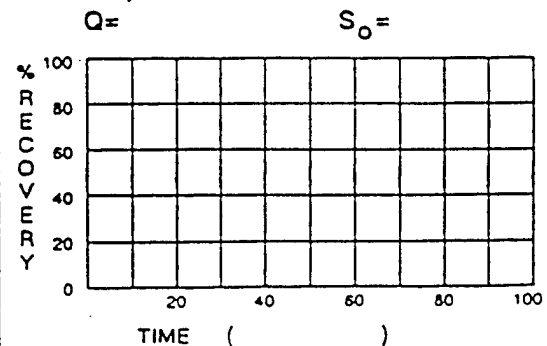
Task	Start		Finish	
	Date	Time	Date	Time
Drilling	_____	_____	_____	_____
Geophys. Logging:	_____	_____	_____	_____
Casing:	_____	_____	_____	_____
Filter Placement:	_____	_____	_____	_____
Cementing:	_____	_____	_____	_____
Development:	_____	_____	_____	_____

Well Development:

Stabilization Test Data:

Time	p H	Spec. Cond.	Temp (C)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Recovery Data:



SITE NAME _____

SUPERVISED BY _____

FIGURE 3.5
MONITORING/SAMPLING POINT
INSTALLATION RECORD

cemented in place using concrete which will be blended to the existing pavement. In areas where pavement is not already present, a 6-inch thick, 1-foot-diameter concrete pad will be constructed around the protective cover. In either case, the concrete immediately surrounding the monitoring point will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

3.2.2.4 Permanent Monitoring Point and Temporary Sampling Point Development

New permanent and temporary points will be developed prior to sampling. Development removes sediment from inside the point casing and flushes fines from the portion of the formation adjacent to the monitoring point screen.

Development will be accomplished using a peristaltic pump provided by ES. The pump tubing will be regularly lowered to the bottom of the permanent monitoring point so that fines which have accumulated in the bottom are agitated and removed from the monitoring point in the development water. Temporary sampling points with tubing extending to the surface will be developed by connecting the peristaltic pump to the tubing.

Development will be continued until enough water has been removed to allow water pH, temperature, specific conductivity, DO, and water clarity (turbidity) to stabilize. If the water remains turbid, monitoring point development will continue until the turbidity of the water produced has been stable after the removal of several casing volumes. Only a few casing volumes of water are anticipated to have to be withdrawn before development occurs because soil corings are not needed to install the monitoring point, and little soil and debris should be present in the casing.

Development waters will be collected in 55-gallon drums provided by ARA. Filled drums will be transported by ARA to the Dover AFB industrial waste collection drain at the oil/water separator located in Building 583 or to other approved facilities for treatment and disposal as authorized by Dover AFB personnel.

3.2.2.5 Permanent Monitoring Point and Temporary Sampling Point Development Records

A record of permanent monitoring and temporary sampling point development will be maintained for each point. The development record will be completed in the field by the field hydrogeologist. Figure 3.6 is an example of the permanent monitoring and temporary

FIGURE 3.6
WELL/POINT DEVELOPMENT RECORD

Page__ of__

Job Number _____
Location _____
Well Number _____

Job Name _____
By _____ Date _____
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:

sampling point development record. A summary point development record form will be prepared for each point and submitted with the EE/CA report. Development records will include:

- Permanent monitoring and temporary sampling point number;
- Date and time of development;
- Development method;
- Predevelopment water level and monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Postdevelopment water level and point depth; and
- Field analytical measurements, including pH and specific conductivity.

3.2.2.6 Water Level Measurements

Water levels at existing monitoring wells and newly installed permanent monitoring points and temporary sampling points will be measured within a short time interval so that the water level data are comparable. Water levels in the newly installed monitoring and sampling points will be measured after development when the water level has stabilized. The depth to water below the measurement datum will be made using an electric water level probe to the nearest 0.01 foot. Water levels in pre-existing wells will be measured with an oil/water interface probe to the nearest 0.01 foot.

3.2.2.7 Permanent Monitoring Point and Temporary Sampling Point Location and Datum Survey

The location and elevation of the new monitoring and sampling points will be surveyed by an ARA provided surveyor soon after point completion. The horizontal location will be measured relative to established Dover AFB coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the monitoring point casing and the measurement datum (top of PVC casing) will be measured relative to a USGS mean sea level datum. The ground surface elevation will be measured to the nearest 0.1 foot and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

3.2.3 Site Restoration

After monitoring point installation and sampling is complete, each site will be restored as closely to its original condition as possible. Clean and contaminated development waters and sampling purge waters will be transferred to and stored in ARA's 55-gallon drums, and then transported by ARA to the industrial waste collection drain located at the oil/water separator in Building 583 or to another authorized location designated by Dover AFB personnel.

3.3 GROUNDWATER SAMPLING

This section describes the scope of work required for collecting groundwater quality samples at existing groundwater monitoring wells and at newly installed permanent monitoring points and temporary sampling points. This section also details grab-sampling using bailers or peristaltic pumps inserted into the penetrometer itself to obtain single, discrete groundwater samples. All groundwater samples will be obtained using a peristaltic pump and dedicated Teflon[®]-lined, polyethylene tubing where groundwater levels permit. 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 trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this plan prior to sample acquisition and will have a copy of the plan available onsite for reference.

The groundwater sampling process is described in Section 3.3.1 and will occur between April 11 and April 22, 1994. Activities that will occur during groundwater sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity (for monitoring point sampling), 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 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;
- Completion of chain-of-custody records; and
- Sample disposition.

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

3.3.1 Groundwater Sampling Strategy

Groundwater samples will be collected from existing monitoring wells and newly installed permanent monitoring and temporary sampling monitoring points. Groundwater samples may also be taken at locations near CPT sites using the grab-sampling technique.

3.3.1.1 Existing Monitoring Well, Permanent Monitoring Point, and Temporary Sampling Point Sampling Locations

Existing groundwater monitoring wells upgradient, downgradient, and within the free-phase plume and the dissolved-phase plume will be sampled. The following nine wells will be sampled to facilitate Bioplume II model calibration: 60D and 60S (lateral to plume); PO5, PO7, PO8, 59D, and 59S (within free-phase plume); and 74S and 74D (downgradient of both free-phase and dissolved phase plumes). All newly installed permanent monitoring points and temporary sampling points also will be sampled.

In addition, new groundwater monitoring wells have recently been installed and developed primarily along the approximated northern half of the contaminant plume (in 1992 by Dames & Moore). These 10 wells were sampled in late December 1993 and early January 1994 by Dames & Moore, and contaminant concentration data for these wells should become available at a later date. These wells will be resampled by ES from April 11 to April 22, 1994.

3.3.1.2 Grab-Sample Sampling Locations

Groundwater samples will be collected using modified CPT/peristaltic pump equipment near many of the proposed CPT locations shown in Figures 3.1 through 3.3. The methods used to sample the groundwater are described in Section 3.3.3.2. Not all the proposed CPT locations will serve as groundwater sampling sites. Locations to be sampled will be recommended by the field hydrogeologist or engineer directing the contaminant plume delineation operations described in Section 3.1.1. The use of grab-samples may be guided by Air Force operations that require groundwater sampling to be conducted quickly so as to minimize the duration of drilling operations in sensitive areas. Sampling locations will be placed in areas where the suspected edges of the dissolved-phase and free-phase product plumes are located.

3.3.2 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 recordkeeping materials will be gathered prior to leaving the office.

3.3.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before use. This includes the CPT tool, water-level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;

- Rinse with distilled or deionized water;
- Rinse with reagent-grade ethanol or methanol;
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling form.

If pre-cleaned, dedicated 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, and therefore will not need to be cleaned in the field. The type of container provided and the method of container decontamination will be documented in the analytical laboratory's permanent record of the sampling event.

3.3.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite measurements of oxygen, carbon dioxide, pH, electrical conductivity, temperature, reduction/oxidation potential, sulfate, nitrate, nitrite, ferrous iron (Fe^{2+}), total iron, ferric iron [$\text{Fe}^{3+} = (\text{total iron}) - \text{Fe}^{2+}$], and manganese.

3.3.3 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 by cross-contamination through insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water 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 3.2.2.2. In addition to the use of properly cleaned equipment, dedicated Teflon[®]-lined, polyethylene tubing will be used at each sampling point, and a clean pair of new, disposable nitrile 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 existing groundwater monitoring wells and newly installed permanent monitoring points and temporary sampling 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.

3.3.3.1 Sampling of Existing Wells, Permanent Monitoring Points, and Temporary Sampling Points

3.3.3.1.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring and sampling 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 sampled well/point.

3.3.3.1.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring well, monitoring point, or sampling point the static water level will be measured. An electrical water level 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. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If free-phase product is encountered, attempts will be made to sample both within and below the oil lens.

3.3.3.1.3 Well/Point Purging

The volume of water contained within the old monitoring wells or the monitoring and sampling point casings at the time of sampling will be calculated, and three times the calculated volume will be removed from the well/point. All purge water will be placed in ARA provided, 55-gallon drums and disposed of by ARA into Dover AFB's industrial waste collection drain (located in the oil/water separator in Building 583) or at other approved locations. Emptied drums will be rinsed with hot water and returned to base personnel for reuse. Dedicated disposable bailers will be used for monitoring well purging, and a peristaltic pump will be used for permanent monitoring and temporary sampling point purging.

If a well/point is evacuated to a dry state during purging, the well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the

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.

3.3.3.1.4 Sample Extraction

Dedicated, Teflon[®]-lined, HDPE tubing and a peristaltic pump will be used to extract groundwater samples from the permanent monitoring points and temporary sampling points. The tubing will be lowered 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 analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for monitoring well/point purge waters and transported for disposal by ARA to the industrial waste drains located at the oil water separator in Building 583 unless instructed otherwise by Dover AFB personnel.

3.3.3.2 Grab-Sample Sampling

3.3.3.2.1 Sampling Interval and Method

The sampling depth and interval will be specified prior to driving the CPT pushrod into the ground. The ES field hydrogeologist or engineer will verify the sampling depth by measuring the length of each pushrod prior to insertion into the ground. A disposable drive tip will be placed on the tip of the pushrod, and the rod will be pushed into the ground using the truck, frames, and hydraulic equipment outlined in Section 3.1. After reaching the desired depth, the penetrometer pushrod will be raised 1 to 3 feet to allow decoupling of the disposable drive tip and to allow water to percolate into the end of the hollow pushrod. A 3/8-inch, Teflon[®]-lined HDPE tube will then be inserted into the pushrod and threaded to the bottom of the rod. Water samples will be collected from water entering the down-hole, open end of the pushrod with a peristaltic pump attached to the Teflon[®]-lined, HDPE tubing at the surface. The groundwater sample will be acquired as described in Section 3.3.3.2.4.

3.3.3.2.2 Preparation of Location

Prior to starting the sampling procedure, the area around the penetrometer insertion point will be cleared of foreign materials, such as brush, rocks, debris, etc. This will prevent sampling equipment from inadvertently contacting foreign materials near the sampling point.

3.3.3.2.3 Water-Level and Total Depth Measurements

Prior to removing any water from the modified CPT/peristaltic pump sample location, the static water will be measured. An electric water level probe will be inserted into the pushrod until it confirms that groundwater has been reached. Output from the pushrod will be fed into a computer algorithm that will calculate the water depth to the nearest 0.1 foot.

3.3.3.2.4 Sample Extraction

A peristaltic pump will be used to extract groundwater samples from the modified CPT/peristaltic pump sampling locations. Prior to sample collection, groundwater will be purged until dissolved oxygen and temperature readings have stabilized. The sample will be transferred directly to 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 analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed in a 55-gallon drum and transported for disposal by ARA to the industrial waste drains located at the oil/water separator in Building 583 unless instructed otherwise by Dover AFB personnel.

3.3.4 Onsite Groundwater Parameter Measurement

The following sections describe the procedures to be used to analyze groundwater samples from monitoring wells/points at Sites SS27/XYZ, ST04/AAFES, and D-7 (Zone D). Methods also are summarized in Table 3.1.

3.3.4.1 Dissolved Oxygen Measurements

DO measurements will be taken using a meter supplied by ES with a down-hole oxygen sensor before, and immediately following groundwater sample acquisition. When DO

measurements are taken in monitoring or sampling wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

3.3.4.2 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 by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded on the groundwater sampling record (see Section 3.3.5.5).

3.3.4.2 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by experienced ES engineers or geologists via titrimetric analysis using HACH® method 8223 (0-250 mg/L as CO₂). All glassware or plasticware used in the analyses will have been previously cleaned by thoroughly washing with a solution of Alconox® and water, and rinsing with deionized water and ethanol to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the groundwater sample with double-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 later transfer by ARA to the industrial waste drains on Dover AFB (Building 583) or another approved disposal facility.

3.3.4.3 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 ES engineers or geologists via titrimetric analysis using EPA-approved HACH® method 8221 (0-5000 mg/L as CaCO₃). Sample preparation and disposal are the same as outlined in Section 3.3.4.2.

3.3.4.4 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 in nitrate reduction in anaerobic environments.

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

All glassware or plasticware used in the analyses will have been previously cleaned by thoroughly washing with a solution of Alconox® and water, and rinsing with deionized water and ethanol to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the portable colorimeter, the analysis will be repeated by diluting the groundwater sample with double-distilled water to a level that falls 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 later transfer by ARA to the industrial waste drains on Dover AFB (Building 583) or another approved disposal facility.

3.3.4.5 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. The ES engineer or geologist 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 (0-70.0 mg/L SO₄) and 8131 (0.60 mg/L S²⁻) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively. Sample preparation and disposal procedures are the same as outlined in Section 3.3.4.4.

3.3.4.6 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 oxidation/reduction 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 for total soluble iron (0-3.0 mg/L $\text{Fe}^{3+} + \text{Fe}^{2+}$) and HACH® method 8146 for ferrous iron (0-3.0 mg/L Fe^{2+}) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels. Sample preparation and disposal procedures are the same as outlined in Section 3.3.4.4.

3.3.4.7 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. EPA approved HACH® method 8034 (0-20.0 mg/L) will be used to prepare the samples for quantitation of manganese concentrations. Sample preparation and disposal procedures are the same as outlined in Section 3.3.4.4.

3.3.5 Sample Handling for Laboratory Analysis

This section describes the handling of samples to be performed by ES personnel from the time of sampling until the samples arrive at the laboratory.

3.3.5.1 Sample Preservation

The analytical laboratory support personnel will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees Centigrade (°C). Samples will be promptly delivered to the analytical laboratory via overnight courier so that all sample holding times are met.

3.3.5.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the analytical laboratory (see Appendix A). The sample containers will be filled as described in Sections 3.3.3.2.4, 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);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.3.5.3 Sample Shipment

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

- Package sample so that it will not leak, spill, or vaporize from its container; and
- Label container with:
 - Sample collector's name, address, and telephone number;
 - Laboratory's name, address, and telephone number;
 - Description of sample;
 - Quantity of sample; and
 - Date of shipment.

The packaged samples will be delivered by overnight courier to the analytical laboratory. Delivery will occur shortly after sample acquisition.

3.3.5.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the analytical laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling contractor after sample delivery to the analytical laboratory, and the other two copies will be retained at the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.3.5.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field hydrogeologist. 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;
- Total monitoring well/point depth;
- Purge volume;
- Water level after purging;
- Monitoring well/point condition;
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity; and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.7 shows an example of the groundwater sampling record.

3.3.6 Laboratory Analyses

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

Analytical laboratory support personnel will specify the necessary QC samples and notify the laboratory to prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to transportation. Containers, ice chests with adequate padding, and cooling media may be sent

FIGURE 3.7
GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - 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 ☐ 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: _____

5 [] SAMPLE EXTRACTION METHOD:

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

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: _____ ° _____ Measured with: _____
pH: _____ Measured with: _____
Conductivity: _____ Measured with: _____
Other: _____

7 [] SAMPLE CONTAINERS (material, number, size):

8 [] ON-SITE SAMPLE TREATMENT:

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

[] Preservatives added:
Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

9 [] CONTAINER HANDLING:

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

10 [] OTHER COMMENTS: _____

by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratory.

3.4 AQUIFER TESTING

Slug tests will be conducted by ES personnel to estimate the hydraulic conductivity of the shallow saturated zone. 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; for the Dover AFB sites, both methods will be used in sequence.

3.4.1 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; a rising head or falling head test. 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 is needed to conduct a slug test:

- Teflon[®], PVC, or metal slugs,
- One-quarter-inch nylon or polypropylene rope,
- Electric water level indicator,
- Pressure transducer/sensor,
- Field logbook/forms,
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE1000B or equal).

3.5.3 Test Methods, General

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of 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 water level measurements show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development or extended pumping, etc., may lead to inaccurate results. It is up to the field hydrogeologist to determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other down-hole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.2.2.2.

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 the falling head test procedures.

1. Decontaminate all downhole equipment prior to initiating the test.

2. Open the well. Where wells are located within the 100-year flood plain, and equipped with water tight 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 Test Data Form (Figure 3.8) 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,
 - Date, and
 - Time intervals (0, 1, 3, 5, 7, 9, 10, and 12 minutes and every 3 minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).
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 owners' manual for proper operation of the data logger.
8. Terminate data recording when the water level stabilizes in the well.

Page _____ of _____

Date _____ Company performing test _____ Measured by _____

Well No _____ Distance from pumping well _____ Type of test: _____ Test No _____

Measuring equipment

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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 procedures.

1. Measure the static 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 owners' manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV and the method of Hvorslev (1951) for confined aquifers, or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. Based on a review of site hydrogeology at site SS27/XYZ (Section 2.2), unconfined conditions dominate the site and the Bouwer and Rice method will be used for a majority of the hydraulic conductivity testing. The standard slug test form (Figure 3.9) is based on equations and test methods developed by Hvorslev (1951). Figure 3.10 is the Bouwer and Rice Analysis Data Form. Figure 3.11 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice Analysis.

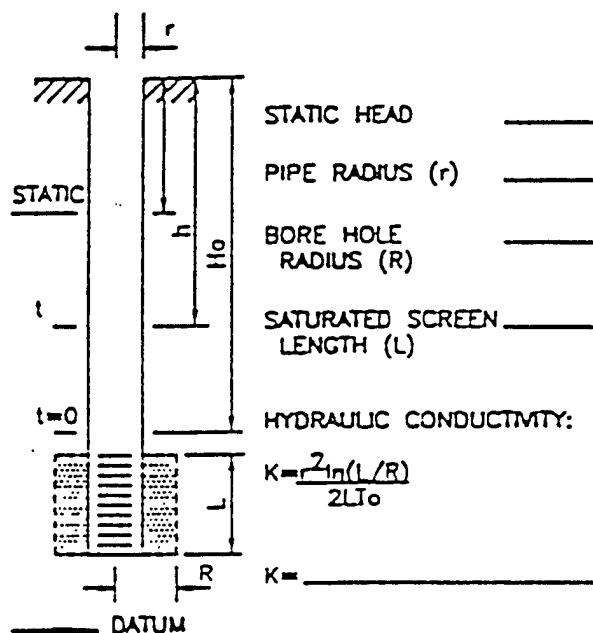
FIGURE 3.9

STANDARD SLUG TEST FORM/
HVORSLEV ANALYSIS

HVORSLEV'S METHOD FOR K

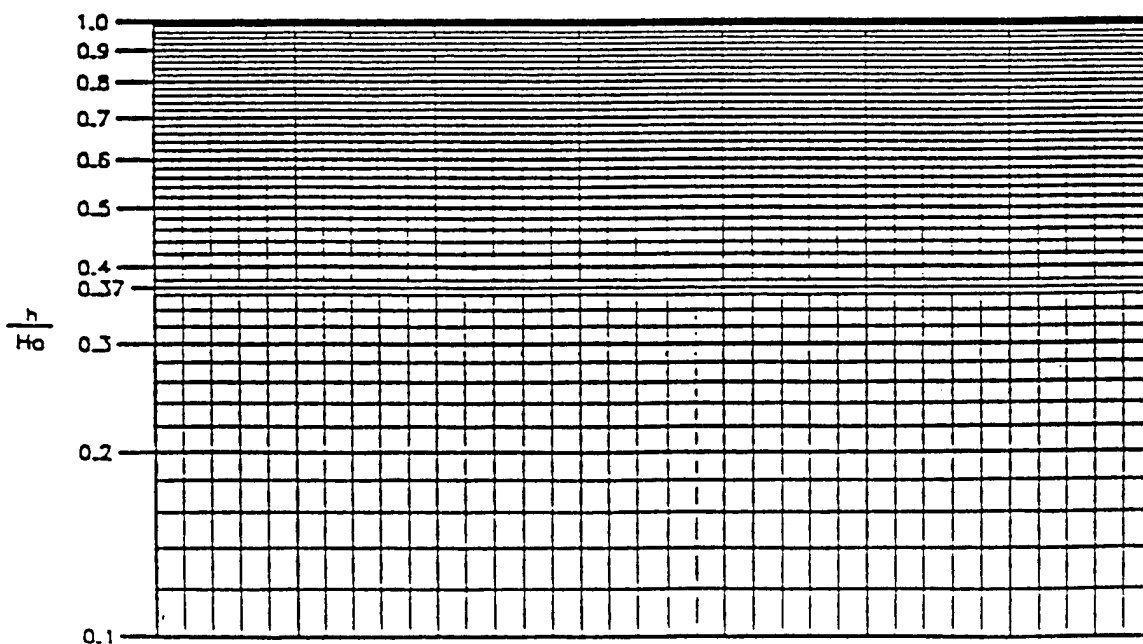
PROJECT _____
WELL NUMBER _____
DATE _____

LOCATION _____
ELEVATION _____



TIME (MIN)	WATER DEPTH (FT)	RECOVERY TO STATIC ± (WATER DEPTH-STAT)	$\frac{h}{H_0}$
STATIC			
00		(H ₀)	1.00
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	

K = _____ FT/MIN K = _____ FT/DAY K = _____ CM/SEC

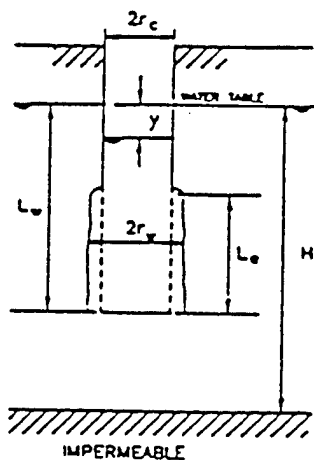


TIME (MINUTES)

BOUWER AND RICE ANALYSES
DATA FORM

(Reference: GROUNDWATER - May, June 1989, Vol. 27, No. 3)

PROJECT _____ LOCATION _____
WELL NUMBER _____ ELEVATION _____
DATE _____



HYDRAULIC CONDUCTIVITY:
(ASSUME $L_y = H$)

$$K = \frac{(r_c) \ln(R_e/r_w)}{2L_e} \quad \begin{bmatrix} 1 \\ t \end{bmatrix} \ln \begin{bmatrix} y_0 \\ y_1 \end{bmatrix}$$

X= _____

[illegible]

K=_____ FT/MIN K=_____ FT/DAY K=_____ CM/SEC

WHERE: $r_c = \{(1-n)r_c^2 + nr_c^2\}$
 $n = \text{POROSITY } (\sim 30\%)$

- r_p TAKES INTO ACCOUNT THE RADIUS OF THE WELL AND THE THICKNESS AND POROSITY OF THE GRAVEL PACK. POROSITY OF THE GRAVEL PACK (n) IS ESTIMATED AT JOE. USE THIS EQUATION IF A GRAVEL PACK IS PRESENT.

ASSUME $L_w = H$ $\ln \frac{R_p}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{(L_w/r_w)} \right]^{-1}$ $C = 1.4$

ASSUME L_w CH: $\ln \frac{R_e}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B \ln[(H-L_w)/r_w]}{(L_w/r_w)} \right]^{-1}$

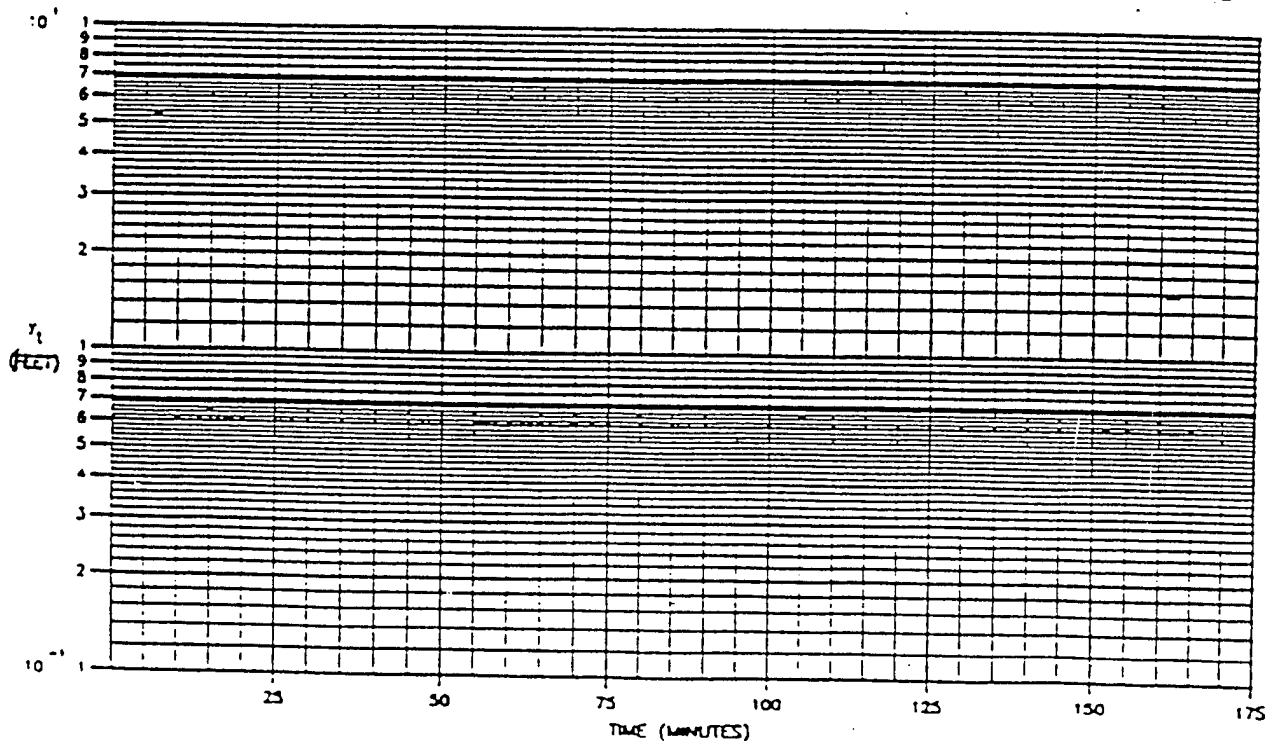
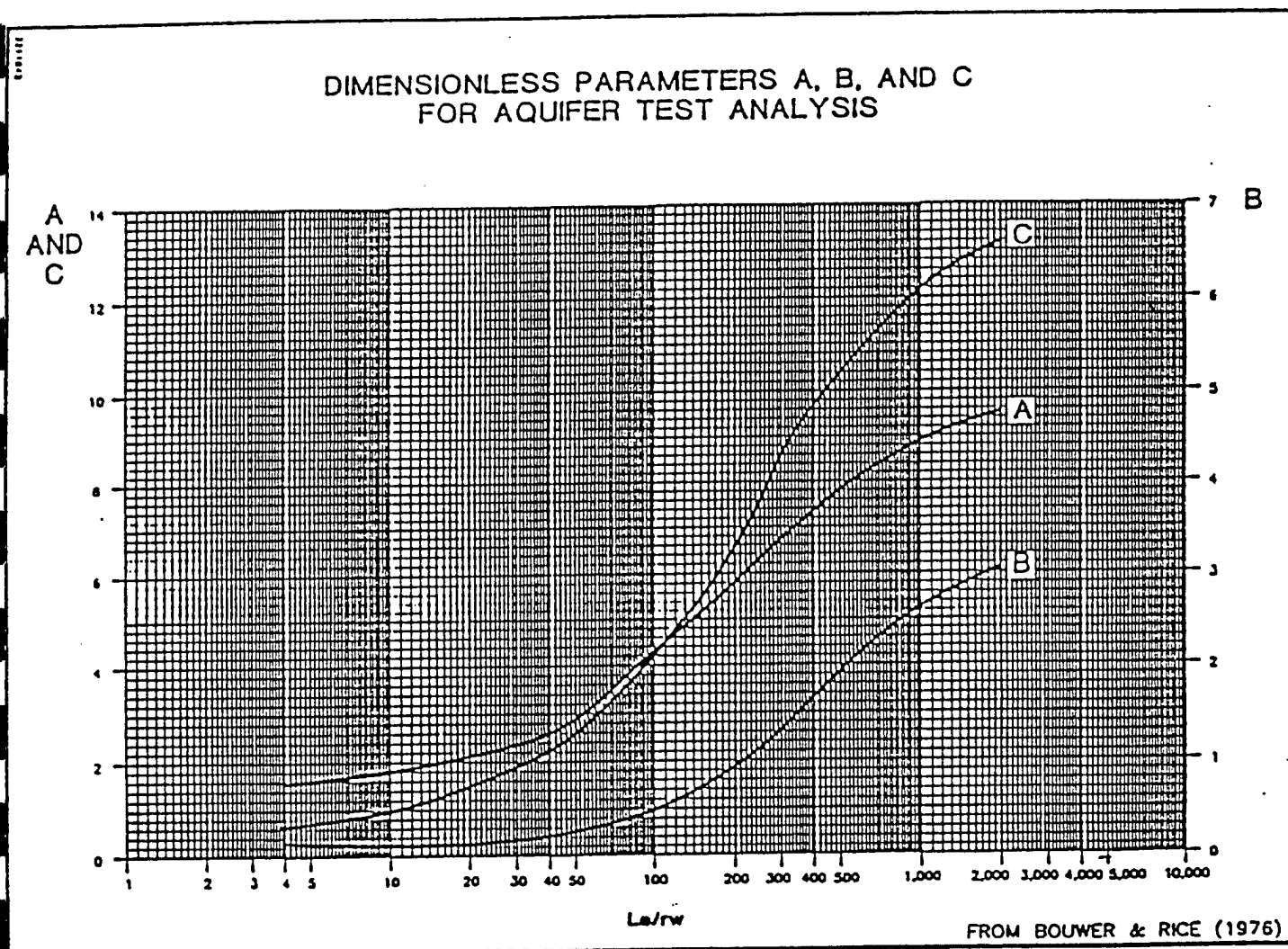


FIGURE 3.11

BOUWER AND RICE ANALYSES
DIMENSIONLESS PARAMETERS



SECTION 4

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of field work, the Bioplume II[®] numerical groundwater model will be used to determine the fate and transport of fuel hydrocarbons dissolved in groundwater at Site SS27/XYZ. 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 BTEX compounds at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, ES will prepare a site-specific, long-term monitoring plan 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 this 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, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, free-product recovery, groundwater pump-and-treat, enhanced biological treatment, bioventing, air sparging, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II[®] model. The model will then be used to predict the BTEX plume (and risk) reduction that should result from remedial actions

Upon completion of Bioplume II[®] modeling and remedial option selection, a report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Figure 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial

approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II[®] model developed for this site.

FIGURE 4.1

EXAMPLE EE/CA REPORT OUTLINE

INTRODUCTION

SITE DESCRIPTION

- Background
- Soil and Groundwater Characteristics
- Site Contamination

IDENTIFICATION OF REMEDIATION OBJECTIVES

- Potential Pathways for Human/Ecological Receptor Exposure
- Chemical-Specific Applicable or Relevant and Appropriate requirements

DESCRIPTION OF REMEDIATION ALTERNATIVES

- Intrinsic Remediation/Long-Term Monitoring
- Alternative 2 (Site Specific)
- Alternative 3 (Site Specific)

ANALYSIS OF REMEDIATION ALTERNATIVES

- Security (Bioplume II[®] Model Results and Discussion)
- Practicality
 - Technical
 - Administrative (Political)
- Cost
 - Capital Costs
 - Operating Costs
 - Present Worth Cost

RECOMMENDED REMEDIATION APPROACH

- How does the recommended technology offer adequate protection for less cost.

APPENDIX A: Supporting Data and Documentation

APPENDIX B: Site-Specific Bioplume II[®] 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 the water level probe and cable; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical 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 4 °C.

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 samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Groundwater samples from 1.405-inch penetrometer samples should provide sufficient volume for some duplicate analysis. Refer to Appendix A for further details on volume requirements.

TABLE 5.1
QA/QC SAMPLE PROGRAM
DOVER AFB, DELAWARE

QA/QC Sample Types	Frequency Collected and/or Analyzed	Analytical Methods
Duplicates	2 Samples (10%)	VOCs
Rinseate Blanks	2 Samples (10%)	VOCs
Field Blanks	1 Sample (5%)	VOCs
Trip Blanks	One per shipping cooler	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)

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 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 existing 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 and conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory and will be transported inside one of the coolers containing samples. This sample will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

Laboratory control samples (LCSs) and laboratory method blanks (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.

SECTION 6

REFERENCES

- Bouwer, Herman, 1989. "The Bouwer and Rice Slug Test - An Update," *Ground Water*, 27(3): 304-309.
- Bouwer, Herman, and R.C. Rice. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells," *Water Resources Research*, 12(3): 423-428.
- Bruce, L., Miller, T., and Hockman, B., 1991, Solubility versus equilibrium saturation of gasoline compounds - a method to estimate fuel/water partition coefficient using solubility or K_{OC} , In, A. Stanley, editor, NWWAI/API Conference on Petroleum Hydrocarbons in Groundwater: NWWA/API, p. 571-582.
- Climates of the States, Third Edition, 1985. Gale Research Company, Detroit, Michigan.
- Dames & Moore and HAZWRAP, 1993. Current Situation Report for Dover AFB, Delaware. May.
- Davis, A., and R.L. Olsen, 1990. "Predicting the fate and transport of organic compounds in groundwater," *Hazardous Materials Control*, 3(4):18.
- Engineering-Science, Inc. (ES), 1983. Installation Restoration Program Phase 1 - Records Search. Dover AFB, Delaware. Engineering-Science. Atlanta, Georgia 30329.
- Engineering-Science, Inc. (ES), 1993. Health and Safety Plan for the Bioplume[®] Modeling Initiative. Prepared for the Air Force Center for Environmental Excellence, Environmental Restoration Division, USAF Contract F41624-92-D-8036.
- Foster, M.D., 1950. "The Origin of High Sodium Bicarbonate Waters in the Atlantic and Gulf Coastal Plains," Geochimica et Cosmochimica Acta, Vol. 1, pps. 33-48.
- HAZWRAP, 1991a. Base-Wide Monitoring Well Water Level Report, April 1991, submitted by Dames & Moore.
- HAZWRAP, 1991b. Base-Wide Monitoring Well Water Level Report, August 1991, submitted by Dames & Moore.
- HAZWRAP, 1991c. Base-Wide Monitoring Well Water Level Report, October 1991, submitted by Dames & Moore.

- HAZWRAP, 1992a. Base-Wide Monitoring Well Water Level Report, January 1992, submitted by Dames & Moore.
- HAZWRAP, 1992b. Base-Wide Monitoring Well Water Level Report, April 1992, submitted by Dames & Moore, May 6, 1992.
- HAZWRAP, 1992c. Base-Wide Monitoring Well Water Level Report, July 1992, submitted by Dames & Moore, July 31, 1992.
- HAZWRAP, 1992d. Base-Wide Monitoring Well Water Level Report, October 1992; Dover Air Force Base, Dover, Delaware, submitted by Dames & Moore, October 20, 1992.
- HAZWRAP, 1993a. Basewide Water Level Summary Report, Dover Air Force Base, Dover, Delaware, submitted by Dames & Moore, February 15, 1993.
- HAZWRAP, 1993b. Ecological Risk Assessment, Phase I: site Characterization; Dover Air Force Base, Dover Delaware, submitted by Dames & Moore, January 20, 1993.
- HAZWRAP, 1993d. Base-Wide Monitoring Well Water Level Report, January 1993; Dover Air Force Base, Dover, Delaware, submitted by Dames & Moore, February 2, 1993.
- Hvorslev, M. J., Time Lag and Soil Permeability in Ground-Water Observations. Report to the Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss., April, 1951.
- Science Applications International Corporation (SAIC), 1986. USAF Installation Restoration Program - Dover AFB, Delaware, Phase II -Stage 1 Confirmation/Quantification.
- Tracer Research Corporation (TRC), 1991. Tracer TightTM Leak Test of 48 Underground Storage Tands and 20,650 Feet of JP-4 Pipelines, Dover AFB, Dover, Delaware.

TABLE A.1

**CONTAINERS, PRESERVATION, PACKAGING, AND SHIPPING REQUIREMENTS
FOR GROUND WATER SAMPLES
(DELIVERED DAILY, BUBBLE PACKED)**

Analysis	Bottles and Jars	Preservation	Holding Time	Volume of Sample
Sulfate	One 1-liter polyethylene bottle	Filter immediately, Cool to 4°C	28 days	Fill 90% full
Sulfide	One 1-liter polyethylene bottle	Filter immediately, zinc acetate and sodium hydroxide to pH >9 Cool to 4°C	7 days	Fill 90% full
Chloride	One 1-liter polyethylene bottle	Filter immediately, Cool to 4°C	28 days	Fill 90% full
Nitrate/Nitrite	One 1-liter polyethylene bottle	Filter immediately, H ₂ SO ₄ to pH <2 Cool to 4°C	28 days	Fill 90% full
Alkalinity	One 1-liter polyethylene bottle	Cool to 4°C	14 days	Fill 90% full
Total Phosphorus	One 1-liter polyethylene bottle	H ₂ SO ₄ to pH <2 Cool to 4°C	28 days	Fill 90% full
Total Organic Carbon	One 1-liter glass bottle	H ₂ SO ₄ to pH <2 Cool to 4°C	28 days	Fill completely
Aromatic Hydrocarbons	Two 40 mL VOA	H ₂ SO ₄ to pH <2 Cool to 4°C	7 days until extraction 40 days after extraction	Fill 100% full
Total Petroleum Hydrocarbons	1-liter amber glass	H ₂ SO ₄ to pH <2 Cool to 4°C	14 days	Fill 90% full
Vinyl Chloride	1-liter amber glass	H ₂ SO ₄ to pH <2 Cool to 4°C	14 days	Fill 90% full

APPENDIX B

**AVAILABLE SOIL AND GROUNDWATER ANALYTICAL
RESULTS**

Table A-1
Historical Water Level Measurements
Dover Air Force Base

WELL ID	DATE	TIME	LAND ELEV.	MEASURED		REFERENCE POINT	WATER ELEV. (MSL)	Calc WL	Error Flag
				TOC ELEV.	WATER LEVEL				
D-4-C	3/27/88			18.81	8.19	BTC	10.62	10.62	
D-4-C	4/6/88			18.81	8.11	BTC	10.70	10.70	
D-4-C	2/15/89			18.81	8.64	BTC	10.17	10.17	
D-4-C	3/3/89			18.81	7.33	BTC	11.48	11.48	
D-4-C	7/11/89		16.31	18.81	5.83	BTC	12.98	12.98	
D-4-C	12/4/89			18.81	7.02	BTC	11.79	11.79	
D-4-D	3/27/88			23.34	7.73	BTC	15.61	15.61	
D-4-D	4/6/88			23.34	7.58	BTC	15.76	15.76	
D-4-D	2/15/89			23.34	8.09	BTC	15.25	15.25	
D-4-D	3/3/89			23.34	9.13	BTC	14.21	14.21	
D-4-D	7/11/89		20.42	23.34	8.18	BTC	15.16	15.16	
D-4-D	12/4/89			23.34	7.84	BTC	15.50	15.50	
D-4-E	3/3/89			24.01	12.64	BTC	11.37	11.37	
D-4-E	7/11/89		21.43	24.01	10.57	BTC	13.44	13.44	
D-4-E	12/4/89			24.01	12.27	BTC	11.74	11.74	
D-4-F	3/3/89			20.38	11.15	BTC	9.23	9.23	
D-4-F	7/11/89		17.63	20.38	8.10	BTC	12.28	12.28	
D-4-F	12/4/89			20.38	9.69	BTC	10.69	10.69	
D-4-G	3/3/89			21.68	12.93	BTC	8.75	8.75	
D-4-G	7/11/89		19.43	21.68	10.37	BTC	11.31	11.31	
D-4-G	12/4/89			21.68	11.66	BTC	10.02	10.02	
D-4-H	7/11/89		19.01	21.21	6.01	BTC	15.20	15.20	
D-4-H	12/4/89			21.21	5.77	BTC	15.44	15.44	
D-4-I	3/3/89			21.87	23.18	BTC	-1.31	-1.31	
D-4-I	7/11/89		18.58	21.87	9.17	BTC	12.70	12.70	
D-4-I	12/4/89			21.87	9.27	BTC	12.60	12.60	
F-1	7/11/89		23.81	26.21	18.41	BTC	7.80	7.80	
F-1	12/4/89			26.21	19.50	BTC	6.71	6.71	
F-2	7/11/89		23.84	25.43	18.76	BTC	6.67	6.67	
F-2	12/4/89			25.43	19.51	BTC	5.92	5.92	
F-3	7/11/89		20.57	22.53	13.81	BTC	8.72	8.72	
F-3	12/4/89			22.53	14.68	BTC	7.85	7.85	
p01	11/6/84	1040	25.92		12.50	BLS	13.42	13.42	
p01	11/16/84	1055		28.02	14.59	BTC	13.43	13.43	
p01	12/10/84	1400		28.02	15.32	BTC	12.70	12.70	
p01	1/9/85	1030		28.02	13.98	BTC	15.04	14.04	<<<<<
p01	12/4/89			27.74	11.08	BTC	16.66	16.66	
p02	11/6/84	1106	25.35		12.50	BLS	12.85	12.85	
p02	11/16/84	1040		27.35	17.19	BTC	10.16	10.16	
p02	12/10/84	1400		27.35	16.28	BTC	11.07	11.07	
p02	1/9/85	1035		27.35	17.34	BTC	10.01	10.01	
p02	12/4/89			26.99	13.73	BTC	13.26	13.26	
p03	11/16/84	1125		26.99	14.30	BTC	12.69	12.69	
p03	12/10/84	1400		26.99	14.26	BTC	12.73	12.73	
p03	1/9/85	1040		26.99	14.07	BTC	12.92	12.92	
p03	12/4/89			26.99	11.86	BTC	15.13	15.13	
p05	11/7/84	1310	22.87		7.60	BLS	15.27	15.27	
p05	11/16/84	1145		24.87	8.84	BTC	16.03	16.03	
p05	12/5/84	1410		24.87	9.22	BTC	15.65	15.65	
p05	1/9/85	1115		24.87	10.60	BTC	14.27	14.27	
p05	12/4/89			24.86	6.71	BTC	18.15	18.15	
p06	11/7/84	1310	26.87		12.00	BLS	14.87	14.87	
p06	11/16/84	1145		28.87	14.10	BTC	14.77	14.77	
p06	12/5/84	1410		28.87	13.20	BTC	15.67	15.67	
p06	1/9/85	1110		28.87	13.53	BTC	15.34	15.34	
p07	11/14/84		23.61		7.15	BLS	16.46	16.46	
p07	11/16/84	1140		26.18	9.91	BTC	16.17	16.27	<<<<<
p07	12/5/84	1410		26.18	10.26	BTC	15.92	15.92	
p07	1/9/85	1110		26.18	10.55	BTC	15.63	15.63	
p07	12/4/89			26.17	8.05	BTC	18.12	18.12	
p08	11/7/84	1305	24.84		9.20	BLS	15.64	15.64	

Table A-1
Historical Water Level Measurements
Dover Air Force Base

WELL ID	DATE	TIME	LAND ELEV.	MEASURED			WATER ELEV. (MSL)	Calc WL	Error Flag
				TOC ELEV.	WATER LEVEL	REFERENCE POINT			
p08	11/16/84	1135		26.84	11.01	BTC	15.83	15.83	
p08	12/5/84	1410		26.84	11.39	BTC	15.45	15.45	
p08	1/9/85	1105		26.84	11.83	BTC	15.01	15.01	
P16A							0.00	0.00	
P-09							0.00	0.00	
P-10							0.00	0.00	
P-11	12/4/89			25.45	12.17	BTC	12.17	13.28	<<<<<
P-12	12/4/89			23.09	10.77	BTC	12.32	12.32	
P-13	12/4/89			24.40	9.50	BTC	14.90	14.90	
P-14	12/4/89			25.37	10.00	BTC	15.37	15.37	
P-15	12/4/89			26.65	14.46	BTC	12.19	12.19	
P-16				27.78				0.00	
P-17	3/27/88			20.77	9.77	BTC	11.00	11.00	
P-17	4/13/88			20.77	9.55	BTC	11.22	11.22	
P-17	2/15/89			20.77	10.40	BTC	10.37	10.37	
P-17	3/3/89			20.77	9.87	BTC	10.90	10.90	
P-17	5/1/89		21.44	20.77	7.85	BTC	12.92	12.92	
P-17	12/4/89			20.77	7.70	BTC	13.07	13.07	
P-18	3/27/88			19.69	8.73	BTC	10.96	10.96	
P-18	4/13/88			19.69	8.53	BTC	11.16	11.16	
P-18	2/15/89			19.69	9.32	BTC	10.37	10.37	
P-18	3/3/89			19.69	8.90	BTC	10.79	10.79	
P-18	5/1/89			19.69	6.85	BTC	12.84	12.84	
P-18	7/11/89		20.26	19.69	5.43	BTC	14.26	14.26	
P-18	12/4/89			19.69	6.80	BTC	12.89	12.89	
P-19	3/27/88			20.82	9.93	BTC	10.89	10.89	
P-19	4/13/88			20.82	9.72	BTC	11.10	11.10	
P-19	2/15/89			20.82	10.55	BTC	10.27	10.27	
P-19	3/3/89			20.82	10.05	BTC	10.77	10.77	
P-19	5/1/89			20.82	8.00	BTC	12.82	12.82	
P-19	7/11/89		21.34	20.82	6.58	BTC	14.24	14.24	
P-19	12/4/89			20.82	8.35	BTC	12.47	12.47	
P-20	3/27/88			21.34	10.48	BTC	10.86	10.86	
P-20	4/13/88			21.34	10.27	BTC	11.07	11.07	
P-20	2/15/89			21.34	11.08	BTC	10.26	10.26	
P-20	3/3/89			21.34	10.64	BTC	10.70	10.70	
P-20	5/1/89			21.34	8.52	BTC	12.82	12.82	
P-20	7/11/89		21.96	21.34	6.82	BTC	14.52	14.52	
P-20	12/4/89			21.34	8.70	BTC	12.64	12.64	
P-21	2/15/89			23.08	13.03	BTC	10.05	10.05	
P-21	3/3/89			23.08	12.55	BTC	10.53	10.53	
P-21	5/1/89			23.08	10.35	BTC	12.73	12.73	
P-21	7/11/89		23.67	23.08	8.45	BTC	14.63	14.63	
P-21	12/4/89			23.08	10.32	BTC	12.76	12.76	
P-22	3/27/88			21.64	11.22	BTC	10.42	10.42	
P-22	4/13/88			21.64	11.04	BTC	10.60	10.60	
P-22	2/15/89			21.64	11.81	BTC	9.83	9.83	
P-22	3/3/89			21.64	11.46	BTC	10.18	10.18	
P-22	5/1/89			21.64	9.19	BTC	12.45	12.45	
P-22	7/11/89		22.30	21.64	7.51	BTC	14.13	14.13	
P-22	12/4/89			21.64	9.27	BTC	12.37	12.37	
P-23	3/27/88			21.03	10.24	BTC	10.79	10.79	
P-23	4/13/88			21.03	10.07	BTC	10.96	10.96	
P-23	2/15/89			21.03	10.75	BTC	10.28	10.28	
P-23	3/3/89			21.03	10.39	BTC	10.64	10.64	
P-23	5/1/89			21.03	8.12	BTC	12.91	12.91	
P-23	7/11/89		21.60	21.03	6.95	BTC	14.08	14.08	
P-23	12/4/89			21.03	9.16	BTC	11.87	11.87	
P-24	3/27/88			22.38	11.75	BTC	10.63	10.63	
P-24	4/13/88		22.60	22.38	11.50	BTC	10.88	10.88	
P-25							0.00	0.00	

Table A-1
Historical Water Level Measurements
Dover Air Force Base

WELL ID	DATE	TIME	LAND ELEV.	MEASURED		REFERENCE POINT	WATER ELEV. (MSL)	Calc WL	Error Flag
				TOC ELEV.	WATER LEVEL				
39S	2/15/89			19.57	9.83 BTC		9.74	9.74	
39S	3/3/89			19.57	7.99 BTC		11.58	11.58	
39S	7/11/89		17.01	19.57	6.66 BTC		12.91	12.91	
39S	12/4/89			19.57	8.18 BTC		11.39	11.39	
40D	2/15/89			20.51	10.69 BTC		9.82	9.82	
40D	3/3/89			20.51	9.30 BTC		11.21	11.21	
40D	7/11/89		18.76	20.51	7.33 BTC		13.18	13.18	
40D	12/4/89			20.51	8.96 BTC		11.55	11.55	
40S	2/15/89			20.68	10.82 BTC		9.86	9.86	
40S	3/3/89			20.68	9.44 BTC		11.24	11.24	
40S	7/11/89		18.66	20.68	7.51 BTC		13.17	13.17	
40S	12/4/89			20.68	9.10 BTC		11.58	11.58	
41D	2/15/89			23.45	13.58 BTC		9.87	9.87	
41D	3/3/89			23.45	12.18 BTC		11.27	11.27	
41D	7/11/89		21.60	23.45	10.19 BTC		13.26	13.26	
41D	12/4/89			23.45	11.79 BTC		11.66	11.66	
41S	2/15/89			23.61	13.58 BTC		10.03	10.03	
41S	3/3/89			23.61	12.33 BTC		11.28	11.28	
41S	7/11/89		21.61	23.61	10.36 BTC		13.25	13.25	
41S	12/4/89			23.61	11.95 BTC		11.66	11.66	
42P	2/15/89			19.41	9.68 BTC		9.73	9.73	
42P	3/3/89			19.41	8.30 BTC		11.11	11.11	
42P	7/11/89		16.84	19.41	6.45 BTC		12.96	12.96	
42P	12/4/89			19.41	7.93 BTC		11.48	11.48	
43D	12/4/89			14.06	6.67 BTC		7.39	7.39	
43S	12/4/89			14.15	6.76 BTC		7.39	7.39	
44D	7/11/89		18.06	20.99	11.45 BTC		9.54	9.54	
44D	12/4/89			20.99	12.40 BTC		8.59	8.59	
44S	7/11/89		17.78	20.61	10.77 BTC		9.84	9.84	
44S	12/4/89			20.61	11.78 BTC		8.83	8.83	
45D	12/4/89			24.69	12.71 BTC		11.98	11.98	
45S	12/4/89			24.56	12.42 BTC		12.14	12.14	
46D	12/4/89			26.41	14.00 BTC		12.41	12.41	
46S	12/4/89			26.91	14.50 BTC		12.41	12.41	
47D				28.43				0.00	
47S				27.87				0.00	
48D				29.11				0.00	
48S	12/4/89			29.11	16.42 BTC		12.69	12.69	
49D							0.00	0.00	
49S							0.00	0.00	
50D	12/4/89			29.29	16.98 BTC		12.31	12.31	
50S	12/4/89			29.05	16.73 BTC		12.36	12.32	<<<<<
51D				25.89				0.00	
51S	12/4/89			25.26	13.80 BTC		11.46	11.46	
52D				25.75				0.00	
52S	12/4/89			25.90	14.62 BTC		11.28	11.28	
53D				26.82				0.00	
53S	12/4/89			27.78	15.25 BTC		12.53	12.53	
54D				26.50				0.00	
54S	12/4/89			26.29	14.58 BTC		11.71	11.71	
55P							0.00	0.00	
56P							0.00	0.00	
59D	12/4/89			24.67	11.10 BTC		13.57	13.57	
59S	12/4/89			24.99	17.28 BTC		7.71	7.71	
60D	12/4/89			25.14	7.28 BTC		17.86	17.86	
60S	12/4/89			25.16	7.28 BTC		17.88	17.88	
61D			25.21	26.51				25.21	<<<<<
61S			24.74	26.77				24.74	<<<<<
62D	2/15/89			22.14	12.20 BTC		9.94	9.94	
62D	3/3/89			22.14	10.78 BTC		11.36	11.36	
62D	7/11/89		19.77	22.14	8.63 BTC		13.51	13.51	

Table A-1
Historical Water Level Measurements
Dover Air Force Base

WELL ID	DATE	TIME	LAND ELEV.	MEASURED			WATER ELEV. (MSL)	Calc WL	Error Flag
				TOC ELEV.	WATER LEVEL	REFERENCE POINT			
62D	12/4/89			22.14	10.32	BTC	11.82	11.82	
62S	2/15/89			22.27	12.33	BTC	9.94	9.94	
62S	3/3/89			22.27	10.92	BTC	11.35	11.35	
62S	7/11/89		19.48	22.27	8.75	BTC	13.52	13.52	
62S	12/4/89			22.27	10.45	BTC	11.82	11.82	
63D	2/15/89			22.20	12.21	BTC	9.99	9.99	
63D	3/3/89			22.20	10.76	BTC	11.44	11.44	
63D	7/11/89		20.15	22.20	8.50	BTC	13.70	13.70	
63D	12/4/89			22.20	10.23	BTC	11.97	11.97	
63S	2/15/89			22.12	12.10	BTC	10.02	10.02	
63S	3/3/89			22.12	10.63	BTC	11.49	11.49	
63S	7/11/89		19.63	22.12	8.40	BTC	13.72	13.72	
63S	12/4/89			22.12	9.90	BTC	12.22	12.22	
64D								0.00	
64S								0.00	
65D	3/3/89			21.59	10.90	BTC	10.69	10.69	
65D	5/1/89			21.59	8.78	BTC	12.81	12.81	
65D	7/11/89		22.31	21.59	7.15	BTC	14.44	14.44	
65D	12/4/89			21.59	8.80	BTC	12.79	12.79	
65S	3/3/89			21.66	10.66	BTC	11.00	11.00	
65S	5/1/89			21.66	8.81	BTC	12.85	12.85	
65S	7/11/89		22.18	21.66	7.20	BTC	14.46	14.46	
65S	12/4/89			21.66	8.85	BTC	12.81	12.81	
66D	2/15/89			22.13	12.02	BTC	10.11	10.11	
66D	3/3/89			22.13	11.52	BTC	10.61	10.61	
66D	5/1/89			22.13	9.34	BTC	12.79	12.79	
66D	7/11/89		22.74	22.13	7.63	BTC	14.50	14.50	
66D	12/4/89			22.13	9.35	BTC	12.78	12.78	
66S	3/3/89			22.02	11.40	BTC	10.62	10.62	
66S	5/1/89			22.02	9.24	BTC	12.78	12.78	
66S	7/11/89		22.64	22.02	7.50	BTC	14.52	14.52	
66S	12/4/89			22.02	9.18	BTC	12.84	12.84	
67D	3/3/89			22.14	11.60	BTC	10.54	10.54	
67D	5/1/89			22.14	9.47	BTC	12.67	12.67	
67D	7/11/89		22.70	22.14	7.72	BTC	14.42	14.42	
67D	12/4/89			22.14	9.44	BTC	12.70	12.70	
67S	3/3/89			21.55	11.03	BTC	10.52	10.52	
67S	5/1/89			21.55	8.85	BTC	12.70	12.70	
67S	7/11/89		22.30	21.55	7.18	BTC	14.37	14.37	
67S	12/4/89			21.55	8.55	BTC	12.70	13.00	<<<<<
68D	12/4/89			23.66	12.33	BTC	11.33	11.33	
68S				23.63				0.00	
69D				20.09				0.00	
69S	12/4/89			20.31	8.92	BTC	11.39	11.39	
70D				21.00				0.00	
70S	12/4/89			20.83	9.33	BTC	11.50	11.50	
71D	12/4/89		22.69	22.49	10.33	BTC	12.16	12.16	
71S	12/4/89		22.68	22.59	10.43	BTC	12.16	12.16	
72D	12/4/89		22.90	22.69	10.78	BTC	11.91	11.91	
72S	12/4/89		22.92	22.55	10.64	BTC	11.90	11.91	
73D	12/4/89		22.53	22.55	10.18	BTC	10.18	12.37	<<<<<
73S	12/4/89		22.57	22.43	10.06	BTC	12.37	12.37	
74D	12/4/89			23.99	6.42	BTC	17.57	17.57	
74S	12/4/89			24.19	6.40	BTC	17.79	17.79	
75D	2/15/89			27.10	16.34	BTC	10.76	10.76	
75D	3/3/89			27.10	16.20	BTC	10.90	10.90	
75D	5/1/89			27.10	12.38	BTC	14.72	14.72	
75D	7/11/89		25.36	27.10	8.99	BTC	18.11	18.11	
75D	12/4/89			27.10	11.25	BTC	15.85	15.85	
75D	12/4/89			27.60	11.25	BTC	16.35	16.35	
75S	2/15/89			27.18	16.44	BTC	10.74	10.74	

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Table A-1
Historical Water Level Measurements
Dover Air Force Base

WELL ID	DATE	TIME	LAND ELEV.	MEASURED TOC ELEV.	WATER LEVEL	REFERENCE POINT	WATER ELEV. (MSL)	Calc WL	Error Flag
75S	3/3/89			27.18	16.24	BTC	10.94	10.94	
75S	5/1/89			27.18	12.45	BTC	14.73	14.73	
75S	7/11/89		25.43	27.18	9.05	BTC	18.13	18.13	
75S	12/4/89			27.18	11.32	BTC	15.86	15.86	
75S	12/4/89			27.68	11.32	BTC	16.36	16.36	
76D	2/15/89			30.88	20.60	BTC	10.28	10.28	
76D	3/3/89			30.88	20.28	BTC	10.60	10.60	
76D	5/1/89			30.88	16.80	BTC	14.08	14.08	
76D	7/11/89		28.68	30.88	13.42	BTC	17.46	17.46	
76D	12/4/89			30.88	16.18	BTC	14.70	14.70	
76D	12/4/89			31.38	16.18	BTC	15.20	15.20	
76S	2/15/89			30.90	20.62	BTC	10.28	10.28	
76S	3/3/89			30.90	20.30	BTC	10.60	10.60	
76S	5/1/89			30.90	16.82	BTC	14.08	14.08	
76S	7/11/89		28.76	30.90	13.42	BTC	17.48	17.48	
76S	12/4/89			30.90	16.18	BTC	14.72	14.72	
76S	12/4/89			31.40	16.18	BTC	15.22	15.22	
77D	12/4/89		24.02	23.49	8.20	BTC	15.29	15.29	
77S	7/11/89		24.67	23.97	6.13	BTC	17.84	17.84	
77S	12/4/89			23.97	6.79	BTC	17.18	17.18	
78D	3/3/89			29.95	19.53	BTC	10.42	10.42	
78D	5/1/89			29.95	15.80	BTC	14.15	14.15	
78D	7/11/89		28.40	29.95	12.00	BTC	17.95	17.95	
78D	12/4/89			29.95	14.88	BTC	15.07	15.07	
78S	3/3/89			29.66	19.25	BTC	10.41	10.41	
78S	5/1/89			29.66	15.53	BTC	14.13	14.13	
78S	7/11/89		27.68	29.66	11.52	BTC	18.14	18.14	
78S	12/4/89			29.66	14.65	BTC	15.01	15.01	
79D				26.65				0.00	
79S	12/4/89			27.43	15.04	BTC	12.39	12.39	
80D				29.81				0.00	
80S	12/4/89			29.54	17.29	BTC	12.25	12.25	
81D	12/4/89			28.54	16.46	BTC	12.08	12.08	
81S				29.15				0.00	
82D	12/4/89			27.29	16.17	BTC	11.12	11.12	
82S				27.56				0.00	
83D	12/4/89			25.45	13.96	BTC	11.49	11.49	
83S	12/4/89			25.49	14.17	BTC	11.32	11.32	
84D				26.22				0.00	
84S				25.99				0.00	
85P	12/4/89			20.71		BTC	0.00	20.71	<<<<<
101	11/14/84	1510	24.56	25.01	13.12	BTC	11.89	11.89	
101	12/5/84	1050	24.56	25.01	13.42	BTC	11.59	11.59	
101	1/9/85	1145		25.01	13.75	BTC	11.26	11.26	
101	2/20/85	1338		25.01	12.64	BTC	12.37	12.37	
101	2/26/88			24.56	13.43	BTC	11.13	11.13	
101	3/2/88			24.56	13.48	BTC	11.08	11.08	
101	3/12/88			24.56	13.43	BTC	11.13	11.13	
101	3/27/88			24.56	13.52	BTC	11.04	11.04	
101	4/6/88			24.56	13.42	BTC	11.14	11.14	
101	4/12/88			24.56	13.29	BTC	11.27	11.27	
101	2/15/89			24.56	14.20	BTC	10.36	10.36	
101	3/3/89			24.56	13.60	BTC	10.96	10.96	
101	5/1/89			24.56	11.57	BTC	12.99	12.99	
101	7/11/89			24.56	9.75	BTC	14.81	14.81	
102	11/14/84	1510		24.51	12.88	BTC	11.63	11.63	
102	12/5/84	1050	24.03	24.51	13.08	BTC	11.43	11.43	
102	1/9/85	1140		24.51	13.40	BTC	11.11	11.11	
102	2/20/85	1340		24.51	12.30	BTC	12.21	12.21	
102	2/26/88			24.03	13.10	BTC	10.93	10.93	
102	3/2/88			24.03	13.14	BTC	10.89	10.89	

Table A-2 (continued)
Water Level Measurements

:\CSRA\TAB A-2.wk1

SITE	WELL ID	ELEV. TOC/msl	ROUND 1 4/91		ROUND 2 8/91		ROUND 3 10/91		ROUND 4 01/92		ROUND 5 04/92		ROUND 6 07/92		ROUND 7 10/92		ROUND 8 01/93	
			TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL
LF15 cont'd	40D	20.51	8.27	12.24	11.17	9.34	11.55	8.96	11.21	9.30	9.42	11.09	10.86	9.65	11.20	9.31	9.97	10.54
	40S	20.68	8.46	12.22	11.40	9.28	11.80	8.88	11.43	9.25	10.62	10.06	11.07	9.61	11.41	9.27	10.14	10.54
	41D	23.45	-	-	14.00	9.45	14.47	8.98	14.13	9.32	12.30	11.15	13.73	9.72	14.13	9.32	12.74	10.71
	41S	23.61	-	-	14.24	9.37	14.64	8.97	14.30	9.31	12.43	11.18	13.90	9.71	14.28	9.33	12.87	10.74
LF13 (D-2)	42P	19.41	7.21	12.20	10.28	9.13	10.63	8.78	10.19	9.22	9.38	10.03	10.92	8.49	10.21	9.20	8.88	10.53
	61D	26.51	13.90	12.61	17.25	9.26	17.35	9.16	16.90	9.61	15.07	11.44	16.80	9.71	16.99	9.52	15.72	10.79
	61S	26.77	14.08	12.69	17.10	9.67	17.45	9.32	17.28	9.49	15.41	11.36	17.79	8.98	17.15	9.62	15.86	10.91
	62D	22.14	9.56	12.58	12.62	9.52	12.90	9.24	12.75	9.39	10.82	11.32	12.28	9.86	12.70	9.44	11.37	10.77
	62S	22.27	9.74	12.53	12.65	9.62	13.01	9.26	12.86	9.41	10.92	11.35	12.40	9.87	12.82	9.45	11.49	10.78
	63D	22.20	9.49	12.71	12.47	9.73	12.84	9.36	12.74	9.46	10.85	11.35	12.20	10.00	12.68	9.52	11.39	10.81
	63S	22.12	9.13	12.99	12.36	9.76	12.79	9.33	12.64	9.48	10.57	11.55	12.10	10.02	12.62	9.50	11.19	10.93
	64D	23.92	10.58	13.34	13.95	9.97	14.33	9.60	14.20	9.72	12.02	11.90	13.62	10.30	14.21	9.71	12.96	10.96
	64S	24.14	10.73	13.41	14.10	10.04	14.54	9.60	14.40	9.74	12.17	11.97	13.81	10.33	14.40	9.74	13.18	10.96
	DM02	26.24	-	-	16.27	9.97	16.58	9.66	16.64	9.60	14.66	11.58	15.91	10.33	16.53	9.71	15.21	11.03
LF22 (D-1)	DM03	24.88	-	-	12.85	12.03	13.69	11.19	9.92	14.96	6.67	18.21	10.59	14.29	10.30	14.58	6.04	18.84
	DM04	26.87	-	-	9.09	17.78	9.41	17.46	6.92	19.95	3.77	23.10	8.66	18.21	8.36	18.51	3.17	23.70
	DM05	24.36	-	-	12.50	11.86	12.85	11.51	11.06	13.30	6.57	17.79	12.11	12.25	11.71	12.65	7.38	16.98
	DM06	24.12	-	-	12.58	11.54	12.95	11.17	11.12	13.00	7.59	16.53	12.37	11.75	12.42	11.70	7.21	16.91
	DM07	23.49	-	-	13.02	10.47	13.55	9.94	13.40	10.09	10.23	13.26	12.74	10.75	13.42	10.07	10.73	12.76
	201D	16.54	3.25	13.29	5.19	11.35	5.69	10.85	5.84	10.70	5.00	11.54	5.58	10.96	5.45	11.09	4.62	11.92
	202D	27.55	17.23	10.32	19.00	8.55	19.31	8.24	18.86	8.69	18.09	9.46	18.78	8.77	18.91	8.64	18.11	9.44
SD12 (D-3)	202S	27.56	17.24	10.32	18.99	8.57	19.33	8.23	18.87	8.69	17.86	9.70	18.79	8.77	18.93	8.63	18.11	9.45
	203D	23.51	8.87	14.64	11.73	11.78	12.50	11.01	12.17	11.34	10.40	13.11	11.95	11.56	12.32	11.19	11.19	12.32
	204D	19.73	6.05	13.68	7.00	12.73	7.80	11.93	8.03	11.70	7.40	12.33	7.69	12.04	7.66	12.07	7.32	12.41
	204S	19.87	6.23	13.64	7.15	12.72	7.72	12.15	8.05	11.82	7.34	12.53	7.70	12.17	7.77	12.10	6.96	12.91
	205D	25.49	14.58	10.91	17.07	8.42	17.50	7.99	17.15	8.34	15.66	9.83	16.80	8.69	17.05	8.44	16.08	9.41
	228S	20.72	10.87	9.85	12.45	8.27	12.72	8.00	12.31	8.41	11.47	9.25	12.33	8.39	12.34	8.38	11.63	9.09
	229S	16.89	5.73	11.16	6.67	10.22	7.50	9.39	6.68	10.21	9.11	7.78	6.94	9.95	6.65	10.24	5.72	11.17
SS27 (XYZ)	DD-1-A	16.41	4.91	11.50	4.68	11.73	5.25	11.16	4.66	11.75	3.36	13.05	5.10	11.31	4.53	11.88	2.85	13.56
	DD-1-B	22.78	5.91	16.87	9.40	13.38	10.58	12.20	10.14	12.64	5.54	17.24	9.76	13.02	10.38	12.40	9.22	13.56
	DD-1-C	23.77	6.92	16.85	11.68	12.09	12.62	11.15	12.15	11.62	8.87	14.90	11.80	11.97	12.36	11.41	10.30	13.47
	DD-1-D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	DD-1-E	25.42	12.62	12.80	16.79	8.63	17.28	8.14	16.41	9.01	12.05	13.37	15.93	9.49	16.41	9.01	11.74	13.68
	DD-1-F	19.09	13.28	5.81	14.59	4.50	14.87	4.22	14.45	4.64	13.25	5.84	14.63	4.46	14.64	4.45	13.38	5.71
	P05	24.87	7.05	17.82	9.45	15.42	10.91	13.96	11.75	13.12	10.23	14.64	10.69	14.18	10.69	14.18	10.42	14.45
	P06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	P07	26.18	8.33	17.85	10.46	15.72	11.68	14.50	12.88	13.30	11.25	14.93	11.73	14.45	11.72	14.46	11.03	15.15
	P08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	59D	24.68	17.48	7.20	18.66	6.02	20.06	4.62	21.42	3.26	20.49	4.19	20.97	3.71	20.90	3.78	-	-

NOTE: TOC- Measured from top of casing (feet)
MSL- Mean Sea Level (feet)

Table A-2 (continued)
Water Level Measurements

:\CSRTAB-A-2.wk1

SITE	WELL ID	ELEV. TOC/mal	ROUND 1 4/91		ROUND 2 8/91		ROUND 3 10/91		ROUND 4 01/92		ROUND 5 04/92		ROUND 6 07/92		ROUND 7 10/92		ROUND 8 01/93	
			TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL
SS27 cont'd	59S	24.96	14.33	10.63	14.17	10.79	15.06	9.90	-	-	17.29	7.67	14.75	10.21	14.29	10.67	-	-
	OW-1	-	-	-	-	-	-	-	17.24	9.91	17.09	10.06	17.34	9.81	-	-	-	-
	60D	25.14	8.42	16.72	10.63	14.51	12.00	13.14	12.84	12.30	11.93	13.21	11.83	13.31	12.00	13.14	12.00	13.14
	60S	25.16	8.46	16.70	10.60	14.56	11.99	13.17	12.85	12.31	12.07	13.09	11.74	13.42	11.95	13.21	12.26	12.90
	74D	23.99	7.10	16.89	9.09	14.90	10.36	13.63	10.95	13.04	9.65	14.34	-	-	-	-	-	-
SS09, SS10 ST11 (ZONE SP)	74S	24.19	6.98	17.21	9.13	15.06	10.42	13.77	10.90	13.29	9.16	15.03	-	-	-	-	-	-
	75D	27.10	13.02	14.08	14.32	12.78	15.38	11.72	15.89	11.21	16.00	11.10	15.45	11.65	15.44	11.66	15.70	11.40
	75S	27.18	13.15	14.03	14.42	12.76	15.47	11.71	16.00	11.18	16.12	11.06	15.55	11.63	15.54	11.64	15.81	11.37
	76D	30.88	17.78	13.10	18.76	12.12	19.68	11.20	20.21	10.67	20.20	10.68	19.82	11.06	19.51	11.37	19.83	11.05
	76S	30.90	17.82	13.08	18.76	12.14	19.69	11.21	20.21	10.69	20.08	10.82	19.84	11.06	19.53	11.37	19.83	11.07
	77D	23.49	6.14	17.35	10.79	12.70	11.77	11.72	12.38	11.11	12.08	11.41	12.80	10.69	12.18	11.31	11.83	11.66
	77S	23.97	6.93	17.04	8.55	15.42	9.11	14.86	8.40	15.57	8.20	15.77	9.04	14.93	10.45	13.52	10.70	13.27
	78D	29.95	16.80	13.15	17.90	12.05	18.78	11.17	19.57	10.38	19.46	10.49	18.86	11.09	18.77	11.18	19.16	10.79
	78S	29.66	16.39	13.27	17.61	12.05	18.50	11.16	19.28	10.38	19.18	10.48	18.58	11.08	18.48	11.18	18.87	10.79
	4A	28.51	18.18	10.33	19.01	9.50	-	-	-	-	-	-	-	-	-	-	-	-
SS20 (SP-9)	4B	29.91	19.61	10.30	20.43	9.48	-	-	-	-	-	-	-	-	-	-	-	-
	5B	26.72	12.68	14.04	17.01	9.71	-	-	-	-	-	-	-	-	-	-	-	-
	6B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
721/724 WP21 (T-1)	DM-11	24.75	12.11	12.64	12.77	11.98	13.33	11.42	14.00	10.75	13.64	11.11	13.60	11.15	13.48	11.27	13.47	11.28
	208D	26.52	14.99	11.53	15.63	10.89	16.17	10.35	16.82	9.70	16.37	10.15	16.28	10.24	16.22	10.30	16.13	10.39
	208S	26.51	14.98	11.53	15.67	10.84	16.21	10.30	16.90	9.61	16.37	10.14	16.30	10.21	16.24	10.27	16.13	10.38
	209D	27.37	16.76	10.61	17.64	9.73	18.13	9.24	18.63	8.74	18.39	8.98	18.23	9.14	18.15	9.22	18.08	9.29
	209S	27.37	16.70	10.67	17.59	9.78	18.09	9.28	18.61	8.76	18.35	9.02	18.19	9.18	18.10	9.27	18.14	9.23
	210D	26.04	15.15	10.89	15.67	10.37	16.18	9.86	16.83	9.21	16.57	9.47	16.22	9.82	16.26	9.78	16.34	9.70
	210S	26.03	15.16	10.87	15.57	10.46	16.08	9.95	16.79	9.24	16.57	9.46	16.18	9.85	16.22	9.81	16.28	9.75
	211D	25.00	12.94	12.06	13.55	11.45	14.11	10.89	14.73	10.27	14.25	10.75	14.26	10.74	14.15	10.85	14.01	10.99
	211S	24.84	12.80	12.04	14.41	10.43	13.97	10.87	14.60	10.24	14.11	10.73	14.12	10.72	14.02	10.82	13.87	10.97
	212D	25.87	14.00	11.87	14.55	11.32	15.12	10.75	15.78	10.09	15.37	10.50	15.25	10.62	15.24	10.63	15.10	10.77
	212S	25.42	13.55	11.87	14.17	11.25	14.67	10.75	15.33	10.09	14.87	10.55	14.79	10.63	14.73	10.69	14.65	10.77
	213D	25.21	12.40	12.81	13.09	12.12	13.66	11.55	14.28	10.93	13.85	11.36	13.88	11.33	13.80	11.41	13.75	11.46
	213S	25.41	12.61	12.80	13.30	12.11	13.87	11.54	14.49	10.92	14.05	11.36	14.09	11.32	14.00	11.41	13.94	11.47
	214D	30.67	18.86	11.81	19.42	11.25	20.05	10.62	20.82	9.85	20.53	10.14	20.19	10.48	20.08	10.59	20.28	10.39
	214S	30.84	19.06	11.78	19.61	11.23	20.24	10.60	20.99	9.85	20.71	10.13	20.38	10.46	20.26	10.58	20.45	10.39
	215D	32.76	22.78	9.98	23.30	9.46	-	-	-	-	-	-	-	-	-	-	-	-
	215S	32.77	22.75	10.02	23.30	9.47	-	-	-	-	-	-	-	-	-	-	-	-
	216D	30.02	19.15	10.87	19.85	10.17	20.37	9.65	21.20	8.82	20.72	9.30	20.46	9.56	20.41	9.61	20.47	9.55
	216S	30.04	19.27	10.77	19.96	10.08	20.50	9.54	21.15	8.89	20.81	9.23	20.57	9.47	20.53	9.51	20.58	9.46
	220D	26.68	16.02	10.66	16.73	9.95	17.26	9.42	17.78	8.90	17.33	9.35	17.06	9.62	17.13	9.55	17.26	9.42

NOTE: TOC- Measured from top of casing (feet)
MSL- Mean Sea Level (feet)

Table A-2 (continued)
Water Level Measurements

SITE	WELL ID	ELEV. TOC/mal	ROUND 1 4/91		ROUND 2 8/91		ROUND 3 10/91		ROUND 4 01/92		ROUND 5 04/92		ROUND 6 07/92		ROUND 7 10/92		ROUND 8 01/93	
			TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL
ST34 (OSTS)	65D	21.59	9.51	12.08	10.18	11.41	10.69	10.90	11.25	10.34	10.93	10.66	10.79	10.80	10.78	10.81	10.63	10.96
	65S	21.66	9.58	12.08	10.22	11.44	10.75	10.91	11.30	10.36	10.98	10.68	10.85	10.81	10.79	10.87	10.70	10.96
	66D	22.13	10.07	12.06	10.73	11.40	11.27	10.86	11.83	10.30	11.47	10.67	11.37	10.78	11.25	10.88	11.27	10.86
	66S	22.02	9.93	12.09	10.60	11.42	11.14	10.88	11.72	10.30	11.35	10.67	11.24	10.76	11.14	10.88	11.14	10.88
	67D	22.14	10.19	11.95	10.83	11.31	11.35	10.79	11.90	10.24	11.55	10.59	11.47	10.67	11.33	10.81	11.35	10.79
ST04 (AAFES)	67S	21.55	9.55	12.00	10.19	11.36	10.76	10.79	11.30	10.25	10.95	10.60	10.85	10.70	10.72	10.83	10.71	10.84
	P-17	20.77	8.50	12.27	9.18	11.59	9.74	11.03	10.33	10.44	9.89	10.88	9.88	10.89	9.77	11.00	9.76	11.01
	P-18	19.69	7.61	12.08	8.22	11.47	8.71	10.98	9.20	10.49	8.93	10.76	8.83	10.86	8.72	10.97	8.72	10.97
	P-19	20.82	8.83	11.99	9.49	11.33	10.00	10.82	10.52	10.30	10.15	10.67	10.11	10.71	10.01	10.81	9.91	10.91
	P-20	21.34	9.30	12.04	9.92	11.42	10.43	10.91	11.00	10.34	10.66	10.68	10.53	10.81	10.46	10.88	10.51	10.83
	P-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	P-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	P-23	21.03	9.16	11.87	9.67	11.36	10.21	10.82	10.88	10.15	10.48	10.55	10.24	10.79	-	-	-	-
	P-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	71D	22.49	10.85	11.64	11.66	10.83	12.18	10.31	12.50	9.99	12.00	10.49	11.92	10.57	11.99	10.50	11.96	10.53
505 ST05 (JP-4)	71S	22.59	10.93	11.66	11.75	10.84	12.28	10.08	12.60	9.99	12.11	10.48	12.02	10.57	12.09	10.50	12.00	10.59
	72D	22.69	12.22	10.47	12.06	10.63	12.61	10.31	12.95	9.74	12.34	10.35	12.33	10.36	12.37	10.32	12.41	10.28
	72S	22.55	12.10	10.45	11.92	10.63	12.47	10.08	12.81	9.74	12.20	10.35	12.18	10.37	12.23	10.32	12.27	10.28
	73D	22.55	10.70	11.85	11.50	11.05	12.05	10.50	12.38	10.17	11.88	10.67	11.82	10.73	11.86	10.69	11.80	10.75
	73S	22.43	10.56	11.87	11.40	11.03	11.95	10.48	12.29	10.14	11.76	10.67	11.71	10.72	11.75	10.68	11.77	10.66
	DM-1	20.75	9.69	11.06	10.48	10.27	10.98	9.77	11.32	9.43	10.95	9.80	10.77	9.98	10.83	9.92	10.90	9.85
	55P	19.72	8.16	11.56	11.75	7.97	12.15	7.57	13.88	5.84	13.17	6.55	13.93	5.79	13.51	6.21	8.56	11.16
	69D	20.00	8.77	11.23	10.27	9.73	10.65	9.35	11.09	8.91	10.65	9.35	10.13	9.87	10.42	9.58	10.36	9.64
	69S	20.30	8.73	11.57	10.21	10.09	10.64	9.66	10.78	9.52	10.08	10.22	10.25	10.05	10.42	9.88	10.33	9.97
	68D	23.66	12.13	11.53	13.66	10.00	14.02	9.64	14.06	9.60	13.34	10.32	13.60	10.06	13.81	9.85	13.56	10.10
LF25 (D-9)	68S	23.63	11.06	12.57	15.70	7.93	15.79	7.84	15.48	8.15	15.31	8.32	16.41	7.22	16.33	7.30	12.91	10.72
	70D	21.00	9.33	11.67	10.93	10.07	11.36	9.64	11.45	9.55	10.63	10.37	10.93	10.07	10.13	10.87	10.96	10.04
	70S	20.83	9.13	11.70	10.75	10.08	11.16	9.67	11.25	9.58	10.47	10.36	10.73	10.10	10.92	9.91	10.83	10.00
	85P	20.99	12.55	8.44	14.25	6.74	14.29	6.70	14.02	6.97	-	-	14.41	6.58	14.10	6.89	13.85	7.14
	P-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	P-26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	P-27	21.67	9.66	12.01	11.40	10.27	11.88	9.79	-	-	-	-	9.45	10.11	9.63	9.93	9.55	10.01
	P-28	19.56	7.99	11.57	9.40	10.16	8.50	11.06	10.00	9.56	9.25	10.31	15.36	6.09	15.30	6.15	15.06	6.39
	DM08	21.45	-	-	15.15	6.30	15.40	6.05	15.64	5.81	15.03	6.42	15.36	4.69	12.00	4.92	11.60	5.32
	DM09	16.92	-	-	11.99	4.93	12.16	4.76	12.31	4.61	11.85	5.07	12.23	3.56	14.71	3.85	14.37	4.19
FT01 (FT-1)	DM10	18.56	-	-	14.78	3.78	14.71	3.85	14.91	3.65	14.72	3.84	15.00	5.76	15.31	5.85	15.09	6.07
	14	-	-	-	-	-	-	-	15.52	5.64	15.15	6.01	15.40	5.76	15.31	5.85	15.09	6.07
	15	11.11	6.67	4.44	6.99	4.12	6.85	4.26	6.98	4.13	6.65	4.46	7.29	3.82	6.76	4.35	6.26	4.85
	16	10.57	6.62	3.95	6.50	4.07	6.60	3.97	6.75	3.82	6.58	3.99	6.87	3.70	6.47	4.10	6.22	4.35
	17	10.27	6.93	3.34	6.99	3.28	6.88	3.39	7.05	3.22	6.93	3.34	7.36	2.91	6.84	3.43	6.61	3.66

NOTE: TOC- Measured from top of casing (feet)
MSL- Mean Sea Level (feet)

Table A-2 (continued)
Water Level Measurements

SITE	WELL ID	ELEV. TOC/mal	ROUND 1 4/91		ROUND 2 8/91		ROUND 3 10/91		ROUND 4 01/92		ROUND 5 04/92		ROUND 6 07/92		ROUND 7 10/92		ROUND 8 01/93	
			TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL	TOC	MSL
SS07 (S-1)	48D	29.11	16.40	12.71	19.06	10.03	19.64	9.47	19.96	9.15	18.83	10.26	18.90	10.21	19.80	9.31	19.46	9.65
	48S	29.11	16.23	12.88	18.85	10.26	19.49	9.62	19.84	9.27	18.70	10.41	18.71	10.40	19.62	9.49	19.37	9.74
	49D	25.11	13.12	11.99	15.42	9.69	16.10	9.01	16.46	8.65	15.54	9.57	15.38	9.73	16.37	8.74	16.18	8.93
	49S	25.14	13.17	11.97	15.40	9.74	16.10	9.04	16.49	8.65	15.60	9.54	15.34	9.80	16.31	8.83	16.27	8.87
	50D	29.30	17.03	12.27	19.44	9.86	21.00	8.30	20.51	8.79	19.54	9.76	19.32	9.98	20.35	8.95	20.17	9.13
	50S	29.05	16.75	12.30	19.16	9.89	19.84	9.21	20.26	8.79	19.30	9.75	19.07	9.98	20.10	8.95	19.94	9.11
	51D	25.89	14.66	11.23	16.73	9.16	17.43	8.46	17.79	8.10	16.86	9.03	16.78	9.11	17.61	8.28	17.49	8.40
	51S	25.80	14.08	11.72	16.11	9.69	16.76	9.04	17.14	8.66	16.23	9.57	16.13	9.67	16.97	8.83	16.86	8.94
	52D	25.76	14.67	11.09	16.67	9.09	17.25	8.51	17.58	8.18	16.65	9.11	16.66	9.10	17.37	8.39	17.23	8.53
	52S	25.91	14.57	11.34	16.75	9.16	17.34	8.57	17.69	8.22	16.78	9.13	16.72	9.19	17.47	8.44	17.34	8.57
LF16, LF17 LF19 (Zone D)	53D	26.82	14.23	12.59	16.82	10.00	17.50	9.32	17.86	8.94	16.85	9.97	16.69	10.13	17.74	9.08	17.53	9.29
	53S	27.79	15.18	12.61	17.80	9.99	18.48	9.31	18.86	8.93	17.81	9.98	17.66	10.13	18.73	9.06	18.53	9.26
	54D	26.51	15.04	11.47	17.17	9.34	17.90	8.61	18.27	8.24	17.42	9.09	17.22	9.29	18.20	8.31	18.04	8.47
	54S	26.29	14.83	11.46	16.96	9.33	17.67	8.62	18.01	8.28	17.21	9.08	17.04	9.25	17.94	8.35	17.83	8.46
	56P	26.38	15.24	11.14	17.34	9.04	17.90	8.48	18.22	8.16	17.30	9.08	17.30	9.08	18.02	8.36	17.88	8.50
	24	25.61	13.70	11.91	16.05	9.56	16.63	8.98	16.97	8.64	16.03	9.58	15.96	9.65	16.75	8.86	16.55	9.06
	25	26.82	14.62	12.20	17.01	9.81	17.64	9.18	17.98	8.84	17.05	9.77	16.93	9.89	17.82	9.00	17.61	9.21
	27	24.21	12.60	11.61	14.78	9.43	15.41	8.80	15.77	8.44	15.93	8.28	14.77	9.44	15.58	8.63	15.44	8.77
	79D	26.65	14.42	12.23	16.86	9.79	17.65	9.00	18.03	8.62	16.05	10.60	16.86	9.79	17.92	8.73	17.76	8.89
	79S	27.43	15.18	12.25	17.65	9.78	18.40	9.03	18.82	8.61	18.84	8.59	17.59	9.84	18.70	8.73	18.55	8.88
80D (Zone D)	80D	29.81	17.67	12.14	20.04	9.77	20.78	9.03	21.20	8.61	20.28	9.53	20.02	9.79	21.06	8.75	20.91	8.90
	80S	29.54	17.36	12.18	19.78	9.76	20.52	9.02	20.93	8.61	20.00	9.54	19.71	9.83	20.81	8.73	20.40	9.14
	81D	28.54	16.59	11.95	18.96	9.58	19.75	8.79	19.22	8.39	19.22	9.32	19.02	9.52	20.04	8.50	19.91	8.63
	81S	29.15	17.17	11.98	19.55	9.60	20.37	8.78	20.76	8.39	19.83	9.32	19.63	9.52	20.66	8.49	20.51	8.64
	82D	27.29	16.37	10.92	18.11	9.18	19.06	8.23	19.43	7.86	18.43	8.86	18.58	8.71	19.39	7.90	19.20	8.09
	82S	27.56	16.67	10.89	18.65	8.91	19.25	8.31	19.71	7.85	18.85	8.71	18.87	8.69	19.66	7.90	19.49	8.07
	83D	25.45	14.24	11.21	16.37	9.08	17.11	8.34	17.45	8.00	16.55	8.90	16.56	8.89	17.42	8.03	17.17	8.28
	83S	25.49	14.26	11.23	16.54	8.95	17.18	8.31	17.52	7.97	16.61	8.88	16.63	8.86	17.47	8.02	17.25	8.24
	84D	26.22	14.26	11.96	16.68	9.54	17.50	8.72	17.88	8.34	16.62	9.60	16.50	9.72	17.54	8.68	17.35	8.87
	84S	25.99	13.49	12.50	16.47	9.52	17.25	8.74	17.61	8.38	16.93	9.06	16.78	9.21	17.79	8.20	17.61	8.38

NOTE: TOC- Measured from top of casing (feet)
MSL- Mean Sea Level (feet)

Table A-2
Summary Basewide Water Level Measurements for
DAFB, April 1991 to January 1992

SITE	WELL ID	ELEV. TOC	ROUND I	ROUND II	ROUND III	ROUND IV
			W.L. (MSL)	W.L. (MSL)	W.L. (MSL)	W.L. (MSL)
XYZ	P02	27.35	-	-	-	-
	P03	26.99	16.79	13.83	13.29	13.45
	P-09	-	-	-	-	-
	P-10	-	-	-	-	-
	P-11	25.45	13.05	10.17	-	-
	P-12	-	-	-	-	-
	P-13	24.40	18.58	14.16	13.75	15.18
	P-14	25.38	16.60	13.26	12.78	12.55
	P-15	26.25	12.23	9.47	9.01	8.69
	P-16	27.78	12.87	11.53	11.50	11.49
	P05	24.87	17.82	15.42	13.96	13.12
	P06	-	-	-	-	-
	P07	26.18	17.85	15.72	14.50	13.30
	P08	-	-	-	-	-
	59D	24.68	7.20	6.02	4.62	3.26
	59S	24.96	10.63	10.79	9.90	NA
	OW-1	27.15	-	-	-	9.91
	60D	25.14	16.72	14.51	13.14	12.30
	60S	25.16	16.70	14.56	13.17	12.31
	74D	23.99	16.89	14.90	13.63	13.04
ZONE SP	74S	24.19	17.21	15.06	13.77	13.29
	75D	27.10	14.08	12.78	11.72	11.21
	75S	27.18	14.03	12.76	11.71	11.18
	76D	30.88	13.10	12.12	11.20	10.67
	76S	30.90	13.08	12.14	11.21	10.69
	77D	23.49	17.35	12.70	11.72	11.11
	77S	23.97	17.04	15.42	14.86	15.57
	78D	29.95	13.15	12.05	11.17	10.38
	78S	29.66	13.27	12.05	11.16	10.38
	721/724	DM-11	12.64	11.98	11.42	10.75
D-1	505	DM-1	11.06	10.27	9.77	9.43
	D-1	DM02	-	9.97	9.66	9.60
		DM03	-	12.03	11.19	14.96
		DM04	-	17.78	17.46	19.95
		DM05	-	11.86	11.51	13.30
	D-3	DM06	-	11.54	11.17	13.00
		DM07	-	10.47	9.94	10.09

Note: Round I- April 29 to May 1, 1991

Round II- August 7 to 10, 1991

Round III- October 15 to 18, 1991

Round IV- January 13 to 15, 1992

TOC- Top of casing

MSL- Mean sea level (feet)

W.L.- Water level

NA- Not available

Revision Date: 5/92

Table A-2
Summary Basewide Water Level Measurements for
DAFB, April 1991 to January 1992

SITE	WELL ID	ELEV. TOC	ROUND I	ROUND II	ROUND III	ROUND IV
			W.L. (MSL)	W.L. (MSL)	W.L. (MSL)	W.L. (MSL)
T-1	233D	19.85	9.63	11.86	11.25	10.77
	233S	19.78	12.49	11.86	11.25	10.73
	234D	27.37	13.60	12.65	11.93	11.62
	234S	27.12	13.71	12.80	12.04	11.73
	235D	28.09	10.30	9.66	9.14	8.60
	235S	28.06	10.29	9.73	9.14	8.60
	236D	25.56	11.12	10.56	10.00	9.38
	236S	25.39	11.10	10.57	10.00	9.40
	9A	-	-	-	-	-
	9B	-	-	-	-	-
	F1	26.21	6.53	4.90	4.87	4.88
	F2	25.43	5.72	4.21	4.08	4.20
	F3	22.53	7.41	5.81	5.49	5.55
	T-1-A	20.88	12.60	11.61	11.16	10.65
	T-1-B	21.08	13.11	12.40	11.90	11.28
	T-1-C	26.20	12.47	11.85	11.16	10.50
	T-1-D	25.83	12.41	11.91	11.49	11.60
	T-1-E	27.70	11.42	10.78	10.13	9.50
	101	24.56	12.40	11.68	11.09	10.51
	102	24.03	12.18	11.49	10.93	10.38
SP-9	103	24.11	12.23	11.52	10.95	10.37
	01j	22.45	12.52	11.80	11.22	10.69
	02j	27.56	12.12	11.48	10.87	10.20
	04j	25.40	11.97	11.37	10.80	10.11
	4A	28.51	10.33	9.50	-	-
	4B	29.91	10.30	9.48	-	-
	5B	26.72	14.04	9.71	-	-
	6B	-	-	-	-	-
	7B	-	-	-	-	-
	8B	-	-	-	-	-
AAFES	71D	22.49	11.64	10.83	10.31	9.99
	71S	22.59	11.66	10.84	10.31	9.99
	72D	22.69	10.47	10.63	10.08	9.74
	72S	22.55	10.45	10.63	10.08	9.74
	73D	22.55	11.85	11.05	10.50	10.17
D-10	73S	22.43	11.87	11.03	10.48	10.14
	05j	20.07	7.39	6.13	5.74	5.80

Note: Round I- April 29 to May 1, 1991
Round II- August 7 to 10, 1991
Round III- October 15 to 18, 1991
Round IV- January 13 to 15, 1992

TOC- Top of casing
MSL- Mean sea level (feet)
W.L.- Water level
NA- Not available

Table A-2
Summary Basewide Water Level Measurements for
DAFB, April 1991 to January 1992

SITE	WELL ID	ELEV. TOC	ROUND I	ROUND II	ROUND III	ROUND IV
			W.L. (MSL)	W.L. (MSL)	W.L. (MSL)	W.L. (MSL)
S-1	48D	29.11	12.71	10.05	9.47	9.15
	48S	29.11	12.88	10.26	9.62	9.27
	49D	25.11	11.99	9.69	9.01	8.65
	49S	25.14	11.97	9.74	9.04	8.65
	50D	29.30	12.27	9.86	8.30	8.79
	50S	29.05	12.30	9.89	9.21	8.79
	51D	25.89	11.23	9.16	8.46	8.10
	51S	25.80	11.72	9.69	9.04	8.66
	52D	25.76	11.09	9.09	8.51	8.18
	52S	25.91	11.34	9.16	8.57	8.22
	53D	26.82	12.59	10.00	9.32	8.94
	53S	27.79	12.61	9.99	9.31	8.93
	54D	26.51	11.47	9.34	8.61	8.24
	54S	26.29	11.46	9.33	8.62	8.28
	56P	26.38	11.14	9.04	8.48	8.16
	S-1/ ZONE D 24	25.61	11.91	9.56	8.98	8.64
	25	26.82	12.20	9.81	9.18	8.84
	27	24.21	11.61	9.43	8.80	8.44
	79D	26.65	12.23	9.79	9.00	8.62
	79S	27.43	12.25	9.78	9.03	8.61
SP-4	80D	29.81	12.14	9.77	9.03	8.61
	80S	29.54	12.18	9.76	9.02	8.61
	81D	28.54	11.95	9.58	8.79	8.39
	81S	29.15	11.98	9.60	8.78	8.39
	82D	27.29	10.92	9.18	8.23	7.86
	82S	27.56	10.89	8.91	8.31	7.85
	83D	25.45	11.21	9.08	8.34	8.00
	83S	25.49	11.23	8.95	8.31	7.97
	84D	26.22	11.96	9.54	8.72	8.34
	84S	25.99	12.50	9.52	8.74	8.38
	45D	24.69	12.51	9.79	9.34	8.99
	45S	24.54	13.16	10.37	9.86	9.34
	46D	26.42	13.02	10.07	9.69	9.47
	46S	26.92	13.13	10.20	9.85	9.75
	47D	28.43	12.70	9.90	9.39	9.07
	47S	27.87	12.64	9.90	9.43	9.11
	P01	28.02	18.04	15.23	14.02	14.30

Note: Round I- April 29 to May 1, 1991

Round II- August 7 to 10, 1991

Round III- October 15 to 18, 1991

Round IV- January 13 to 15, 1992

TOC- Top of casing

MSL- Mean sea level (feet)

W.L.- Water level

NA- Not available

TABLE 12-1
SS27 (XYZ)
CHEMICAL DATA FOR GROUNDWATER
ONSITE ANALYSIS

SELECTED VOCs (ug/L)

Site I.D.	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27	SS27
Location I.D.	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
Sample I.D.	GP3001	GP3002	GP3003	GP3004	GP3005	GP3006	GP3007	GP3008	GP3009	GP3010	GP3012	GP3014
Sample Date	04/21/93	04/21/93	04/21/93	04/21/93	04/21/93	04/20/93	04/20/93	04/21/93	04/20/93	04/21/93	4/22/93	04/22/93
Depth (feet)	11.5	8.5	10	11.5	10	11	10	11	11.5	11.5	14.5	14.5
Vinyl Chloride	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Freon 113	< 0.5	< 0.5	< 1500	< 0.5	< 0.5	< 150	< 1500	< 3000	< 150	< 0.5	< 0.5	< 1500
1,1-DCE	< 1.0	< 1.0	< 3000	< 1.0	< 1.0	< 300	< 3000	< 6000	< 300	< 1.0	< 1.0	< 3000
Methylene Chloride	< 2.0	< 2.0	< 6000	< 2.0	< 2.0	< 600	< 6000	< 12000	< 600	< 2.0	< 2.0	< 6000
t-1,2-DCE	< 5.0	< 5.0	< 15000	< 5.0	< 5.0	< 1500	< 15000	< 30000	< 1500	< 5.0	< 5.0	< 15000
Chloroform	< 0.5	< 0.5	< 1500	< 0.5	< 0.5	< 150	< 1500	< 3000	< 150	< 0.5	< 0.5	< 1500
1,1,1-TCA	< 0.5	< 0.5	< 1500	< 0.5	< 0.5	< 150	< 1500	< 3000	< 150	< 0.5	< 0.5	< 1500
TCE	< 0.5	< 0.5	< 1500	< 0.5	< 0.5	< 150	< 1500	< 3000	< 150	< 0.5	< 0.5	< 1500
PCE	< 0.5	< 0.5	< 1500	< 0.5	< 0.5	< 150	< 1500	< 3000	< 150	< 0.5	< 0.5	< 1500
Benzene	2.3	< 2.0	670000	6000	32	2600000	26000000	38000000	3000000	1200	240	1800000
Toluene	2.9	< 2.0	270000	2000	11	1700000	13000000	19000000	1800000	740	140	830000
Ethylbenzene	2.3	< 2.0	130000	< 2.0	< 2.0	920000	16000000	16000000	1600000	< 2.0	220	560000
Total Xylenes	5.3	< 2.0	150000	6200	40	1800000	15000000	20000000	1700000	2200	47	550000
Total Volatiles	650	57	7800000	110000	1000	49000000	490000000	740000000	49000000	18000	2600	20000000

Site I.D.	SS27	SS27	SS27	SS27	SS27	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB
Location I.D.	XYZ	XYZ	XYZ	XYZ	XYZ	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB	DAFB
Sample I.D.	GP3016	GP3017	GP3018	GP3021	GP3023	GP3063	GP3064	GP3065	GP3066	GP3067	GP3068	GP3069
Sample Date	04/20/93	04/20/93	03/22/93	04/19/93	03/26/93	04/13/93	04/13/93	04/20/93	04/13/93	04/13/93	04/13/93	04/20/93
Depth (feet)	9	11.5	20.5	8.5	17.5	14.5	14.5	11.5	14.5	14.5	14.5	11.5
Vinyl Chloride	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Freon 113	< 150	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1.5	< 150
1,1-DCE	< 300	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 3.0	< 300
Methylene Chloride	< 600	< 2.0	21	< 2.0	< 2.0	< 2.0	< 2.0	2.9	2.9	< 2.0	< 6.0	< 600
t-1,2-DCE	< 1500	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 15	< 1500
Chloroform	< 150	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1.5	< 150
1,1,1-TCA	< 150	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1.5	< 150
TCE	< 150	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	5	< 0.5	< 0.5	< 1.5	< 150
PCE	< 150	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1.5	< 150
Benzene	2300000	210	< 2.0	< 2.0	< 2.0	5.6	< 2.0	150	70	2700	2600	430000
Toluene	1400000	20	< 2.0	< 2.0	< 2.0	5.5	< 2.0	17	5.2	380	2800	200000
Ethylbenzene	900000	< 2.0	< 2.0	< 2.0	< 2.0	4.3	< 2.0	61	26	< 2.0	< 2.0	76000
Total Xylenes	1000000	70	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	9.2	< 2.0	190	890	99000
Total Volatiles	34000000	4100	49	< 45	34	67	< 45	3000	2000	7100	18000	7300000

TABLE 12-1 (cont'd)

SELECTED VOCs (ug/L)

Site I.D.	DAFB	DAFB	DAFB	
Location I.D.				
Sample I.D.	GP3070	GP3071	GP3097	
Sample Date	04/20/93	04/20/93	04/20/93	MCL
Depth (feet)	11.5	8.5	8.5	FINAL
Vinyl Chloride	NT	NT	NT	2
Freon 113	< 150	< 0.5	< 0.5	
1,1-DCE	< 300	< 1.0	< 1.0	7
Methylene Chloride	< 600	< 2.0	< 2.0	5
1,1,2-DCE	< 1500	< 5.0	< 5.0	70
Chloroform	< 150	< 0.5	< 0.5	100
1,1,1-TCA	< 150	< 0.5	< 0.5	200
TCE	< 150	< 0.5	< 0.5	5
PCE	< 150	< 0.5	< 0.5	5
Benzene	280000	22	6.8	5
Toluene	47000	10	< 2.0	1000
Ethylbenzene	45000	< 2.0	< 2.0	700
Total Xylenes	170000	36	< 2.0	10000
Total Volatiles	9400000	480	13000	

Source: Drinking Water Standards - EPA (May 1993) Drinking Water Regulations
and Health Advisories, Office of Drinking Water, Washington, D.C.

CHEMICAL STATISTICAL REPORT FOR DOVER CSR
AAVES
For Groundwater

Chemical Class	Analyte	Unit	Concentration	Flag	Maximum Sample Id	Date	Minimum Concentration	Lab Flag	Mean	Median	Qty of Hits	Qty of Samples
EIN	ALKALINITY	STD U	270.000		720	08/04/88	25.000		85.857	36.000	7	7
EIN	PH	STD U	6.400		71S	08/04/88	4.500		5.150	5.000	6	6
EIN	SPECIFIC CONDUCTIVITY	STD U	410.000		720	08/04/88	88.000		201.167	185.000	6	6
EIN	TEMPERATURE	STD U	28.000		72S	08/04/88	21.000		23.000	22.000	6	6
EIN	TOTAL DISSOLVED SOLIDS	STD U	220000.000		71S	08/04/88	58000.000		126428.571	100000.000	7	7
METALTOT	LEAD	UG/L	760.000		73SD	08/04/88	2.000		114.286	4.000	7	7
MNI	CHLORIDE	UG/L	69000.000	*	71S	08/04/88	6900.000		19500.000	14000.000	7	7
MNI	NITRATE-NITRITE	UG/L	3800.000		710	08/04/88	500.000		2082.857	1800.000	7	7
MNI	SULFATE	UG/L	36000.000		72S	08/04/88	8600.000		22920.000	27000.000	5	7
VOC	BENZENE	UG/L	110.000		72S	08/04/88	0.200	*	36.867	0.400	3	7
VOC	ETHYLBENZENE	UG/L	1.300	*	710	08/04/88	0.500	*	0.900	0.900	2	7
VOC	P-XYLENE	UG/L	1.700		710	08/04/88	1.400		1.550	1.550	2	8
VOC	TOLUENE	UG/L	0.600	*	71S	08/04/88	0.400	*	0.500	0.500	2	7

For Soil

Chemical Class	Analyte	Unit	Concentration	Flag	Maximum Sample Id	Date	Minimum Concentration	Lab Flag	Mean	Median	Qty of Hits	Qty of Samples
METAL	LEAD	MG/KG	9.200		SB-66-11.5	05/27/88	1.700		4.729	4.500	7	7
VOC	ACETONE	UG/KG	3600.000		SB-66-11.5	05/27/88	7.600	BJ	1657.933	1560.500	6	7
VOC	BENZENE	UG/KG	7200.000	J	SB-67-11.5-5	05/27/88	170.000	J	2513.333	170.000	3	7
VOC	ETHYLBENZENE	UG/KG	640.000	J	SB-66-11.5-R	05/27/88	640.000	J	640.000	640.000	2	7
VOC	METHYL ETHYL KETONE	UG/KG	8000.000		SB-66-11.5	05/27/88	4.600	BJ	3902.920	5100.000	5	7
VOC	METHYLENE CHLORIDE	UG/KG	26.000	BJ	SB-66-5-7	05/27/88	2.000	BJ	10.067	2.200	3	7
VOC	TOLUENE	UG/KG	2200.000	*	SB-66-11.5	05/27/88	1000.000	*	1466.667	1200.000	3	7
VOC	XYLENE (TOTAL)	UG/KG	4300.000		SB-66-11.5-R	05/27/88	4200.000	*	4250.000	4250.000	2	7

CHEMICAL STATISTICAL REPORT FOR DOVER CSR
ZONE D
For Groundwater

Chemical Class	Analyte	Unit	Maximum		Minimum		Lab Flag	Mean	Median	Qty of Hits	Qty of Samples
			Concentration	Sample Id	Date	Concentration					
EIN	ALKALINITY	STD U	170.000	81S	07/26/88	17.000		75.455	71.000	11	11
EIN	PH	STD U	6.700	79D	07/26/88	5.300		5.740	5.600	10	10
EIN	SPECIFIC CONDUCTIVITY	STD U	420.000	79S	07/25/88	22.000		214.727	200.000	11	11
EIN	TEMPERATURE	STD U	17.000	79S	07/25/88	14.000		15.727	16.000	11	11
EIN	TOTAL DISSOLVED SOLIDS	STD U	250.000	79S	07/25/88	52.000		113.385	100.000	13	13
METALTOT	ALUMINUM	UG/L	4100.000	82SD	07/26/88	120.000		965.385	390.000	13	13
METALTOT	BARIUM	UG/L	190.000	82SD	07/26/88	30.000		75.385	62.000	13	13
METALTOT	BORON	UG/L	410.000	79D	07/26/88	12.000		68.188	20.000	8	13
METALTOT	CALCIUM	UG/L	34000.000	79S	07/25/88	4900.000		13153.846	12000.000	13	13
METALTOT	CHROMIUM	UG/L	8.000	79S	07/25/88	8.000		8.000	8.000	1	13
METALTOT	COPPER	UG/L	11.000	79S	07/25/88	7.000		8.000	7.500	6	13
METALTOT	IRON	UG/L	19000.000	81S	07/26/88	61.000		4254.250	1300.000	12	13
METALTOT	LEAD	UG/L	37.000	83S	07/26/88	2.000		8.615	7.000	13	13
METALTOT	MAGNESIUM	UG/L	9000.000	81S	07/26/88	57.000		3950.538	3400.000	13	13
METALTOT	MANGANESE	UG/L	810.000	81S	07/26/88	18.000		154.833	46.500	12	13
METALTOT	MERCURY	UG/L	1.000	79S	07/25/88	1.000		1.000	1.000	1	13
METALTOT	POTASSIUM	UG/L	17000.000	79S	07/25/88	14000.000		15500.000	15500.000	2	13
METALTOT	SILICON	UG/L	15000.000	80D	07/25/88	5500.000		11407.692	11000.000	13	13
METALTOT	SODIUM	UG/L	38000.000	80S	07/25/88	6800.000		14023.077	12000.000	13	13
METALTOT	VANADIUM	UG/L	12.000	82SD	07/26/88	11.000		11.500	11.500	2	13
METALTOT	ZINC	UG/L	50.000	79D	07/26/88	21.000		34.769	36.000	13	13
MNI	CHLORIDE	UG/L	27000.000	79S	07/25/88	3500.000		14450.000	12700.000	8	8
MNI	FLUORIDE	UG/L	740.000	79D	07/26/88	390.000	*	565.000	565.000	2	8
MNI	NITRATE-NITRITE	UG/L	45000.000	79S	07/25/88	50.000	*	6757.500	235.000	8	8
MNI	SULFATE	UG/L	90000.000	79S	07/25/88	340.000	*	23017.500	13000.000	8	8
SVOC	1,4-DICHLOROBENZENE	UG/L	3.500	81S	07/26/88	0.900		2.200	2.200	2	13
SVOC	2-METHYLNAPHTHALENE	UG/L	10.000	83S	07/26/88	1.100	J	5.550	5.550	2	13
SVOC	BIS(2-ETHYLHEXYL) PHTHALA	UG/L	4.500	80D	07/25/88	1.700	B*	2.967	2.700	3	13
SVOC	DI-N-BUTYL PHTHALATE	UG/L	6.000	84D	07/26/88	1.900	BJ	3.809	3.400	11	12
SVOC	N-NITROSODIMETHYLAMINE	UG/L	10.000	83S	07/26/88	10.000		10.000	10.000	2	13
SVOC	NAPHTHALENE	UG/L	1.600	81S	07/26/88	1.600	J	1.600	1.600	1	13
SVOC	O-XYLENE	UG/L	10.000	81S	07/26/88	0.300	*	4.933	4.500	3	14
VOC	1,1-DICHLOROETHANE	UG/L	1.600	81S	07/26/88	0.500		1.050	1.050	2	13

CHEMICAL STATISTICAL REPORT FOR DOVER CSR
ZONE D
For Groundwater

Chemical Class	Analyte	Unit	Concentration	Flag	Maximum Sample Id	Date	Minimum Concentration	Lab Flag	Mean	Median	Qty of Hits	Qty of Samples
VOC	1,2-DICHLOROETHENE	UG/L	3,400	*	83S	07/26/88	3,400	*	3,400	3,400	1	13
VOC	ACETONE	UG/L	3600.000	*	80S	07/25/88	3,100	BJ	479.456	31,000	9	13
VOC	BENZENE	UG/L	6,300	*	81S	07/26/88	1,200	*	3,750	3,750	2	13
VOC	CHLOROETHANE	UG/L	1,400	*	83S	07/26/88	0,900	*	1,150	1,150	2	13
VOC	CHLOROFORM	UG/L	1,100	*	790	07/26/88	0,070	*	0,493	0,400	4	13
VOC	ETHYLBENZENE	UG/L	3,600	*	81S	07/26/88	0,400	*	2,000	2,000	2	13
VOC	M-XYLENE	UG/L	0,900	*	790	07/26/88	0,900	*	0,900	0,900	1	13
VOC	METHYL CHLORIDE, CHLOROME	UG/L	3,000	J	81S	07/26/88	3,000	J	3,000	3,000	1	13
VOC	TETRACHLOROETHENE	UG/L	0,900	*	790	07/26/88	0,030	*	0,279	0,200	8	13
VOC	TOLUENE	UG/L	40,000	*	81S	07/26/88	0,200	*	20,100	20,100	2	13
VOC	TRICHLOROFLUOROMETHANE	UG/L	0,300	*	82SD	07/26/88	0,200	*	0,250	0,250	2	13
VOC	VINYL CHLORIDE	UG/L	130,000	*	81S	07/26/88	13,000	*	71,500	71,500	2	13
VOC	XYLENE (TOTAL)	UG/L	5,800	*	81S	07/26/88	5,800	*	5,800	5,800	1	13