

**EPA Superfund  
Record of Decision:**

**DOVER AIR FORCE BASE  
EPA ID: DE8570024010  
OU 09  
DOVER, DE  
09/30/1997**

INSTALLATION RESTORATION PROGRAM

RECORD OF DECISION FOR NATURAL ATTENUATION OF  
GROUNDWATER AND NO FURTHER ACTION FOR SOIL  
FOR FIRE TRAINING AREA 3 (FT03),  
WITHIN THE EAST MANAGEMENT UNIT AT  
DOVER AIR FORCE BASE, DELAWARE

AUGUST 1997

Submitted to  
436th Airlift Wing, CES/CEV  
Dover Air Force Base, Delaware 19902-6600

Submitted by  
HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM  
Environmental Restoration and Waste Management Programs  
Oak Ridge, Tennessee 37831-7606  
managed by  
LOCKHEED MARTIN ENERGY SYSTEMS, INC.  
for the  
U.S. Department of Energy  
Under Contract DE-AC05-84OR21400

CONTENTS

LIST OF FIGURES ..... iii

LIST OF TABLES..... iii

ACRONYMS..... iv

1. DECLARATION OF SELECTED REMEDY.....1

    1.1 SITE NAME AND LOCATION.....1

    1.2 STATEMENT OF BASIS AND PURPOSE.....1

    1.3 ASSESSMENT OF THE SITE.....1

    1.4 DESCRIPTION OF THE SELECTED REMEDY.....2

    1.5 STATUTORY DETERMINATIONS.....2

2. DECISION SUMMARY.....4

    2.1 INTRODUCTION.....4

    2.2 PUBLIC PARTICIPATION.....5

    2.3 SITE BACKGROUND.....5

    2.4 SUMMARY OF SITE RISKS.....9

    2.5 REMEDIAL ACTION OBJECTIVE.....13

    2.6 SUMMARY OF ALTERNATIVES.....13

        2.6.1 Alternative 1-No Action.....15

        2.6.2 Alternative 2-In Situ Remediation of Groundwater Using Natural Attenuation.....15

        2.6.3 Alternative 3-In Situ Remediation Using Density-Driven Convection.....17

        2.6.4 Alternative 4-In Situ Remediation Using Permeable Reactive Barrier Walls.....20

        2.6.5 Alternative 5-Ex Situ Remediation Groundwater Using Air Stripping.....21

    2.7 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES.....23

        2.7.1 Overall Protection of Human Health and the Environment.....23

        2.7.2 Compliance with ARARs.....24

        2.7.3 Long-Term Effectiveness and Permanence.....24

        2.7.4 Reduction of Toxicity, Mobility, and Volume.....24

        2.7.5 Short-Term Effectiveness.....35

        2.7.6 Implementability.....35

        2.7.7 Cost.....36

        2.7.8 Regulatory Acceptance.....36

        2.7.9 Community Acceptance .....36

    2.8 SELECTED REMEDY .....36

        2.8.1 Performance Standard for the Selected Remedy .....38

    2.9 STATUTORY DETERMINATION .....39

GLOSSARY .....A-1

RESPONSIVENESS SUMMARY.....B-1

TIME CALCULATIONS FOR NATURAL ATTENUATION.....C-1

LIST OF FIGURES

Figure 1 Location of Dover Air Force Base.....6  
 Figure 2 Management Units and Areas of Investigation, Dover Air Force Base.....7  
 Figure 3 Previous Sampling Locations at Fire Training Area 3(FT03).....10  
 Figure 4 EMU Monitoring Points, Dover Air Force Base .....18

LIST OF TABLES

Table 1. Hypothetical Future Commercial/Industrial Scenario for Groundwater.....11  
 Table 2. Summary of Contaminants Detected During the RI in FT03 Groundwater.....12  
 Table 3. Comparative Analysis of Alternatives for FT03 .....25  
 Table 4. Summary of Comparative Analysis of Alternatives for FT03.....31  
 Table 5. Summary of Potential ARARs .....32  
 Table 6. Action Alternative Cost Summary for FT03 .....37

ACRONYMS

1,2-DCE	1,2-Dichloroethene
ARAR	Applicable or relevant and appropriate requirements
AS	Air sparging
AWQC	Ambient Water Quality Criteria
bgs	Below ground surface
BRA	Baseline Risk Assessment
BTEX	Benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Cfm	Cubic feet per minute
COC	Contaminant of concern
DAFB	Dover Air Force Base
DDC	Density-driven convection
DNREC	State of Delaware Department of Natural Resources and Environmental Control
EMU	East Management Unit
ER-L	Effects Range-Low
FFS	Focused Feasibility Study
FS	Feasibility Study
ft.	Feet or foot
ft <sup>2</sup>	Square feet
FT03	Fire Training Area 3
FTA	Fire training area
GAC	Granular activated carbon
gal	Gallon
gpm	gallons per minute
HI	Hazard Index
IRP	Installation Restoration Program
lbs/day	Pounds per day
LECR	Lifetime excess cancer risk
MCL	Maximum Contaminant Level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	Operations and maintenance
OWS	Oil/water separator
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PP	Proposed Plan
psig	Pounds per square inch-gauge
RAO	Remedial action objective
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
TCE	Trichloroethene
TPH	Total petroleum hydrocarbon

USACE	U.S. Army Corp of Engineers
USAF	U.S. Air Force
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	Underground storage tank
VOC	Volatile organic compound
Ig/L	Micrograms per Liter

## 1. DECLARATION OF SELECTED REMEDY

### 1.1 SITE NAME AND LOCATION

Fire Training Area 3 (FT03), East Management Unit (EMU), Dover Air Force Base (DAFB), Kent County, Delaware.

### 1.2 STATEMENT OF BASIS AND PURPOSE

This record of decision (ROD) presents the selected remedial action for groundwater at FT03, which was chosen in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations Part 300. The U.S. Air Force (USAF), the lead agency, as the owner/operator of the base, prepared this decision based on the Administrative Record for the site. The U.S. Environmental Protection Agency (USEPA) Region III and the State of Delaware Department of Natural Resources and Environmental Control (DNREC) provided support.

The state of Delaware concurs with the selected remedy. The Information Repository for the Administrative Record contains the information supporting this remedial action decision and is at the Dover Public Library, Dover, Delaware.

### 1.3 ASSESSMENT OF THE SITE

DAFB identified soil and groundwater contamination related to the activities that occurred in and around the FT03 site. FT03 is the location of two former fire training areas (FTA). The older of the two former FTAs was located between the circular parking pad and Pipe Elm Branch. Before construction of the newer FTA between the older area and the parking pad in 1970, the site of the older FTA was backfilled and graded. The original surface of the older FTA is now buried approximately 6 to 8 feet (ft.) below ground surface (bgs). The newer, former FTA was located directly adjacent to the parking pad and included dumpsters that were ignited during training exercises.

Remediation of the newer FTA was completed in 1992. The dumpsters, soil, and gravel near the parking pad were removed and the site was covered with a clay cap. An underground storage tank (UST) and an oil/water separator (OWS) (Site OT56) were also removed during the remediation activities. No further action needs to be conducted on the soils at the older former FTA.

Early environmental investigations identified oil and grease and several volatile organic compounds (VOCs), including vinyl chloride, in groundwater. Of the VOCs detected, concentrations of 1,2-dichloroethene (1,2-DCE) and vinyl chloride each equaled or exceeded their maximum contaminant levels (MCLs) once. Fuel-related compounds (i.e., benzene, ethylbenzene, and toluene) were also detected, but only benzene was detected at a concentration above its MCL. The fuel compounds and VOCs, migrating towards the older FTA, are likely related to the former UST at the newer, now remediated FTA. No other contaminants are a concern. The remedial action for the soil at the newer FTA site has already been completed. Subsequent findings from pre-remediation soil sampling and RI investigations indicate that contaminant concentrations have been reduced to below action levels for both the older and newer FTAs.

A Baseline Risk Assessment (BRA) was conducted for FT03. The total lifetime excess cancer risks (LECRs) associated with exposure to FT03 groundwater under the hypothetical future commercial/industrial use scenario is 1E-04. The estimated Hazard Index (HI) for hypothetical future commercial/industrial exposure to groundwater is three. The HI is the criterion used to evaluate the noncarcinogenic effects. Because the HI is above 1, it is

appropriate to consider risk-reducing action at this site. The risks associated with FT03 groundwater are due to vinyl chloride, arsenic, and manganese. Remaining soil contaminants do not appear to be a human health or ecological risk based on the RI BRA; therefore, a ROD for No Further Action of the soil at FT03 has been previously selected.

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.

#### 1.4 DESCRIPTION OF THE SELECTED REMEDY

The selected remedy consists of in situ remediation of groundwater using natural attenuation, institutional controls consisting of continuation of the restrictions on using on-base groundwater from the Columbia Aquifer, and performance of groundwater monitoring. Final evaluation of the performance of this remedy of contaminated groundwater beneath the site and compliance with applicable or relevant and appropriate requirements (ARARs) will occur in the final basewide ROD.

#### 1.5 STATUTORY DETERMINATIONS

The selected remedial action satisfies the remedial selection process requirements of CERCLA and NCP. As required under CERCLA, the selected remedy provides the best balance of trade-offs among the nine evaluation criteria. The selected action provides protection of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the action, and is cost effective. This remedy uses permanent solutions and alternative treatment technology to the maximum extent practicable and satisfies the statutory preference for remedies that use treatments that reduce toxicity, mobility, or volume as a principal element.

Because the remedy will result in the continued presence of hazardous substances on the site above action levels, a review will be conducted within 5 years of commencement of the remedial action to ensure the remedy continues to provide adequate protection of human health and the environment in accordance with NCP Section 300.430 (f)(4)(ii). This 5-year review will be performed as part of a basewide monitoring program.

<IMG SRC 97177A>

## 2. DECISION SUMMARY

### 2.1 INTRODUCTION

DAFB recently completed a draft Feasibility Study (FS) and a technical assessment of natural attenuation processes at DAFB that addressed contaminated groundwater in the immediate vicinity of FT03. FT03 is located along the eastern boundary of DAFB, Delaware, and is the location of two former fire training areas.

The Draft Feasibility Study, East Management Unit, Dover Air Force Base (Dames & Moore May 1997) was undertaken as part of the USAF's Installation Restoration Program (IRP). The basis for the FS was the Draft Final Basewide Remedial Investigation (RI), East and North Management Units, Dover Air Force Base report (Dames & Moore August 1995), which characterized contamination and evaluated potential risks to public health and the environment. This was supplemented by two administrative reports titled Hydrogeologic and Water-Quality Data for the East Management Unit of Dover Air Force Base, 1995-96 and Assessment of Natural Attenuation of Contamination from Three Source Areas in the East Management Unit, Dover Air Force Base, both prepared by the U.S. Geological Survey (USGS), Baltimore, Maryland, in February and March 1997, respectively.

Early environmental investigations identified oil and grease and several VOCs, including vinyl chloride, in groundwater. Of the VOCs detected, concentrations of 1,2-DCE and vinyl chloride each equaled or exceeded their MCLs once. Fuel-related compounds (i.e., benzene, ethylbenzene, and toluene) were also detected, but only benzene was detected at a concentration above its MCL. The fuel compounds are likely related to the former USTs at the newer, now remediated FTA. The solvents likely originated from the older, buried FTA.

This ROD addresses the source of hazardous substances present in FT03 groundwater that was evaluated in the RI and FS. Also, this ROD summarizes the FS, describes the remedial alternatives that were evaluated, identifies the remedial alternative selected by DAFB and USEPA, and explains the reasons for this selection. The State of Delaware concurs with the remedy selected in this ROD. The remedial action for the site soil has already been completed and subsequent findings from post-remediation soil sampling indicates that contaminant concentrations have been reduced to below action levels. Remaining soil contaminants do not appear to be a human health or ecological risk based on the RI BRA (Draft Final RI Report, August 1995); therefore, a ROD for No Further Action of the soil at FT03 has been recommended.

As an aid to the reader, a glossary of the technical terms used in this ROD is provided at the end of the summary.

### 2.2 PUBLIC PARTICIPATION

DAFB offered opportunities for public input and community participation during the RI/FS and Proposed Plan (PP) for FT03 in the EMU. The PP was made available to the public in the Administrative Record. Documents composing the Information Repository for the Administrative Record for the site are available at the Dover Public Library, Dover., Delaware. The notice of availability for the PP was published in the local newspaper and the base newspaper. A public comment period was held from Monday, June 16, 1997, until Wednesday, July 15, 1997. The public comment period was not extended as there were no requests for an extension. No written comments were received from the public, and no public meeting was requested. These community participation activities fulfill the requirements of Section 113(k)(2)(B)(I-v) and 117(a)(2) of CERCLA.

Comments submitted by the USEPA and DNREC consisted of editorial changes and clarification of some issues; however, the editing and clarification did not result in any significant change to the preferred alternative presented in the PP.

### 2.3 SITE BACKGROUND

DAFB is located in Kent County, Delaware, 3.5 miles southeast of the city of Dover (Figure 1) and is bounded on the southwest by the St. Jones River. DAFB comprises approximately 4,000 acres of land, including annexes, easements, and leased property (Figure 2).

DAFB is relatively flat, with elevations ranging from approximately 10 to 30 ft. above mean sea level. The surrounding area is primarily cropland and wetlands.

DAFB began operation in December 1941. Since then, various military services have operated out of DAFB. The current host organization is the 436th Airlift Wing. Its mission is to provide global airlift capability, including transport of cargo, troops, equipment, and relief supplies.

DAFB is the U.S. East Coast home terminal for the C-5 Galaxy aircraft. The base also serves as the joint services port mortuary, designed to accept casualties in the event of war. The C-5 Galaxy, a cargo transport plane, is the largest aircraft in the USAF, and DAFB is one of the few military bases at which hangars and runways are designed to accommodate these planes.

The portion of DAFB addressed in this RODCIRP Site FT03C is located within the EMU, one of four management units into which the base has been divided (Figure 2). FT03 is one of several associated areas identified in the EMU. FT03 is the site of two former FTAs. The older of the two former FTAs was located between the circular parking pad and Pipe Elm Branch. Before construction of the newer FTA between the older area and the parking pad in 1970, the site of the older FTA was backfilled and graded. The original surface of the older FTA is now buried approximately 6 to 8 ft. bgs. The newer, former FTA was located directly adjacent to the parking pad and included dumpsters that were ignited during training exercises.

FT03 is two to three acres and located in the northeast portion of DAFB, east of the N/S runway. The site is situated approximately 800 ft. from the installation boundary and 400 ft. south of IRP Site ST58. It is mainly flat, with a gentle slope to the north and east, and is located in a maintained grass-turf area is likely used by grazers and insect-hunting birds. Surface water runoff flows overland to the north, where it is collected by a drainage ditch and ultimately discharges to the Pipe Elm Branch of Little River.

<IMG SRC 97177B>

<IMC 97177C>

The Columbia Formation is the shallowest water-bearing unit and holds the water table aquifer. Deeper aquifers are protected by the extensive upper clay of the Calvert Formation. The upper portion of the Columbia Formation is finer grained and contains more silt and clay lenses than the deeper portions. The deeper portion of the Columbia Formation typically consists of fine-to-coarse-grained sand with occasional lenses of fine-to-medium sand and discontinuous gravel lenses interpreted as channel lag deposits. The thickness of the Columbia Formation at FT03 is approximately 50 ft. The water table is generally encountered at a depth of 10 to 15 ft. bgs at FT03.

Other former structures at FT03 included a UST, an OWS, and dumpsters with support piers. The OWS was studied separately as Site OT56. It was installed in the early 1970s, was probably constructed of reinforced concrete, and was 77 in. wide by 34 in. long by 18 in. deep. The OWS was removed in 1992, at which time OT56 was closed to subsequent investigation.

FT03 is the most recent location of fire training exercises at DAFB and was used between 1970 and 1989. The controlled burn was contained within an area constructed of a 12-in. soil-and-gravel berm. Waste oils and non-specification fuels were ignited twice weekly for fire training activities. Approximately 200 to 700 gallons (gal) of fuel were burned in each exercise. Unconsumed fuel, water, and foam were then drained to the OWS at OT56. Oil was collected periodically by a contractor for reuse and recovery. A 2,000-gal UST north of the training pit was used to store fuels for the training exercises. Other than vehicular traffic, no activities occur regularly in the vicinity of these sites.

FT03 has undergone three previous investigations, two conducted by Science Applications International Corporation (1984 and 1989) and one, the RI, conducted by Dames & Moore (1995). The 1984 investigation identified oil and grease and several VOCs, including vinyl chloride, in groundwater. Soil data revealed fuel-related and chlorinated VOCs, lead, and total petroleum hydrocarbons (TPHs). The VOCs occurred primarily within or adjacent to the more recent FTA. Surface water and sediment contained metals above published background levels. Groundwater downgradient of the site did not contain concentrations of metals at levels above their action criteria, and there was no evidence that runoff flowed from the FTA pit to the



streams. Thus, there was no support for a migration pathway from FT03 to the sediment. Metals detected in surface water could not be attributed solely to the sediment.

The 1989 investigation indicated that fuel-related compounds [i.e., benzene, toluene, ethylbenzene, and xylenes (BTEX)], TPH, and lead in soils were highest within the area of the then-active FTA pit. A second deeper zone of elevated lead and TPH concentrations was within the estimated boundary of the older FTA. Detected compounds included BTEX, chlorinated solvents, and several pesticides. The two zones of soil contamination appeared to be separated by a subsurface clay layer. Chlorinated solvents [e.g., vinyl chloride and tetrachloroethene (PCE)] were detected in groundwater beneath and downgradient of the site. The presence of contaminants in the upper and lower portions of the Columbia Aquifer and downgradient of the suspected source area was evidence that contaminants in the saturated zone were migrating both vertically and laterally in the direction of groundwater flow. The contaminant concentrations found in groundwater relative to the concentrations found in soils, suggested that the clay zone beneath FT03 may retard the migration of contaminants in the unsaturated zone.

These investigations led to a Focused Feasibility Study (FFS) and subsequent remedial activities for the contaminated soil and structures at the site. Based on the FFS, a ROD was signed in September 1990. Remediation began in March 1992 and was completed in October 1992. The remedial action included removal and disposal of approximately 1,000 tons of contaminated soil and structures (i.e., OWS, piping, UST, and dumpsters), and installation of a clay cap and soil cover over the newer FTA. Confirmatory sampling and analysis indicated that compounds remaining in the soil were below action levels.

The RL conducted from February 1993 to May 1994, detected BTEX, TPH, and lead in soil, but their levels have been reduced to below action levels because of earlier remedial actions. In groundwater, several VOCs and semivolatile organic compounds (SVOCs) were detected immediately downgradient of the former UST. Benzene exceeded its MCL. At the older FTA, vinyl chloride exceeded its MCL and 1,2-DCE equaled its MCL at the newer FTA. Table 1 provides a summary of the contaminants and their concentrations detected during the RI. The extent of VOCs near the older FTA appeared limited, as no VOCs were detected at a downgradient well pair.

Pesticides and polychlorinated biphenyls (PCBs) were detected in soil and groundwater at the site; however, their concentrations were below action levels for soil and water (Table 1). Aroclor 1260 was the only PCB detected in two soil samples. The low concentrations of pesticides in soil and groundwater are generally attributed to the widespread use of these compounds across the base and surrounding farmlands.

The only SVOC detected above its MCL was bis(2-ethylhexyl)phthalate, but this compound was also detected in laboratory blanks and is thus considered a laboratory artifact. Several metals were detected above their respective MCL or the base-specific background concentrations. Table 1 provides a summary of the contaminants and their concentrations detected during the RI.

Six soil borings and 15 monitoring wells have, been installed during the investigation of FT03. Figure 3 illustrates the FT03 and sampling locations. The estimated size of the FT03 source area is 28,000 ft.

## 2.4 SUMMARY OF SITE RISKS

The purpose of the BRA (Draft Final RI Report, August 1995) is to determine whether exposure to site-related contaminants could adversely affect human health and the environment. The focus of the BRA is on the possible human health and environmental effects that could occur under current or potential future use conditions if the contamination is not remediated. The risk is expressed as LECR for carcinogens and as HI for noncarcinogens. For example, an LECR of 1E-06 represents one additional case of cancer in one million exposed population, whereas an HI above one presents a likelihood of noncarcinogenic health effects in exposed populations. The USEPA has established the target risk range of 1E-04 to 1E-06 for LECR. Risks greater than 1E-04 generally warrant an action under CERCLA. An HI greater than one indicates a possibility of adverse noncancer health effects based on exposure to multiple contaminants or pathways.

The uncertainty with noncancerous health toxicity values is a factor of 10, so HI values greater than one for any potable purposes may not necessarily require an action under CERCLA in

order to be protective of human health. It is considered very unlikely that the Columbia Aquifer would be used by the base. To ensure the Columbia Aquifer would not be used, institutional controls for restrictions of the groundwater use at FT03 would be implemented as part of the selected alternative. The restriction would be applicable for all future scenarios, including residential, recreational, and commercial/industrial.

<IMG SRC 97177D>

The RI/FS focused on the collection of data to determine the extent of contamination in the vicinity of FT03. Groundwater contained several contaminants of concern (COCs):

VOCS:	1,2-DCE	Metals:	Arsenic
	Benzene		Cobalt
	Ethylbenzene		Manganese
	Vinyl chloride		Magnesium

SVOCS: 2-Methylnaphthalene  
 Bis(2-ethylhexyl)phthalate

Pesticides: Dieldrin  
 Endosulfan II  
 Endosulfan sulfate  
 Endrin aldehyde  
 Endrin ketone

A summary of the COCs and their concentrations in groundwater is given in Table 1. The detected concentrations of twelve (12) contaminants in groundwater exceeded their respective MCLs or base-specific background concentrations in at least one of the samples collected during the RI in the vicinity of the source area. The source area for groundwater contamination is in close proximity to the base boundary and the groundwater discharge point is to a drainage ditch connected to Pipe Elm Branch of Little River; hence, the potential exists for the future off-base migration of contaminants with groundwater.

The BRA, performed as part of the base-wide RI, considered hypothetical future groundwater use from the Columbia Aquifer under the commercial/industrial scenario. Details concerning the selection of the COCs and the evaluation of the human health risks may be reviewed in the Draft Final RI, Volumes III and IV, August 1995.

The total LECRs for the hypothetical commercial/industrial exposure to groundwater is 1E-04. Vinyl chloride and arsenic are the primary contributors to the LECR. HI for groundwater is 3E+00. Manganese is the primary contributor to the HI for groundwater. The resulting risk exposures are presented in Table 2.

Table 1. Hypothetical Future Commercial/Industrial Scenario for Groundwater

Pathway	Hazard Index	LECR
Ingestion	3E+00	1E-04
Inhalation	3E-01	2E-05
Total	3E+00	1E-04

Table 2. Summary of Contaminants Detected During the RI in FT03 Groundwater

Analyte	Highest concentration (I g/L)	Number of hits	Number of samples	Maximum contaminant levels (I g/L)
Volatile organic compounds				
Benzene	150.0	1	8	5
1,2-Dichloroethene	70	2	8	70
Ethylbenzene	380	1	8	700
Vinyl chloride	21.0	1	8	2
Semivolatile organic compounds				
2-Methylnaphthalene	8.0	1	6	
Bis(2-ethylhexyl)phthalate	24.0	1	6	6
PCBs/Pesticides				
Dieldrin	0.024	4	6	
Endosulfan II	0.002	2	6	
Endosulfan sulfate	0.003	1	6	
Endrin aldehyde	0.016	1	6	
Endrin ketone	0.002	1	6	
Metals (Total)				
Arsenic	46.4	4	6	50
Beryllium	6.3	3	6	4
Cadmium	37.3	2	6	5
Chromium	303	6	6	100
Cobalt	35.6	3	6	10.4*
Lead	88.6	4	6	15
Magnesium	23,800	6	6	18,300*
Manganese	1910	6	6	1,440*
Nickel	121	3	6	100

\*DAFB-specific background concentrations (I g/L) for dissolved metals

## 2.5 REMEDIAL ACTION OBJECTIVE

Remedial action objectives (RAOs) are media-specific goals to be reached during site remediation that are protective of human health. These objectives are typically achieved by preventing exposure and reducing contaminant levels (Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, USEPA, October 1988).

The RAO for FT03 is the reduction of contaminant concentrations in groundwater to the Safe Drinking Water Act (SDWA) MCLs or Delaware's DNREC regulatory levels. The selected acceptable contaminant levels are MCLs. For COCs that do not have an MCL, the DAFB-specific background level will be used. The area to be remediated is defined as the area of attainment. The area of attainment defines the area over which cleanup levels will be achieved in the groundwater. It encompasses the area outside the boundary of any waste remaining in place and up to the boundary of the contaminant plume. Cleanup levels are to be achieved throughout the area of attainment. Within the area of attainment, the goal of the remedial action for groundwater is to reduce the concentrations of COCs below their MCLs.

DAFB does not use the Columbia Aquifer for two primary reasons: (1) the aquifer cannot meet the residential and industrial demand and (2) the water quality is less desirable than that of the deeper aquifer. Land-use restrictions will remain in place because DAFB is one of the few airports capable of servicing the C-5 Galaxy aircraft; therefore, it very likely will remain a USAF base in the distant future. These institutional controls help minimize exposure to site contaminants.

The potential off-base migration of groundwater contaminants to areas not under DAFB land-use restrictions is another route of exposure. In this case, the objective is to prevent unacceptable levels of contaminants from migrating off-base by achieving the remedial action objective within the area of attainment.

The selected acceptable contaminant levels are MCLs, which are available for most of the COCs, including the primary contributors to the total LECR in groundwater, vinyl chloride (2 Ig/L) and arsenic (50 Ig/L). For manganese, the primary contributor to the HI risk, which does not have an MCL, the DAFB-specific background level is used (1,440 Ig/L-dissolved).

## 2.6 SUMMARY OF ALTERNATIVES

General response actions are the steps that could be taken to achieve the RAOs for the groundwater at FT03. Based on results of the initial screening of the response action technologies presented in the FS and the selection of representative process options, the following six technologies are considered to be applicable:

- No Action
- Institutional Controls
  - Land-use restrictions
  - Groundwater-use restrictions
  - Groundwater monitoring
- In situ Groundwater Treatment
  - Natural attenuation
  - Density-driven convection
  - Permeable reactive barrier wall
- Groundwater Collection
  - Vertical groundwater extraction wells
- Ex situ Groundwater Treatment
  - Metals pretreatment
  - Air stripping
- Groundwater Disposal
  - Surface water discharge

These technologies are combined to form five distinct alternatives that have varying degrees of success at achieving the RAOs for FT03. The five alternatives and features of each technology are summarized as follows.

- Alternative 1-No Action. This alternative involves no activities to reduce contamination or to monitor site conditions. Institutional controls (e.g., restriction of groundwater use by DAFB) are already in place and are likely to remain so in the future. These controls, however, do not apply beyond the base boundary.
- Alternative 2-In Situ Remediation of Groundwater Using Natural Attenuation. This alternative relies on passive treatment of contaminated groundwater through natural physical, chemical, and biochemical processes. These processes, particularly biodegradation processes, result in the reduction of groundwater contaminant concentrations at reasonably predicted rates. Institutional controls consisting of continuation of the restrictions on using the Columbia Aquifer and performance of groundwater monitoring are also included.
- Alternative 3-In Situ Remediation of Groundwater Using Density-Driven Convection. Density-driven convection is an in situ groundwater treatment technology that specifically addresses source-area contamination. The distal end of the plume is addressed by natural attenuation. Institutional controls consisting of continuation of the restrictions on using the Columbia Aquifer and performance of groundwater monitoring are also included.
- Alternative 4-In Situ Remediation of Groundwater Using Permeable Reactive Barrier Walls. Groundwater in the source area is treated in situ using a permeable wall of reactive iron filings. The distal end of the plume is addressed by natural attenuation. Institutional controls consisting of continuation of the restrictions on using the Columbia Aquifer and performance of groundwater monitoring are also included.
- Alternative 5-Ex Situ Remediation of Groundwater Using Air Stripping. Groundwater is removed from the source areas using extraction wells. The extracted water undergoes metals pretreatment and is then processed through an air stripper. The treated water is subsequently discharged to an on-base stream: Pipe Elm Branch. The distal end of the plume is addressed by natural attenuation. Institutional controls consisting of continuation of the restrictions on using the Columbia Aquifer and performance of groundwater monitoring are also included.

These remedial alternatives are described in the following subsections. In addition, the capital, annual operation and maintenance (O&M), and present worth costs of each alternative are provided.

#### 2.6.1 Alternative 1-No Action

Alternative 1, the No Action alternative, is considered in the range of alternatives to serve as a baseline or to address sites that do not require active remediation. The NCP and CERCLA guidance require that the No Action alternative be evaluated. This alternative assumes that no remedial action will occur and that the site would be left in its present condition. No efforts are undertaken to reduce groundwater contaminants. Any changes to the site would be a direct result of natural processes, and no monitoring would be conducted to document changes in contaminant levels. Existing land-use restriction in place at DAFB will continue to be enforced to prohibit the unauthorized extraction and use of groundwater from the Columbia Aquifer. This action will prevent human exposure to the groundwater, thereby averting a public health risk at DAFB. This alternative does not comply with the chemical-specific ARARs of the SDWA MCLs and success at meeting the RAOs must be determined (See Table 5). No cost is associated with this alternative.

#### Alternative 1

Cost Category	Cost (\$)
Capital	0
Annual Operations and	0

## 2.6.2 Alternative 2-In Situ Remediation of Groundwater Using Natural Attenuation

Alternative 2, in situ remediation of groundwater using natural attenuation, relies on passive treatment of contaminated groundwater through natural physical, chemical, and biochemical processes. USGS conducted an extensive natural attenuation study of the EMU sites (USGS, 1997) and concluded that none of the COCs were currently migrating past the base boundary above MCL concentrations in either groundwater or surface water. In addition, the COCs are not predicted to migrate off-base in the future. Nonetheless, groundwater monitoring will be employed to demonstrate that natural attenuation is effectively reducing contaminant concentrations and preventing their off-base migration at levels above the RAO concentrations over the long term. Natural attenuation processes, particularly biodegradation processes, result in the reduction of groundwater contaminant concentrations at reasonably predicted rates.

Based on the aquifer characteristics and findings from the RI Report and the Natural Attenuation Study, the USGS reasoned that most of the attenuation is the result of biodegradation. The estimated time needed for biodegradation of chlorinated aliphatic hydrocarbons [e.g., vinyl chloride, 1,2-DCE] to decrease concentrations by one order of magnitude ranges from 0.1 to 3.7 years; the time needed for biodegradation to decrease concentrations by two orders of magnitude ranges from approximately 0.3 to 7.4 years. Using the longest flow path from Landfill 13 (west of FT03) to Pipe Elm Branch, approximately 3000 ft. long, the groundwater travel times are somewhere between 8 and 180 years from recharge to discharge. Given these conditions, the USGS then reasoned that biodegradation can decrease concentrations to near or below the detection level in the long flow path. In the short flow path, it was concluded that although biodegradation can decrease concentrations, it would only do so by an order of magnitude. A table is included at the end of this summary which shows the comparison of remediation times for natural attenuation of groundwater versus the calculated groundwater travel times. The results showed that for short travel paths (i.e., 100 ft. at FT03) and high flow velocities (i.e., 376 ft./year), natural attenuation processes are insufficient to decrease concentrations by one order of magnitude. In a couple of cases, the intermediate flow path of 1500 ft. and a high flow velocity was not satisfactory to decrease concentrations of TCE by one order of magnitude. It should be noted that the initial concentration of a specific contaminant will dictate cause for concern that groundwater will discharge to a surface water body and pose a risk to human health or the environment. Potential concerns for FT03 are described in the following paragraphs.

For FT03, concentrations of vinyl chloride (21 Ig/L) in groundwater may be sufficiently high that natural attenuation could be ineffective to meet the remedial objective of 2 Ig/L. This assumes the worst case of a short flow path of 100 ft. to a surface water body, a high flow velocity of 376 ft./year, and the highest contaminant concentration detected in the RI. However, because of the relatively low levels of vinyl chloride present at this site, it is expected that the vinyl chloride will naturally attenuate by dilution to MCLs within a relatively short distance. The estimated remediation time through natural attenuation processes for FT03 groundwater ranges from less than 1 year to 4 years. Soil remediation has been accomplished through a previous removal action.

The RI and Natural Attenuation Study showed that concentrations of aliphatic and aromatic hydrocarbons (i.e., fuel-related components) are greatest near the spill sites and least downgradient. No fuel-related hydrocarbons were detected in the surface water samples collected in 1995 and 1996. In general, the USGS concluded that redox conditions measured at the sites are favorable for biodegradation of these compounds. One could then hypothesize that fuel-related hydrocarbons are being successfully biodegraded prior to discharge to the surface water bodies.

The proposed monitoring network is illustrated in Figure 4 and consists of two groundwater wells. To the extent possible, existing wells were selected for monitoring. At FT03, the well within the source area (MW19) and a new well at the base boundary (well POCl) are proposed for monitoring to confirm the predicted decrease in concentrations at MW19 and to observe that contaminant levels are below MCs at the base boundary. Well points and monitoring locations illustrated on Figure 4 and not specified for use at this site, are planned for use in other

nearby site monitoring programs. Groundwater samples will be collected using dedicated pumps installed in each of the monitoring wells. During the Remedial Design for this site, the base will develop, with DNREC and EPA review and approval, an "Operation and Maintenance" plan, which will detail the monitoring wells, sampling parameters, frequency and performance standards necessary to support the natural attenuation decision both prior to and after the issuance of the final base-wide ROD.

This alternative is considered capable of complying with the chemical-specific (e.g., MCLs) and action-specific (e.g., long-term monitoring) ARARs (see Table 5). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit the use of the contaminated aquifer will remain in place. This action will prevent human exposure to the groundwater, thereby averting a public health risk.

#### Alternative 2

Cost Category	Cost (\$)
Capital	4,200
Annual Operations and Maintenance	7,300
Present Worth	35,000

#### 2.6.3 Alternative 3-In Situ Remediation Using Density-Driven Convection

This alternative includes the in situ treatment of groundwater using density-driven convection (DDC) over the source areas of contamination. The DDC process is a recently developed in situ method for removal of VOCs from the saturated zone. The DDC process involves injection of air into the bottom of a well screened at both the top and the bottom. The injected air bubbles rise upward in the well and create a turbulent, frothing action inside of the wellbore. The rising air bubbles strip contaminants from the water and increase the dissolved oxygen content of the water. The rising bubbles create a frictional drag, which produces a positive hydraulic head (i.e., greater than static aquifer head) at the bottom of the well. Thus, the frictional drag acts as a groundwater pump, sucking contaminated water from the surrounding aquifer through the bottom well screen, and pushing the water through the wellbore and out of the top well screen. Aerated water discharged through the top well screen then infiltrates back down to the water table, while the discharged air bubbles travel through the vadose zone and are captured by soil vapor extraction (SVE) wells. The designed air injection pressures range from 12 to 16 pounds per square inch - gauge (psig) with an injection flow rate of 20 cubic feet per minute (cfm) for DDC wells.

The DDC wells are assumed to have a diameter of 8 in. and will be installed to the bottom of the Columbia Aquifer at an average depth of 45 ft. bgs. The DDC wells will have a dual well screen. The bottom screen will be 15 ft. long and anchored at the bottom of the well. The bottom screen will be connected to a 5-ft. section of well casing to which the upper screen will be connected. The upper screen will be 15 ft. long and will straddle the water table. The well packing of the two screened intervals will be separated by a bentonite seal. Before completion of the well, a "tee" with a capped 3-ft. horizontal extension will be installed 3 ft. below grade to facilitate air piping. The wells will be completed with a flush-mount manhole and concrete cap.

The DDC wells will be operated by injecting air into the wells with a blower or compressor. Based on the estimated number of DDC wells, one air compressor unit will be used at FT03. The compressor station can service 4 to 15 DDC wells. For costing purposes, the air compressor is assumed to have a 5-horse power motor producing 36 cfm at 16 psig. The air compressor unit will have a control panel and will be located within a weatherproofed shed. The control panel will have pressure controls, flow rate indicators, and control valves for each sparging line.

The DDC system will operate in tandem with an SVE system to capture volatile contaminants stripped from the saturated zone. SVE wells are constructed of slotted screen pipe surrounded by gravel or sand pack; a vacuum-tight seal at the ground surface will prevent short circuiting of air. The SVE wells are connected to a vacuum pump by air-handling piping. The vacuum pump produces a lateral air flow through the soil that picks up and carries gaseous-phase

contaminants that are located in the interstitial soil pore spaces of the vadose zone. An air/liquid separator is used to remove liquids before entering the vacuum blower. An offgas carbon adsorption treatment system is included to remove extracted VOCs before atmosphere discharge of the gas stream.

<IMG SRC 97177E>

Based on the formation permeability and thickness, the vendor that offers this technology (Wasatch Environmental) estimated that the effective radius of influence for single DDC wells will be 50 ft. This radius of influence was used to determine the location and the number of the wells that will be required to remediate the source areas. The radius of influence for an SVE well is estimated to be 45 ft. based on the air sparging (AS)/SVE treatability study conducted at WP21 in the West Management Unit (Extended Aquifer Air Sparging/Soil Vapor Extraction Treatability Study for Site SS59 (WP21), Dover Air Force Base, EA Engineering, Science and Technology, 1994). SVE wells were spaced approximately 80 ft. apart, allowing for some overlap and providing full coverage. Based on the spacing requirements, FT03 is estimated to need six DDC wells and nine SVE wells.

Using the results of the AS/SVE treatability study at WP21, the extraction vacuum pressures and flow rates are assumed to be 50 to 70 in. water column pressure and 25 to 30 cfm, respectively. For FT03 SVE wells, an estimated one vapor extraction station will be used. The extraction station will receive and treat vapors from nine vapor extraction wells. The extraction station will consist of a knock-out pot, a vacuum pump, and a vapor phase carbon adsorption unit to treat VOC-contaminated vapors. The knock-out pot will be located between the extraction wells and the vacuum pump and will separate entrained water in the extracted gas stream. Water generated in each knock-out pot will be piped to a 55-gal liquid phase carbon adsorption unit. Liquid phase granular activated carbon (GAC) treatment units will be used to reduce the level of the organics to levels that comply with discharge requirements (see Table 5). Following treatment, the treated water will be discharged into surface drainage that flows into Pipe Elm Branch.

Vapor from the knock-out pot will be treated in vapor-phase carbon adsorption units where organic contaminants will be removed. The air flow at each station will be split into two parallel streams, each of which will be treated using a 150-lb canister of GAC. For the one SVE station, two carbon canisters will be required. Initially (i.e., the first year of operation), the carbon canisters will have to be replaced about every 6 months. Each extraction station will be located within a weatherproofed shed. During subsequent years of operation, the carbon consumption rate will be progressively less as the contaminant extraction ratio, decline.

The SVE system will require periodic monitoring. For costing purposes, 10 air samples are assumed to be collected and analyzed the first month during startup. The first month's samples will be collected both upstream and downstream of the vapor-phase GAC units weekly. Thereafter, one air sample/month will be collected to track the progress and efficiency of remediation. In addition, the emissions from the SVE station will be monitored semiannually to ensure that it is in compliance with standards (see Table 5).

A field pilot test of the DDC system will be necessary before final design of the remediation action. The study will be used for system design and modeling of contaminant removal rates. Selected test wells will be installed to evaluate field responses to applied air pressures, identify the locations of clay lenses, confirm the radius of influence of the vapor extraction wells, determine the radius of influence of the DDC wells, and determine optimum operating conditions. The system addresses the source area at the site. The distal ends of the plume will be allowed to attenuate naturally.

Groundwater monitoring will be performed to track the long-term progress and effectiveness of groundwater remediation and to monitor contaminant migration. One new monitoring well will be installed at FT03. The well, in addition to the one existing well, will be used to monitor plume migration. Samples will be collected and analyzed from the two wells semiannually. All groundwater samples will be tested for all COCs. The actual frequency, duration, and analytical parameters may change, depending on the long-term results of sampling. For costing purposes, monitoring is assumed to occur for 5 years.



Cost Category	Cost (\$)
Capital	160,000
Annual Operations and Maintenance	19,000
Present Worth	210,000

This alternative is considered capable of complying with the chemical-specific (e.g., emissions and MCLs) and action-specific (e.g., active land treatment and long-term monitoring) ARARs (see Table 5). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit the use of the contaminated aquifer will remain in place. This action will prevent human exposure to the groundwater, thereby averting a public health risk.

#### 2.6.4 Alternative 4-In Situ Remediation Using Permeable Reactive Barrier Walls

Alternative 4 is the in situ treatment of groundwater using permeable reactive barrier walls. For FT03, this alternative includes the construction of a 300-ft.-long trench containing 2,000 cubic yards of reactive iron filings to capture and channel the contaminated plume through the reactive wall where the contaminants will be degraded. The capture was modeled using the two-dimensional groundwater model TWODAN.

The base-wide RI report indicates that the water table is located at a depth of approximately 10 to 12 ft. bgs in this portion of the site. The reactive metal walls will be installed using a one-pass trenching tool. The width and thickness of the permeable barrier wall will be determined based on the results of a treatability study. The treatability study will be performed to determine the residence time required of the contaminated groundwater within the reactive wall. The study will consist of bench-scale tests that will use samples of the contaminated groundwater and pass them over the reactive metal to measure the contaminant degradation and, thus, determine residence time requirements. Based on the known groundwater velocity at the wall, the residence time will determine wall thickness.

Groundwater monitoring will be performed to track the long-term progress and effectiveness of the groundwater remediation systems. It is proposed that one additional well will be installed at FT03. The new well and one existing well will be used in the groundwater monitoring program. Samples will be collected and analyzed from the wells semiannually. The groundwater samples are assumed to be tested for all COCs. The actual frequency, duration, and analytical parameters may change, depending on the long-term results of sampling. For estimating purposes, monitoring for 5 years is assumed.

This alternative is considered capable of complying with the chemical-specific (e.g., MCLs) and action-specific (e.g., active land treatment and long-term monitoring) ARARs (see Table 5). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit the use of the contaminated aquifer will remain in place. This action will prevent human exposure to the groundwater, thereby averting a public health risk.

#### Alternative 4

Cost Category	Cost (\$)
Capital	1,200,000
Annual Operations and Maintenance	17,000
Present Worth	1,300,000

#### 2.6.5 Alternative, 5-Ex Situ Remediation Groundwater Using Air Stripping

This alternative includes groundwater extraction, pretreatment of groundwater for metals removal, air stripping treatment to remove chlorinated solvents and fuel compounds, and surface water discharge of treated groundwater from FT03.

Groundwater extraction will be accomplished by using two new extraction wells installed at the site. The extraction well locations were selected to control and capture the areas of contaminated groundwater at the site. The extraction rates and capture area from the wells were

estimated using the two-dimensional groundwater model TWODAN.

Two extraction wells operating at 7.5 gallons per minute (gpm) each will be required at FT03. The two wells will create a capture zone that will limit further migration of contaminants and prevent discharge to the adjacent drainage ditch.

The base-wide RI report indicates that the water table is located at a depth of approximately 10 to 12 ft. bgs in the FT03 area. The RI/FS reports also indicate that the most significant contamination is found in the upper third of the Columbia Aquifer. Therefore, extraction wells at FT03 will be installed across the upper portion of the Columbia Aquifer and will be screened using slotted stainless steel casing from 10 ft. bgs (screen length of approximately 20 ft.) to 30 ft. bgs. The wells will be 6 in. in diameter. The filter pack for the wells will extend a minimum of 1 ft. above the well screen. Above the filter pack, a minimum 2-ft. bentonite seal will be installed, and the wells will be grouted to the surface using a bentonite grout.

Contaminated groundwater will be extracted using 4-in. stainless steel electric submersible pumps. Following extraction, the groundwater will be pumped through 2-in. Schedule 80 plastic piping to the treatment system. The piping will be buried below the frost line at a minimum depth of three (3) ft.. An estimated 425 ft. of pipe will be required at FT03 to convey extracted water from the recovery wells to the treatment system and from the treatment system to the closest surface water discharge point.

The groundwater treatment system includes an initial pretreatment stage to reduce the metals content. This stage is added to prevent iron and manganese fouling in the subsequent air stripping unit as well as to ensure compliance with the National Pollutant Discharge Elimination System discharge standards. Groundwater will be pumped on a continual to an equalization tank, where it will be dosed with potassium permanganate to oxidize iron and manganese to their insoluble forms followed by pH adjustment with sodium hydroxide. Next, a cationic polymer will be introduced into a rapid mix tank, where it will be mixed instantly into solution. Rapid mixing will be followed by slow mixing or flocculation. The clarification tank follows flocculation and provides for quiescent settling of the metal-polymer flocs. The flocs will settle and produce an aqueous sludge. Clarified groundwater will be sent to subsequent treatment systems void of high concentrations of iron and manganese, which can interfere with operation of the system. A bench-scale treatability study (EA Engineering, 1994) was conducted for groundwater at WP21 to determine the type and amount of chemicals required for the metals pretreatment process. The results of this study were used to estimate the chemical dosage required for metals pretreatment.

A sludge characterization test such as the Toxicity Characteristic Leachate Procedure test will have to be conducted to determine the leachability of the metals and thus the method and cost of disposal (see Table 5). For costing purposes, the sludge will be assumed to be nonhazardous. The sludge will be dewatered to reduce the volume requiring disposal.

After pretreatment for metals, groundwater will be pumped to the top of a low-profile, four-tray air stripper. The water will be uniformly distributed across each tray and brought into contact with air forced up from the bottom of the unit by a blower. The counter-current airflow through the stripper unit transfers VOCs dissolved in the groundwater to the air stream. The air stream containing the VOCs then exits through the top of the air stripper unit, while the treated groundwater flows out through the bottom of the air stripper unit. The air stripper unit selected has a liquid throughout capacity of up to 20 gpm.

Based on the average VOC concentration of groundwater samples collected at each site, an appropriate extraction rate, and assuming complete removal during treatment, 0.28 pounds per day (lbs/day) of VOCs will be stripped from the groundwater at FT03. The air stream exiting the air stripper will not require treatment before release to the atmosphere because the total VOC discharge is less than 2.5 lbs/day. Air samples will be collected monthly to ensure continued compliance with air emission standards. (see Table 5)

Preliminary modeling of the air stripper performance using recent groundwater data from the site and the expected flow rate indicate that the treated groundwater will meet the surface water discharge standards without further polishing or treatment (see Table 5). The model also shows that air emissions will be significantly below the emission standard of 2.5 lbs/day (see

Table 5).

Effluent samples will be collected from the groundwater treatment system at a rate required, to satisfy regulatory requirements (which is assumed to be weekly for the first month and semiannually thereafter) (see Table 5). All groundwater and effluent samples are assumed to be tested for VOCs and manganese. Sampling is assumed to continue for 5 years.

The groundwater pump-and-treat system will address contamination in the source area. The distal ends of the plume will be treated by natural attenuation. Groundwater monitoring will be performed to track the long-term progress and effectiveness of the groundwater remediation system. To perform the groundwater monitoring accurately, one additional well will be installed. As was shown in Figure 4, the well (POC1) will be located at the base boundary. Samples will be collected and analyzed from two wells semiannually.

#### Alternative 5

Cost Category	Cost(\$)
Capital	190,000
Annual Operations and Maintenance	27,000
Present Worth	260,000

This alternative is considered capable of complying with the chemical-specific (e.g., MCLs) and action-specific (e.g., active land treatment, waste handling, and long-term monitoring) ARARs (see Table 5). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit the use of the contaminated aquifer will remain in place. This action will prevent human exposure to the groundwater, thereby averting a public health risk.

## 2.7 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparative analysis of the five remedial alternatives that were evaluated in detail in the FS and described in Section 2.6 of this ROD. The focus of the comparative analysis is on the relative advantages and disadvantages offered by each of the alternatives in relation to the seven evaluation criteria (excluding regulatory and community acceptance) that were analyzed. A detailed summary of this analysis is provided in Table 3, and an illustrative comparative summary is presented in Table 4.

### 2.7.1 Overall Protection of Human Health and the Environment

The overall protectiveness criterion is a composite of other evaluation criteria, especially short-term effectiveness, long-term effectiveness, and compliance with ARARs. All five of the alternatives are considered to be protective of human health because of institutional controls that prohibit the unauthorized extraction or use of contaminated groundwater on-base, thereby preventing human exposure. The institutional controls, however, do not apply to off-base properties.

Alternative 1 (No Action) is not considered effective at protecting human health and the environment past the base boundary because no provisions are made to monitor the groundwater migration off-base or to evaluate compliance with the RAO.

Alternatives 2 (Natural Attenuation), 3 (Density-Driven Convection), 4 (Permeable Reactive Barrier Wall/Pump and Treat), and 5 (Pump and Treat) will all meet the RAOs and are considered highly protective of human health and the environment.

### 2.7.2 Compliance with ARARs

The RAOs that have been established for the EMU sites are based on achievement of MCLs across the area of attainment. Alternative 1 (No Action) provides no mechanism to evaluate compliance with the MCLs and therefore does not comply with chemical-specific ARARs. The

treatment actions and groundwater monitoring provisions of Alternatives 2 through 5 will result in demonstrated compliance with the MCLs. A summary of the ARARs used in the evaluation of the alternatives is provided in Table 5. Table 5 specifies which ARARs are applicable to each alternative.

A number of other ARARs including the Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act must be considered for Alternatives 3, 4, and 5. Primary among them are compliance with VOC emission limitations to the atmosphere, land treatment regulations, and effluent discharge limitations to surface water. Alternatives 2 through 5 are in compliance with the ARARs relevant to their respective technologies.

### 2.7.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion considers primarily the magnitude of residual risk that would remain after the implementation of an alternative, and the adequacy and reliability of the controls instituted. All of the alternatives provide for the long-term protection of human health through the existing land-use restrictions. However, reliance upon land-use restrictions is considered neither a permanent remedy nor applied to off-base property.

Under Alternative 1 (No Action), the contamination in groundwater will not be monitored. Therefore, as groundwater migrates from the EMU off-base, the adequacy and reliability of this alternative cannot be established. Hence, the long-term protectiveness of this alternative cannot be demonstrated.

All of the action alternatives employ remedial measures to control the source areas and rely upon natural attenuation to address the distal ends of the plumes. The magnitude of residual contamination residing in the source area is dependent on the time allowed for the remediation to continue. For Alternative 2 (Natural Attenuation), physical, chemical, and biochemical attenuation processes will continue to reduce contaminant concentrations indefinitely into the future. Alternatives 3 (Density-Driven Convection), 4 (Permeable Reactive Barrier Walls/Pump and Treat), and 5 (Pump and Treat) will all be operated and/or maintained for finite periods of time until high levels of confidence are reached that natural attenuation can address remaining contamination.

All four action alternatives are considered reliable. The efficacy of Alternative 2 was proven in a 2-year natural attenuation study by USGS at the EMU sites. The technologies associated with Alternatives 3, 4, and 5 have been applied successfully at other installations.

### 2.7.4 Reduction of Toxicity, Mobility, and Volume

Reduction in toxicity, mobility, or volume will not be documented with the implementation of Alternative 1 (No Action). While dilution and dispersion of all contaminants occurs naturally, only the organic contaminants will degrade, and it cannot be demonstrated that the RAOs will be met at the base boundary for all contaminants over time. The four action alternatives include components that are capable of reducing significantly the toxicity and/or mobility of contaminants in groundwater through irreversible treatment processes.

TABLE 3

## Comparative Analysis of Alternatives for FT03

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Description	No action.	In situ remediation of FT03 groundwater using natural attenuation.	In situ remediation of FT03 groundwater using density-driven convection (DDC).	In situ remediation of FT03 groundwater using permeable reactive barrier walls	Ex situ treatment of FT03 groundwater using air stripping
Overall Protection					
o Human Health Protection	Offers a high level of overall protection of human health through the existing land-use restrictions on-base, but cannot be guaranteed effective past the base boundary.	Offers a high level of overall protection of human health through the existing land-use restrictions on-base. Biodegradation of source area constituents allow achievement of RAOs off-base as demonstrated through groundwater monitoring.	Offers a high level of overall protection of human health through the existing land-use restrictions. Active treatment of source area constituents allow achievement of RAOs off-base as demonstrated through groundwater monitoring.	Offers a high level of overall protection of human health through the existing land-use restrictions. Active treatment of source area constituents allow achievement of RAOs off-base as demonstrated through groundwater monitoring.	Offers a high level of overall protection of human health through the existing land-use restrictions. Active treatment of source area constituents allow achievement of RAOs off-base as demonstrated through groundwater monitoring.
o Environmental Protection	Does not provide a mechanism to monitor groundwater constituent concentrations. Therefore, potential impacts to surface water from discharging groundwater cannot be assessed.	Groundwater constituents discharging to surface water meet MCLs off-base.	Groundwater constituents discharging to surface water meet MCLs off-base.	Groundwater Constituents discharging to surface water meet MCLs off-base.	Groundwater constituents discharging to surface water meet MCLs off-base.  Groundwater released to surface water through pump and treat operations will meet surface water quality criteria
Compliance with ARARs					
o Chemical-Specific ARARs	Success at meeting RAOs will be determined.	Natural attenuation is considered capable of maintaining RAO compliance.	Density-driven convection treatment is considered capable of maintaining RAO compliance	This technology is capable of maintaining RAO compliance.	Pump and treat system considered capable of maintaining RAO compliance.  Air stripper system will comply with DRGCAP requirements

TABLE 3 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
o Action-Specific ARARs	Does not provide for long term groundwater monitoring.	Long-term groundwater monitoring is provided	Complies with DRGHW for active land treatment. Long-term groundwater monitoring provided	Complies with DRGHW for active land treatment. Long-term groundwater monitoring provided.	Long-term groundwater monitoring provided
Long-term Effectiveness and Permanence					
o Magnitude of risk	<p>Because DAFB is expected to remain active lot the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-base.</p> <p>However, this alternative provides no mechanisms to determine whether the RAOs are achieved over time (i.e., preventing risks due to off-base migration of contaminants above RAO levels).</p>	<p>Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-base.</p> <p>Risk for potential off-base users will be reduced as contaminant levels are lowered.</p>	<p>Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-base.</p> <p>Risk for potential off-base users will be reduced as contaminant levels are lowered.</p>	<p>Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-base.</p> <p>Risk for potential off-base users will be reduced as contaminant levels are lowered.</p>	<p>Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-base.</p> <p>Risk for potential off-base users will be eliminated as contaminant levels are lowered.</p>
o Reliability of Controls	<p>Land-use restrictions enforced by DAFB are considered extremely reliable in preventing on-base exposure</p> <p>Off-base, the reliability of this alternative is questionable because there is no mechanism to determine whether the RAOs are being met</p>	<p>Land-use restrictions enforced by DAFB are considered extremely reliable in preventing on-base exposure.</p> <p>The 2-year study conducted by the USGS indicates that natural attenuation can be relied upon to achieve the RAOs beyond the base boundary</p>	<p>Land-use restrictions enforced by DAFB are considered extremely reliable in preventing on-base exposure.</p> <p>The DDC technology is considered reliable. However, because operation of the DDC system will change the redox condition of the aquifer in the source areas, high efficiency removal of the polychlorinated constituents will be required</p>	<p>Land-use restrictions enforced by DAFB are considered extremely reliable in preventing on-base exposure.</p> <p>Treatability studies are required to design the reactive barrier walls. Reductions achieved via abiotic reactions catalyzed by the reactive metal will supplement the active biodegradation processes.</p>	<p>Land-use restrictions enforced by DAFB are considered extremely reliable in preventing on-base exposure.</p> <p>The extraction system will establish hydraulic control over the source areas in a relatively short time preventing the further migration of contaminants.</p> <p>The proposed technologies are proven and highly reliable</p>

TABLE 3 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Reduction of Toxicity, Mobility, and Volume					
ø Treatment Process Used	Not applicable	Dominant process is biodegradation. Other attenuation processes include volatilization, adsorption, and dilution.	Source area treatment using density-driven convection combined with soil vapor extraction (SVE).  Distal ends of plumes treated by natural attenuation processes.	Source areas treated in situ via reductive dehalogenation.  Distal ends of plumes treated by natural attenuation processes.	Source are groundwater addressed by extraction followed by metals pretreatment and air stripping  Sludge generated during metals pretreatment will be sent off-site for disposal.  Distal ends of plumes treated by natural attenuation processes
ø Amount Treated	Not applicable.	Area covered by FT03 is approximately 3 acres.	Area covered by FT03 is approximately 3 acres.	Area covered by FT03 is approximately 3 acres.	Area covered by FT03 is approximately 3 acres.
ø Reduction in toxicity, mobility, and volume through treatment	None demonstrated.	Reduction in groundwater toxicity achieved through natural attenuation processes. No reductions in mobility or volume.	DDC process reduces groundwater toxicity in the source area. Contaminant mobility is increased during treatment, but mobilized contaminant should be captured by SVE.  Natural attenuation reduces the toxicity of the distal ends of the plumes.	In situ reductive dehalogenation reduces groundwater toxicity in source areas. The technology does not impact the volume of contamination.  Natural attenuation reduces the toxicity of the distal ends of the plumes.	Groundwater extraction will provide hydraulic control of the source areas thereby reducing the mobility of contaminants away from the EMU.  Removal of volatile organic constituents present in groundwater by air stripping will reduce the toxicity of groundwater. The volume of contaminated media is not affected.  Natural attenuation reduces the toxicity of distal ends of the plumes
ø Irreversibility of Treatment	Not applicable.	Natural attenuation will provide permanent removal of constituents through irreversible processes	DDC treatment results in permanent removal of constituents through irreversible processes.	Reductive dehalogenation treatment results in the permanent removal of constituents through irreversible processes	Air stripping treatment results in the permanent removal of constituents through irreversible processes

TABLE 3 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
ø Type and Quality residue	No residues generated	No residues generated	Spent activated carbon will be generated from air treatment	No residues generated	Metals pretreatment generates small volumes of sludge which will require disposal
Short-term Effectiveness					
ø Protection of Community During Remedial Action	No short term impact on the community surrounding the site.	No short-term impact on the community surrounding the site.	No significant risk to the community surrounding the site during construction or operation.	No significant risk to the community surrounding the site during construction or operation.	No significant risk to the community surrounding the site during construction or operation.
ø Protection of Workers During Remedial Action	Not applicable.	Standard health and safety procedures and personal protective equipment will prevent exposure during well installations and sampling	Worker's exposure will be minimized by applying dust control techniques and providing personal protection equipment during construction.	Worker's exposure will be minimized by applying dust control techniques and providing personal protection equipment during construction.	Worker's exposure will be minimized by applying dust control techniques and providing personal protection equipment during construction.
ø Environmental Impact	None	Minimal disturbance will result from installing new monitoring wells. Environmental impacts related to construction are minimal.	Moderate land disturbance due to installment of new DDC, SVE, and monitoring wells. Environmental impacts related so construction are minimal.	Moderate land disturbance due to installation of barrier walls and grout curtains. Environmental impacts related to construction are minimal.	Moderate land disturbance due to installation of extraction and monitoring wells. Environmental impacts related to construction are minimal  Discharge of treated groundwater to Pipe Elm Branch is not expected to adversely impact the environment
ø Time Required	Unknown This alternative does not monitor for RAO compliance.	It is predicted that RAOs will continue to be met while contaminants naturally degrade. Data will be evaluated after 5 years of monitoring to determine whether contaminant concentrations are significant enough to warrant continued monitoring	It is predicted RAO compliance will be maintained during the course of remediation. Two years of source area treatment is estimated.	It is predicted RAO compliance will be maintained during the course of remediation. Five years of treatment at FT03 is estimated.	It is predicted RAO compliance will be maintained during the course of remediation. Two years of source area treatment is estimated.



TABLE 3 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
<b>Implementability</b>					
o Ability to Construct and Operate Technology	Not applicable.	This alternative requires the installation of new monitoring wells. No difficulties are anticipated.	No difficulties are anticipated in installation of the DDC/SVE wells or equipment. Operation of the DDC system is straight forward.	No difficulties are anticipated in construction of the barrier walls or grout curtains.	No difficulties are anticipated in construction of groundwater extraction wells and operation of the technology.
o Reliability of Technology	Not applicable.	USGS confirms ongoing natural attenuation in the EMU. Continued attenuation of constituents is anticipated in the future.	DDC and SVE are reliable technologies for removal and destruction of VOCs homogenous permeable soils. However, presence of clay layers in the EMU reduces the reliability of these technologies.	Technology is innovative and has been minimally field tested. However, technology is extremely simple. Very little to go wrong.	Air stripping technology is highly reliable of removal of volatile organic constituents.
o Ease of Undertaking Additional Action	Not applicable.	Additional actions could easily be performed if necessary.	If contaminant rebound occurs that may result in RAO failure, additional remediation can be performed by restarting the in situ treatment. The DDC/SVE well networks could be expanded or scrapped and replaced with new technologies if necessary.	Reactive barrier wall placement is permanent. However, additional actions could easily be performed if necessary.	If containinant rebound occurs that may result in RAO failure, additional remediation can be performed by restarting the treatment system. The extraction network and/or treatment system could be expanded or augmented if necessary, or replaced with new technologies
o Ability to Monitor	Not applicable	Performance of natural attenuation is easily monitored.	Performance of the DDC system is easily monitored	Performance of the reactive barrier walls is easily monitored.	Performance of the pump and treat system is easily monitored.
o Regulatory Agency Coordination/Approval	None.	Coordination with appropriate personnel at DAFB is necessary. Groundwater wells will require state permits.	Coordination with appropriate personnel at DAFB is necessary. Groundwater wells will require state permits	Coordination with appropriate personnel at DAFB is necessary. Groundwater wells will require state permits	Effluent limits set by DNREC's NPDES branch have to be met prior to discharge to surface water. Groundwater wells will require State permits.  Coordination with the appropriate personnel at DAFB is necessary.

TABLE 3 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
ø Availability of Services	Not applicable.	Readily available	The density-driven convection component will require a specialty contractor, however, the remaining portions of this alternative are readily available	Installation of the reactive metal barrier will require a specialty contractor.	Readily available
ø Availability of Equipment	Not applicable	Readily available	Readily available	Readily available	Readily available
ø Availability of Technology	Not applicable.	In place.	Readily available.	Readily available	Readily available
Cost (IRP Site FT03)					
Capital Cost	\$0	\$4,200	\$160,000	\$1,200,000	\$190,000
Annual O&M Cost (first year)	\$0	7,300	19,000	17,000	27,000
Net Present Worth Cost	\$0	35,000	210,000	1,300,000	260,000

&lt;IMG SRC 97177F&gt;

Table 5. Summary of ARARs

Environmental Laws and Regulations	Consideration as an ARAR	Retain for ARAR Analysis?
I. RCRA (42 USC 6901-92k, esp. 6921-39c), Delaware Hazardous Waste Management Act (7 Del. Code Ann. 6301-19, esp. 6306-07), Delaware Solid Waste Management Act (7 Del Code Ann. 6401-60)		
A. Delaware Solid Waste Disposal Regulations (DNREC Regulations Governing Solid Waste)	A solid waste landfill will not be constructed on-base.	No
B. Delaware Hazardous Waste Management Regulations (DNREC Regulations Governing Hazardous Waste (DRGHW))		
1. Closure and Postclosure (DRGHW Part 264, Subpart G)	Waste will not be contained in place.	No
2. Groundwater Monitoring and Protection (DRGHW Part 264, Subpart F)	Groundwater monitoring shall be conducted in accordance with monitoring criteria.	Yes
3. Standards applicable to containers and tanks (DRGHW Part 264, Subpart I and J)	Contaminated groundwater may be temporarily stored on-site in tanks or containers awaiting treatment.	Yes
4. Standards applicable to surface impoundments, waste piles, land treatment facilities (other than closure and post-closure requirements) (DRGHW Part 264, Subpart K, L, and M)	In Situ treatment technologies such as air sparging and soil vapor extraction may be considered land treatment. Excavated soil may be temporarily stored in piles awaiting shipment for off-site disposal	Yes
5. Location Standards (DRGHW Part 264.18)	The site is not located in a 100-year floodplain, as defined by RCRA	No
6. Transportation Standards (DRGHW Part 263)	Any shipment of hazardous waste off-base must comply with transporter standards and manifesting requirements.	Yes
7. Incinerator Standards (DRGHW Pan 264, Subpart O)	On-site incineration is not considered a remedial alternative	No
8. Landfill Standards (DRGHW Part 264, Subpart N)	A hazardous waste landfill will not be constructed on-base	No
9. Underground Storage Tank Regulations (Delaware Regulations Governing USTs)	UST rules are not applicable to remedial alternatives for this site	No
10. Land Disposal Restrictions (DRGHW Part 268)	Land disposal restriction and treatment requirements shall be met with respect to residuals generated by the alternatives under consideration	Yes

Table 5. (cont.) Summary of ARARs

Environmental Laws and Regulations	Consideration as an ARAR	Retain for ARAR Analysis?
II. Delaware Environmental Control Act (7 Del. Code Ann. 6001-93) and Delaware Water Pollution Control Regulations (11 Code of Del. Reg. 70 500 005)		
A. Delaware National Pollutant Discharge Elimination System (NPDES) Regulations (Delaware Water Pollution Control Regulations (DWPCR) Section 4	Discharges to surface water would have to meet NPDES requirements	Yes
B. Delaware Industrial Waste Effluent Limitations (DWPCR Section 8)	Effluents generated by site remedial activities may require pretreatment Any effluent discharge to POTW's must meet pretreatment standards	Yes
C. Delaware Water Quality Standards (DNREC Surface Water Quality Standards)	Remedial alternatives resulting in discharge to surface water may affect water quality.	Yes
III. Clean Water Act, 33 USC 1251-1387, esp. 1311-17		
A. Effluent guidelines (40 CFR 403)	Effluents discharged to a POTW would be subject to general pretreatment guidelines	Yes
B. Ambient Water Quality Criteria (AWQC)(Federal Register 1980, 1985)	Erosion of soils during remediation activities may affect the surrounding surface water.	Yes
IV. Safe Drinking Water Act (SDWA), 42 USC 300f		
A. Underground Injection Control (40 CFR Parts 144-147)	Extracted groundwater may be reinjected under some remedial alternatives.	Yes
B. Maximum Contaminant Levels (MCLs)(40 CFR Parts 141 and 143)	Some compounds exceed thier MCLs in groundwater, remedial action shall reduce contaminants to below MCLs.	Yes
V. Marine Protection, Research, and Sanctuaries Act		
A. Incineration at sea requirements (40 CFR Part 761)	No wastes for the site will be incinerated at sea	No
VI. Toxic Substances Control Act (TSCA)		
A. Polychlorinated biphenyls (PCB) requirements (40 CFR Part 761)	PCBs are not present at the site.	No

Table 5. (cont.) Summary of ARARs

Environmental Laws and Regulations	Consideration as an ARAR	Retain for ARAR Analysis?
VII. U.S. Army Corps of Engineers Program		
A. Dredge and fill (33 CFR Part 323)	Remedial alternatives under consideration will not involve dredging or filling in of a navigable waterway.	No
B. Construction in waterways (40 CFR Part 323)	No construction in navigable waters will be required for the remedial actions under consideration.	No
VIII. Clean Air Act (CAA) (42 USC Sections 7401-7671q)		
A. National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50)	Groundwater treatment alternatives may involve emissions to air	Yes
IX. Delaware Regulations Governing the Control of Air Pollution (8 Code of Del. Reg. 70 100 003 (NAAQS))	Groundwater treatment alternatives may involve emissions to air.	Yes
X. U.S. Department of Transportation Regulations (49 CFR Parts 170-179)	Waste may be transported off-site for treatment or disposal under the considered remedial alternatives.	Yes
XI. Response in a Floodplain or Wetlands (40 CFR Part 6, Appendix A, and Executive Orders 11988 and 11990)	The site is not located within a 100-year floodplain	No
XII. Conservation of Wildlife Resources (Endangered Species Act; 16 USC 1531, 50 CFR 200; 50 CFR 402)	Threatened or endangered species are not found at the site. If they are found, remedial action shall be implemented so as to conserve threatened or endangered species or resources.	No
XIII. Wild and Scenic Rivers Act (16 USC 1274; 50 CFR 27)	No wild and scenic rivers are found in the vicinity of the site.	No
XIV. Preservation of Scientific, Historic, or Archaeological Data (National Historic Preservation Act, 16 U.S.C. 470, 40 CFR 6.301(b), 36 CFR 800, Archaeological and Historic Preservation Act of 1974, 16 U.S.C. 469, 40 CFR 6.301 (c); Historic Sites, Buildings, and Antiquities Act, 16 U.S.C. 461-467; 40 CFR 6.301(a), 36 CFR Part 65)	Scientific, historic, or archaeological site are located in the vicinity of the site. Consultations with State Historic Preservation officials have been made.	Yes
XV. Delaware Erosion and Sedimentation Act (7 Delaware Code Annotated Chapter 40)	Alternatives resulting in the disturbance of soil will require measures to control erosion.	Yes

Alternative 2 (Natural Attenuation) relies upon a variety of physical, chemical, and biochemical processes to achieve reductions in contaminant concentrations and lowered groundwater toxicity. Anaerobic biodegradation is the dominant process.

Alternative 3 (Density-Driven Convection) uses an in situ technology to strip volatile compounds from the source area and oxygenate the groundwater. Oxygenating the groundwater will stimulate aerobic biodegradation processes, which will augment one another to reduce groundwater toxicity.

Alternative 4 (Permeable Reactive Barrier Wall/Pump and Treat) uses two separate technologies. Contact with the reactive barrier wall causes contaminated groundwater to undergo an abiotic reductive dehalogenation reaction, thus reducing the toxicity of the groundwater. The pump-and-treat component creates a hydraulic barrier to contaminant migration, thus limiting mobility. Treatment of the extracted groundwater using air stripping reduces its toxicity.

Alternative 5 (Pump and Treat) offers the benefits of extraction and treatment discussed for Alternative 4 but includes all of the EMU sites.

All of the action alternatives satisfy the CERCLA statutory preference for treatment.

#### 2.7.5 Short-Term Effectiveness

Alternative 1 (No Action) provides no remedial actions. Therefore no short-term effects on community or worker health or the environment will result from construction activities. However, because Alternative 1 does not provide monitoring to ensure compliance with the RAOs established for this project, it is considered to be ineffective.

Alternatives 2 (Natural Attenuation), 3 (Density-Driven Convection), 4 (Permeable Reactive Barrier Wall/Pump and Treat), and 5 (Pump and Treat) will be effective in reducing groundwater contaminant concentrations in the EMU. None of the alternatives is expected to have significant impacts on worker or public health or the environment.

Alternative 2 is currently meeting the RAOs and is projected to continue meeting them in the future. Alternative 3 will change the redox character of the source areas from anaerobic (reducing) to aerobic (oxidative). An aerobic environment is less conducive to the biodegradation of polychlorinated alkenes than an anaerobic environment, thus the DDC system operation will have to continue until the polychlorinated compounds are removed to low levels. DDC system operation is estimated to continue for 2 years. Alternative 4 includes the permanent installation of reactive barrier walls, which will greatly enhance the rate of abiotic reductive dehalogenation reactions. These abiotic reactions augment the naturally occurring biodegradation reactions. Maintenance of the barrier wall is estimated to continue for 5 years. The pump-and-treat components of Alternatives 4 and 5 are estimated to continue for 2 years.

#### 2.7.6 Implementability

Three main factors are considered under this criterion: technical feasibility, administrative feasibility, and availability of services and materials. All five alternatives are administratively feasible, and the required services and materials are readily available. Hence, the comparison will focus on the technical feasibility of implementing the alternatives.

No technical feasibility considerations are associated with Alternative 1 (No Action). Of the action alternatives, Alternative 2 (Natural Attenuation) has by far the fewest implementability considerations. Because the USGS natural attenuation study in the EMU has already been completed, long-term, groundwater monitoring is the only component remaining and is easily implemented.

Alternatives 3 (Density-Driven Convection) and 4 (Permeable Reactive Barrier Wall/Pump and Treat) are relatively the most complex systems to design, construct, and operate. Both of these alternatives require treatability studies before their design and include the most extensive construction. Alternative 3 includes installing and balancing a total of 31 DDC wells and 50 SVE wells for three sites, whereas Alternative 4 includes installing a total of 750 linear feet of grout curtains and 375 linear feet of reactive barrier wall, all to depths of 40

ft.

Alternative 5 (Pump and Treat) involves systems that are much easier to design, install, and operate relative to the systems included under Alternatives 3 and 4, but it is still more complex than Alternative 2.

All of the technologies considered in the action alternatives are considered reliable and are easily monitored. None of the technologies precludes the implementation of additional remedial measures at a later time if they are deemed necessary.

#### 2.7.7 Cost

No direct costs are associated with the implementation of Alternative 1 (No Action). The estimated costs of the four action alternatives, including capital costs, annual O&M costs, and present net worth, are summarized in Table 6. Alternative 2 (Natural Attenuation) offers a substantial cost advantage over the other action alternatives with a present worth cost of \$35,000. Alternatives 3 (Density-Driven Convection) and 5 (Pump and Treat) offer higher present worth costs of \$210,000 and \$290,000, respectively. The present worth cost of Alternative 4 (Permeable Reactive Barrier Wall/Pump and Treat) is substantially more costly at \$1,300,000.

#### 2.7.8 Regulatory Acceptance

The USEPA and the state of Delaware have reviewed the alternatives and are in agreement with the selected remedy for FT03.

#### 2.7.9 Community Acceptance

No comments were received during the public comment period, and no community opposition to the preferred remedy was noted.

### 2.8 SELECTED REMEDY

The selected remedy for cleanup of groundwater at Site FT03 is Alternative 2, which includes the following major components:

- natural attenuation,
- continued enforcement of existing land-use restrictions,

TABLE 6  
Action Alternative Cost Summary  
for FT03

Alternative	Capital Cost	Annual O&M*	Net Worth
2. Natural Attenuation	\$4,200	\$7,300	\$35,000
3. Density Driven Convection	\$160,000	\$19,000	\$210,000
4. Permeable Reactive Barrier Wall	\$1,200,000	\$17,000	\$1,300,000
5. Groundwater Extraction with Air Stripping	\$190,000	\$27,000	\$260,000

- First year O&M costs.



- restrictions of groundwater use, and
- groundwater monitoring.

The reasoning to support the selected remedy for cleanup of groundwater at FT03 is summarized as follows:

- Natural attenuation is capable of meeting the RAOs. The USGS conducted an extensive natural attenuation study of the site and concluded that none of the COCs were currently migrating past the base boundary above MCL concentrations in either groundwater or surface water. In addition, the COCs are not predicted to migrate off-base in the future.
- Alternative 2 is considered protective of human health and the environment. It complies with all ARARs that address off-site migration or movement of contamination and reduces the toxicity of contaminants in the groundwater.
- The technology offers good long-term and short-term effectiveness.
- Alternative 2 offers a great implementability advantage over all other alternatives. The only component of Alternative 2 still requiring implementation is the long-term groundwater monitoring. Simple monitoring well construction and operation considerations are required in addition to the groundwater monitoring requirements. The monitoring program will verify the status of the groundwater contamination and therefore protect future receptors before exposure. The monitoring program is currently being developed in consultation with the USEPA and DNREC. As Alternative 2 is implemented, the monitoring program will provide the data necessary to verify that natural attenuation of groundwater contaminants is working.
- Alternative 2 offers substantially lower capital, O&M, and present worth costs than any of the other action alternatives. This cost advantage is particularly important given that all of the alternatives offer similar performance. There are no treatment by-products (e.g., spent carbon and sludges) produced and no hazardous chemicals (e.g., oxidizing agents) need to be stored on-site with Alternative 2.
- Institutional controls are already in place to limit access to or use of the site resources, including soil and groundwater.

DAFB, USEPA, and DNREC have agreed that the installation of additional monitoring points (i.e., monitoring wells, well points, etc.) is necessary to help demonstrate that the remedial action will accomplish its intended goal and that if the additional data collected during the remedial action suggests otherwise, that the remedial action will be readdressed in the basewide ROD.

#### 2.8.1 PERFORMANCE STANDARD FOR THE SELECTED REMEDY

The COCs in groundwater at this site, which are listed in Section 2.4 of this ROD, shall not exceed their respective federal MCLs at or beyond the boundary of DAFB. COCs that do not have an MCL shall not exceed DAFB-specific background levels at or beyond the boundary of DAFB.

The concentrations of the COCs in groundwater at this site, also listed in Section 2.4 of this ROD, shall be reduced to below federal MCLs (or, if no MCL exists, the DAFB-specific background level) within the area of attainment within a reasonable time, not to exceed 30 years. The area of attainment is the area outside the boundary of any waste that remains in place at the site and up to the boundary of the contaminant plume. Existing institutional controls, which are more fully described in DAFB's Real Estate Property Management System, and site use restrictions shall continue to remain in effect.

#### 2.9 STATUTORY DETERMINATION

Based on consideration of the requirements of CERCLA, the comparative analysis, and comments, DAFB, USEPA, and the State of Delaware believe Alternative 2 provides the best balance of the trade-offs among the alternatives with respect to the criteria used to evaluate

remedies. The selected remedy is consistent with CERCLA and, to the extent practicable, the NCP. The selected remedy is protective of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, is cost-effective, and uses permanent solutions and alternative treatment to the maximum extent practicable.

The reliability of natural attenuation mechanisms such as bio-degradation, adsorption/desorption, and dilution for the cleanup of petroleum and chlorinated-based media, has been demonstrated at various sites around the country to be cost effective and, if properly monitored, an environmentally sound solution to groundwater contamination. It results in permanent reduction in concentrations of contaminants in the subsurface. Investigative data show natural attenuation is already at work within the site area. Therefore, Alternative 2 is the selected remedial action for Site FT03.

Because the hazard index and LECR calculated for the different soil scenarios in the BRA are within an acceptable risk range, no further action, than that already taken, is determined to be appropriate for site soils.

## GLOSSARY

air sparging - A process whereby air is pumped into the subsurface, groundwater, or soils to enhance the volatilization or aerobic biodegradation of compounds.

air stripper - A device to remove (strip) volatile organics from contaminated water by bringing the water into contact with air, causing volatile compounds to change from liquid phase to the vapor phase.

aquifer - A geologic formation capable of yielding water to wells and springs.

Applicable or Relevant and Appropriate Requirements (ARARs) - Criteria set forth by federal, state, or local regulations that must be considered in the evaluation of remedial alternatives and govern the environmental actions at a particular site.

Ambient Water Quality Criteria (AWQC) - Regulatory standards for surface water quality.

Baseline Risk Assessment (BRA) - A statistical evaluation of the current and future risks to human health and the environment from the exposure to contaminants at a site if no remedial actions are taken.

Benzene, toluene, ethylbenzene, and xylene (BTEX) - Chemical compounds that are common constituents of fuels and petroleum products.

biodegradation - The breakdown of organic constituents by microorganisms into less complex compounds.

bioremediation - The cleanup of a contaminated medium through natural biological processes.

bioventing - A treatment process that introduces air into the subsurface soils to stimulate the growth of microorganisms that naturally attack certain compounds. This process speeds up the rate at which some chemicals biodegrade.

Capital Cost - Cost incurred for the construction and startup of a facility.

Carcinogen - A chemical capable or suspected of producing cancer as a result of exposure.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - A federal law passed in 1980 and revised in 1986 by the Superfund Amendments and Reauthorization Act (SARA). CERCLA provides federal authority and money for the USEPA to respond directly to the release or threatened release of hazardous substances into the environment at inactive sites.

Density-driven convection (DDC) - An in situ process for removal of VOCs from the groundwater using air to strip contaminants from the water.

The State of Delaware Department of Natural Resources and Environmental Control (DNREC) - State regulatory agency in charge of overseeing environmental programs at DAFB.

Delaware Regulations Governing the Control of Air Pollution (DRGCAP) - Regulatory protocols and standards for control of particulates and emissions to the air within the state.

Delaware Regulations Governing Hazardous Waste (DRGHW) - Regulatory protocols and standards for control of handling, transport, storage, and disposal of hazardous wastes within the state.

Electromagnetic (EM) - A geophysical survey instrument used to locate changes in specific conductance in subsurface materials.

Feasibility Study - A study to develop and evaluate options for remedial actions.

Granular activated carbon (GAC) - Carbon material that has ionically charged sites capable of filtering organic and inorganic compounds from a waste stream.

Groundwater - Subsurface water residing in a zone of saturation.

Ground penetrating radar (GPR) - A geophysical survey instrument used primarily to locate changes in lithological character of the subsurface soil.

Hazard Index (HI) - An indicator of the health risk associated with exposure to a noncarcinogenic chemical.

in situ - In the original location (in the ground for this report).

Installation Restoration Program (IRP) - The Department of Defense (DOD) program designed to identify, report, and correct environmental deficiencies at DOD installations. At DAFB, this program implements the requirements for cleanup under CERCLA.

leachate - The solubilization and transport of constituents in soil through the percolation of surface water to groundwater.

Lifetime Excess Cancer Risk (LECR) - Represents the risk of exposure to cancer-causing compounds over a lifetime.

Maximum Contaminant Level (MCL) - Federal drinking water standards enacted by the Safe Drinking Water Act.

Natural attenuation - A remediation approach that depends upon natural processes such as dilution, dispersion, sorption, volatilization, chemical transformation, and biodegradation, that act to contain contaminants, reduce contaminant concentrations, and restore soil and groundwater quality.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP) - The federal regulation that provides a contingency plan for discharges or releases of hazardous substances, pollutants, contaminants, or oil into the environment that may present an immediate danger to public health or welfare.

Operation and Maintenance Costs (O&M) - Annual costs incurred for operation and maintenance of a facility.

plume - A recognizable distribution of constituents in groundwater.

Selected Alternative - The clean-up strategy that offers the best chance of success in protecting human health and the environment from contamination at a site. The selected alternative is selected from several clean-up strategies because it satisfies USEPA criteria for effectiveness, implementability, cost, and public and regulatory acceptance.

Remedial Action Objective (RAO) - Clean-up goal established for remediation.

Reactive iron filings - For the case proposed in Alternative 4, metal shavings are placed in the path of a contaminant plume to act as a catalyst in the abiotic degradation of halogenated organic compounds. The plume is allowed to pass through a permeable wall that contains the iron filings. This actual physicochemical degradation process is also called dehalogenation.

Resource Conservation and Recovery Act (RCRA) - Federal law enacted to address environmental issues created by current waste disposal, spills, and handling practices.

Remedial Investigation (RCRA) - An investigation that involves sampling the air, soil, and water to determine the nature and extent of contamination at an abandoned waste site and the human health and environmental risks that result from that contamination.

Record of Decision (ROD) - A legal document that explains the specific clean-up alternative to be implemented at a Superfund site.

Superfund Amendments and Reauthorization Act (SARA) - A congressional act that modified CERCLA. SARA was enacted in 1986 and again in 1990 to authorize additional funding for the Superfund program.

Soil vapor extraction (SVE) - A process by which air and volatilized compounds are extracted from the subsurface soils through screened wells using a vacuum.

Toxicity Characteristics Leaching Procedure (TCLP) - An analytical procedure that measures the level of organic leachate from a soil sample. This method is commonly used to determine whether soil to be disposed of is hazardous.

Total Petroleum Hydrocarbons (TPH) - This analytical parameter is a measure of the hydrocarbons, often within a particular petroleum weight range.

U.S. Environmental Protection Agency (USEPA) - The federal regulatory agency in charge of overseeing environmental programs at DAFB.

vadose zone - Soil zone above the water table.

## RESPONSIVENESS SUMMARY

The following Responsiveness Summary is a compilation of the comments and responses on the Proposed Plan for Natural Attenuation of Groundwater, Fire Training Area 3 (FT03), Dover Air Force Base, Dover, Delaware (HAZWRAP, June 1997), Proposed Plan for Natural Attenuation of Groundwater, Liquid Waste Disposal Area 14 (WP14) and Landfill 15 (LF15), Dover Air Force Base, Dover, Delaware (HAZWRAP, June 1997), and Proposed Plan for Natural Attenuation of Groundwater, Landfill 13 (LF13), Dover Air Force Base, Dover, Delaware (HAZWRAP, June 1997).

Dover Air Force Base (DAFB) offered opportunities for public input and community participation during the Remedial Investigation (RI)/Feasibility Study (FS) and Proposed Plans (PP) for all three sites in the East Management Unit. The PPs were made available to the public in the Administrative Record. Documents composing the Information Repository for the Administrative Record for the site are available at the Dover Public Library, Dover, Delaware. The notice of availability for the PPs was published in the local newspaper and the Base newspaper. A public comment period was held from Monday, June 16, 1997 until Wednesday, July 15, 1997. The public comment period was not extended as there were no requests for an extension. No written comments were received from the public and no public meeting was requested. These community participation activities fulfill the requirements of Section 113(k)(2)(B)(i-v) and 117(a)(2) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

Comments submitted by the U.S. Environmental Protection Agency (USEPA) and the State of Delaware Department of Natural Resources and Environmental Control (DNREC), requested editorial changes and clarification of some issues; however, the editing and clarification did not result in any significant change to the preferred alternative presented in the PPs.

## TIME CALCULATIONS FOR NATURAL ATTENUATION

<IMG SRC 97177G>