FINAL

FORSCOM

CORRECTIVE ACTION PLAN

FOR THE

3d Inf Div (Mech)

3d ENGINEERING BRIGADE, NORTHWEST OF BUILDING 1340 (SOLID WASTE MANAGEMENT UNIT 27F) AT FORT STEWART MILITARY RESERVATION FORT STEWART, GEORGIA

Prepared for

U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT

Contract No. DACA21-95-D-0022
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July 2002

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FOR THE
3d ENGINEERING BRIGADE, NORTHWEST OF BUILDING 1340
(SOLID WASTE MANAGEMENT UNIT 27F)
AT
FORT STEWART MILITARY RESERVATION
FORT STEWART, GEORGIA

<u>REGULATORY AUTHORITY</u>
Resource Conservation and Recovery Act
40 *CFR* 264, Title II, Subpart C, Section 3004;
42 USC 6901 et seq.

Prepared for
U.S. Army Corps of Engineers
Savannah District
Under Contract DACA21-95-D-0022
Delivery Order Number 0078

Prepared by
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Oak Ridge, Tennessee 37831

July 2002

The undersigned certifies that I am a qualified groundwater scientist who has received a baccalaureate or postgraduate degree in the natural sciences or engineering and have sufficient training and experience in groundwater hydrology and related fields, as demonstrated by state registration and completion of accredited university courses, to enable me to make sound professional judgments regarding groundwater monitoring and contaminant fate and transport. I further certify that this report was prepared by myself or by a subordinate working under my direction.

GEORGIA REGISTERED 22851 PROFESSIONAL ENGINEER A. STOLL 7/2/02

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SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

CONTENTS

APPENDICES

FIGURES

TABLES

ACRONYMS

amsl	above mean sea level
AT123D	Analytical Transient 1-, 2-, 3-Dimensional
bgs	below ground surface
BHHRA	baseline human health risk assessment
CAP	Corrective Action Plan
CFR	Code of Federal Regulations
CMCOPC	contaminant migration constituent of potential concern
COC	constituent of concern
COPC	constituent of potential concern
CY	calendar year
DO	dissolved oxygen
DPT	direct-push technology
ECOPC	ecological constituent of potential concern
EPA	U.S. Environmental Protection Agency
EPRE	ecological preliminary risk evaluation
ESV	ecological screening value
FSMR	Fort Stewart Military Reservation
GEPD	Georgia Environmental Protection Division
GSSL	generic soil screening level
HHCOC	human health constituent of concern
HHCOPC	human health constituent of potential concern
HHPRE	human health preliminary risk evaluation
HQ	hazard quotient
ID	inside diameter
MCL	maximum contaminant level
NTU	nephelometric turbidity unit
O&M	operations and maintenance
OSWER	Office of Solid Waste and Emergency Response
OWS	oil/water separator
PVC	polyvinyl chloride
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
Redox	oxidation-reduction potential
RFI	RCRA facility investigation
SESOIL	Seasonal Soil Compartment
SRC	site-related constituent
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TRV	toxicity reference value
VOC	volatile organic compound

1.0 INTRODUCTION

1.1 SCOPE OF THE CORRECTIVE ACTION PLAN

Solid Waste Management Unit (SWMU) 27F, northwest of Building 1340, is one of two oil/water separators (OWSs) that support the vehicle maintenance activities of the 3d Engineer Brigade and one of 32 OWSs distributed across 29 sites that support the vehicle maintenance facilities within the garrison area. A Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) report has been completed for SWMU 27F, and the results were reported in the revised final addendum (SAIC 2001) to the revised final Phase II RFI report for 16 SWMUs (SAIC 2000). With the concurrence of the Georgia Environmental Protection Division (GEPD), the revised final Phase II RFI report recommended that a Corrective Action Plan (CAP) be developed for SWMU 27F to address human health constituents of concern (HHCOCs) in groundwater (benzene) and soil [benzo(*a*)pyrene].

The conclusions and recommendations listed below were made based on the results of the Phase II RFI [see Chapter 11.0 of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000)].

- The nature and extent of soil contamination at the site were determined during the Phase II RFI activities, and the information gathered is sufficient for development of a CAP.

- Benzo(*a*)pyrene was identified as an HHCOC in surface soil. Benzo(*a*)pyrene was detected above its remedial level in only one (MW10) of the 11 surface soil samples collected at the site. It was not detected in the surface soil collected from MW11, the deep well located adjacent to MW10. Benzo(*a*)pyrene was not identified as a contaminant migration constituent of potential concern (CMCOPC), indicating that it is not likely to migrate to groundwater. The extent of benzo(*a*)pyrene in surface soil is confined to a single location near the OWS and the heavily used vehicle maintenance facility. This limited surface soil contamination does not represent widespread contamination and is probably the result of the operations of the maintenance facility rather than a release from the OWS. The OWS is located within a fenced, active maintenance area. The extent of benzo(*a*)pyrene in surface soil has been defined by the Phase II RFI, and no additional investigation and/or evaluation is required. A remedial level of 0.89 mg/kg was recommended for benzo(a)pyrene in soil.

- Benzene was identified as an HHCOC in groundwater. A remedial level of 5 μg/L was recommended for benzene in groundwater.

- Fort Stewart recommended that a CAP be developed for SWMU 27F, northwest of Building 1340, and submitted to GEPD in accordance with a schedule to be determined by the Director [Condition IV.E.2 of Fort Stewart's Hazardous Waste Facility Permit #HW-045(S&T)], if this recommendation was approved. The purpose of the CAP would be to determine the appropriate corrective action(s) to remediate benzo(*a*)pyrene in soil and benzene in groundwater to the proposed remedial levels.

This CAP report uses information from the Phase I and Phase II RFIs to evaluate institutional controls and various remedial actions for achieving the remedial levels proposed in Section 10.7 of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000). The options analyzed for achieving the stated remedial levels included an evaluation of monitored natural attenuation in accordance with the published guidance document (EPA 1999). This report analyzes the feasibility of applicable remedial actions, monitored natural attenuation, and institutional controls on a site-specific basis.

This report has been prepared by Science Applications International Corporation for the U.S. Army Corps of Engineers, Savannah District, under Contract No. DACA21-95-D-0022, Delivery Order No. 0078.

1.2 SITE BACKGROUND

A Phase I RFI was conducted at SWMU 27F in 1998 to determine if a release to the environment had occurred. Direct-push technology (DPT) techniques were used to collect four soil and groundwater samples at the site. The four soil samples were collected based on field headspace screening for volatile organic compounds (VOCs). The soil and groundwater samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), and lead. The results of the Phase I RFI [see the revised final Phase II RFI report (SAIC 2000) for these results] indicated a release to the environment had occurred, and a Phase II RFI was recommended.

The objectives for the Phase II RFI, as defined by the work plan (SAIC 1997) approved by GEPD on October 10, 1997, were as follows:

- determine the horizontal and vertical extents of contamination;
- determine whether contaminants present a threat to human health or the environment;
- determine the need for future action and/or no further action; and
- gather data necessary to support a CAP, if warranted.

The scope of the Phase II RFI fieldwork performed in October 1999 included the activities listed below.

- Collection of soil samples during monitoring well installation.

- Installation of permanent groundwater monitoring wells both upgradient and downgradient of the site.

- Groundwater sampling at newly installed monitoring wells around SWMU 27F.

- Surveying of the positions of all sample locations.

1.3 REGULATORY BACKGROUND

The regulatory authority governing the action at SWMU 27F at Fort Stewart is Title 40, Code of Federal Regulations (CFR), Part 264, Title II, Subpart C, Section 3004 (Title 42, United States Code, Part 690 et seq.). With the promulgation of RCRA and the subsequent approval of the Georgia Hazardous Waste Management Act by the U.S. Environmental Protection Agency (EPA), the state was granted RCRA permitting authority. In accordance with RCRA, the state issued a Hazardous Waste Permit [Georgia Environmental Division Permit HW-045 (S&T)] to Fort Stewart in August 1987. The permit was renewed in August 1997. The 3d Engineer Brigade, northwest of Building 1340, (SWMU 27F) is a listed SWMU in Appendix A of Fort Stewart's Subpart B Permit and, therefore, is subject to investigation according to 40 CFR 264.101(c) [as reported in Section 10.15 of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report dated April 2000 (SAIC 2000)] and to corrective action (the subject of this CAP), if necessary.

1.4 REPORT ORGANIZATION

This CAP consists of six sections. Chapter 1.0 summarizes the scope of the CAP, describes the background of the site and regulatory authority, and gives the report's organization. Chapter 2.0 discusses the site characterization and RFI results and summarizes the natural attenuation modeling results. Chapter 3.0 describes the justification and purpose of the corrective action and presents the remedial response objectives and remedial levels developed in the RFI. Chapter 4.0 presents the screening of the corrective actions. Chapter 5.0 summarizes the report conclusions and recommendations for the corrective action. The references are presented in Chapter 6.0.

This report also contains four appendices. Appendix A presents the detailed results of the fate and transport modeling. Appendix B contains a cost estimate summary for the corrective action alternatives. Appendix C contains an Operations and Maintenance (O&M) Plan for the selected corrective action, monitored natural attenuation. Appendix D lists considerations for the selection of monitored natural attenuation in accordance with the guidance provided in Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P (EPA 1999).

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2.0 SITE CHARACTERIZATION

Fort Stewart (then known as Camp Stewart) was established in June 1940 as an antiaircraft artillery training center. Between January and September 1945, the Installation operated as a prisoner-of-war camp. The Installation was deactivated in September 1945. In August 1950 Fort Stewart was reactivated to train antiaircraft artillery units for the Korean Conflict. The training mission was expanded to include armor training in 1953. Fort Stewart was designated a permanent Army installation in 1956 and became a flight training center in 1966. Aviation training at the Fort Stewart facilities was phased out in 1973. In January 1974 the 1st Battalion, 75th Infantry was activated at Fort Stewart. Fort Stewart then became a training and maneuver area, providing tank, field artillery, helicopter gunnery, and small arms training for regular Army and National Guard units. These activities comprise the Installation's primary mission today. The 24th Infantry Division, which was reflagged as the 3d Infantry Division in May 1996, was permanently stationed at Fort Stewart in 1975.

The Fort Stewart Military Reservation (FSMR) is located in portions of Liberty, Bryan, Long, Tattnall, and Evans counties, Georgia, approximately 40 miles west-southwest of Savannah, Georgia (Figure 2-1). The cantonment, or garrison area, of FSMR is located within Liberty County, on the southern boundary of the reservation.

2.1 SITE DESCRIPTION AND HISTORY

SWMU 27F, northwest of Building 1340, is one of two OWSs that support the vehicle maintenance activities of the 3d Engineer Brigade and one of 32 OWSs distributed across 29 sites that support the vehicle maintenance facilities within the garrison area (Figure 2-2). The OWS is located along the northwestern boundary of the motorpool area, approximately 200 feet northwest of Building 1340 (Figure 2-3). The OWS was closed in 2001. The closure consisted of placing plywood over the metal grates covering the OWS and plugging the drains located at the adjacent, covered maintenance pad. The OWS received wastewater from an adjacent, covered maintenance pad. Maintenance activities for military vehicles are performed at the maintenance pad. Floor drains from the maintenance pad are piped to the OWS; however, as part of the closure activities, these drains were plugged. The effluent from the OWS discharged to the Industrial Wastewater Treatment Plant, and the oil was pumped out of the holding unit and burned at the Central Energy Plant. No surface water or sediment pathways exist at this site.

2.1.1 Phase I RCRA Facility Investigation Activities

A Phase I RFI was conducted at SWMU 27F, northwest of Building 1340, in January 1998 [see the revised final Phase II RFI report (SAIC 2000) for the results]. During the Phase I RFI, DPT techniques were used to collect four soil and groundwater samples at the site. The soil and groundwater samples were analyzed for VOCs, SVOCs, and lead.

Acetone, ethylbenzene, total xylenes, and lead were detected in subsurface soil samples and were considered to be site-related constituents (SRCs) in subsurface soil. Toluene; total xylenes; 1,1,1-trichloroethane; 1,1,2-trichloroethane; 1,1-dichloroethane; acetone; benzene; ethylbenzene; methylene chloride; styrene; 2-methylnaphthalene; bis(2-ethylhexyl)phthalate; naphthalene; and phenanthrene were identified as SRCs in groundwater. The Phase I RFI concluded that the vertical and horizontal extents of potential groundwater contamination had not been determined and recommended that additional groundwater screening and shallow and possibly deep groundwater monitoring wells be installed at the site (upgradient and downgradient).

Figure 2-1. Regional Location Map for Fort Stewart Military Reservation, Georgia

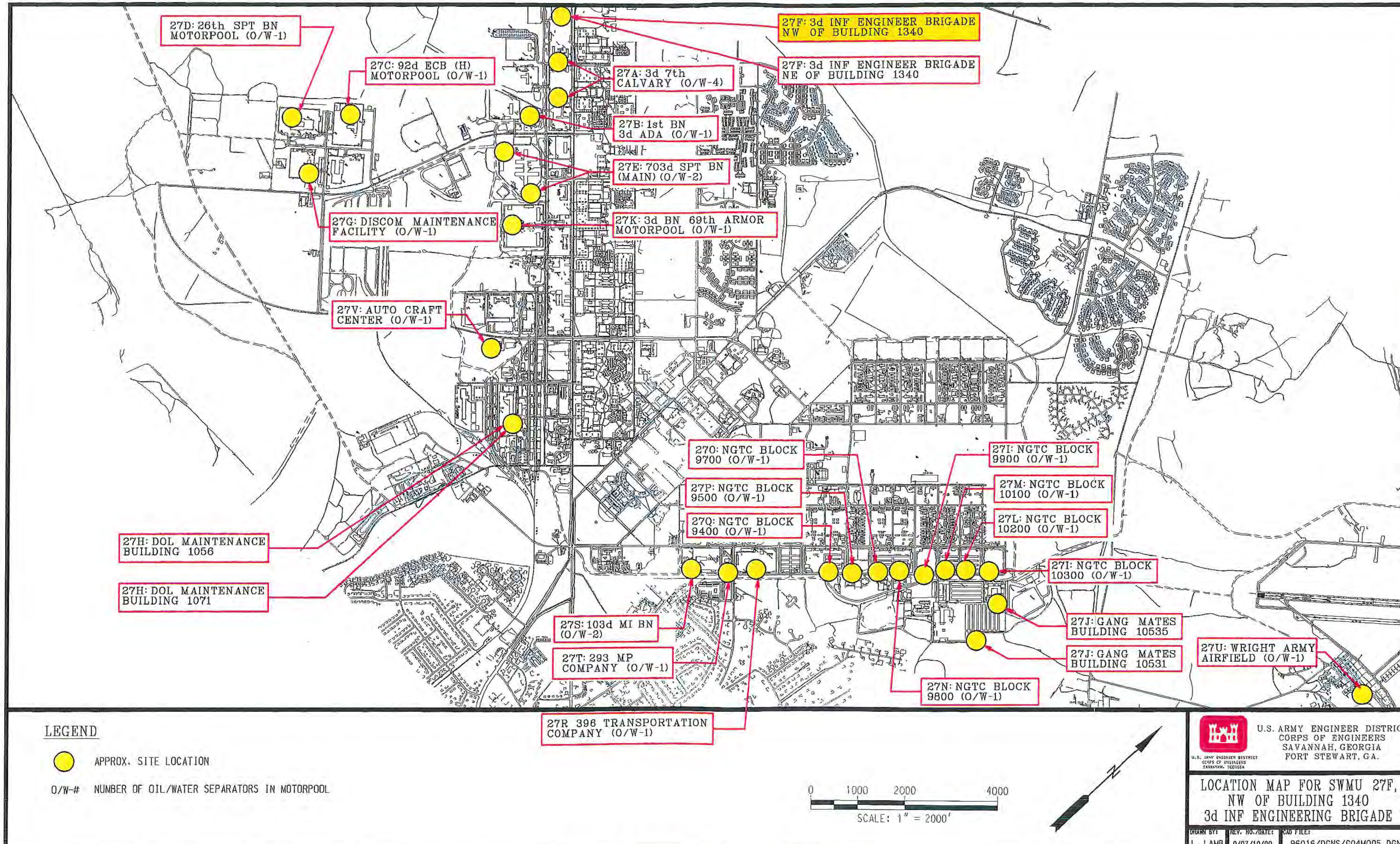

Figure 2-2. Location Map for SWMU 27F, Northwest of Building 1340

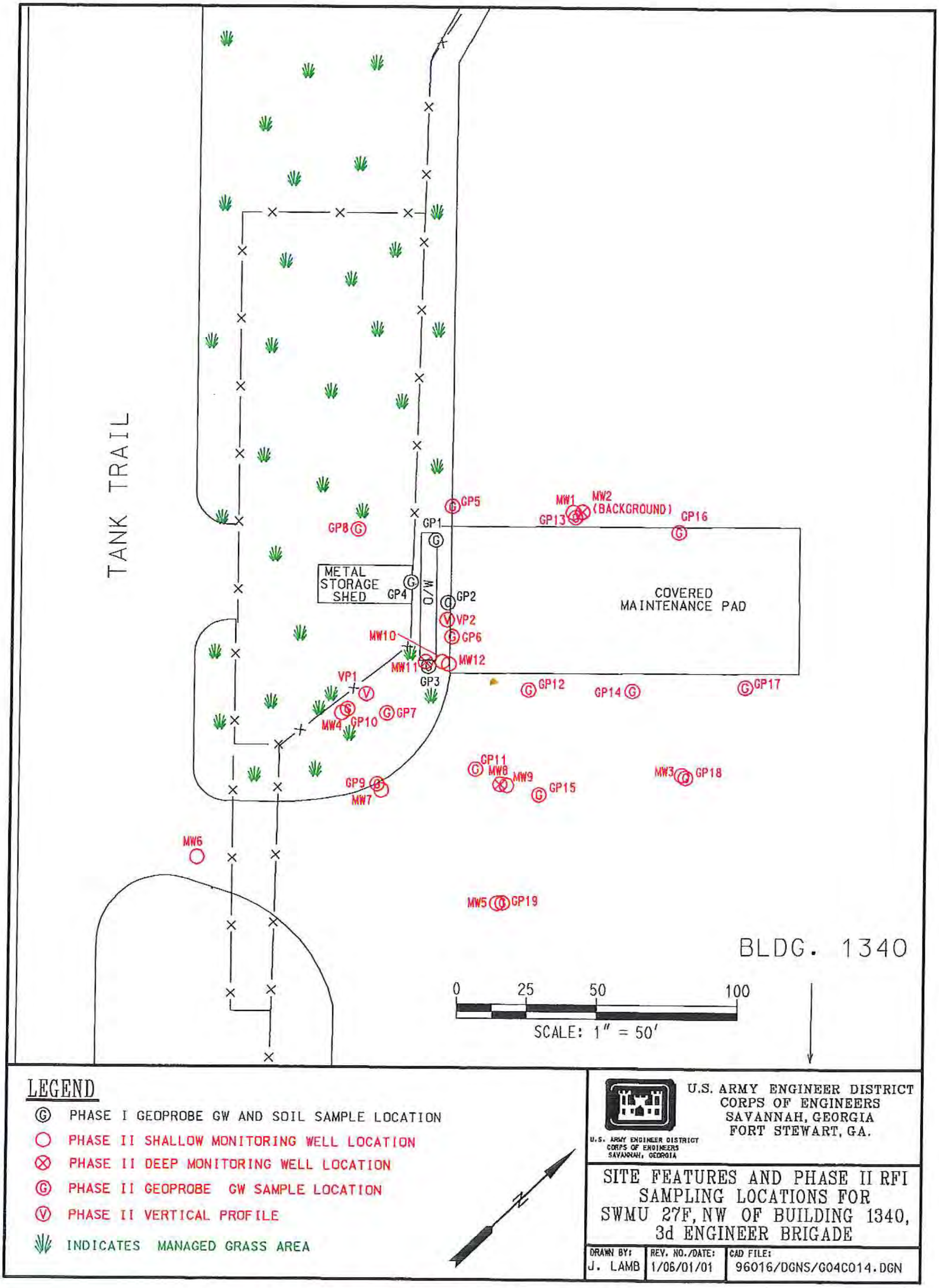

Figure 2-3. Site Features and Phase II RFI Sampling Locations at SWMU 27F, Northwest of Building 1340

2.1.2 Phase II RCRA Facility Investigation Activities

A Phase II RFI was conducted in October 1999 that consisted of initial screening using DPT techniques to collect 14 groundwater samples to determine the horizontal and vertical extents of groundwater contamination. The DPT groundwater screening samples were analyzed for VOCs. Two vertical-profile borings were installed at the groundwater screening locations that indicated the highest levels of contamination to investigate its vertical extent. The vertical-profile samples were analyzed for VOCs. The results of the groundwater screening were used to locate 11 monitoring wells (eight shallow and three deep) at the site. One shallow and one deep monitoring well were installed upgradient (background). In addition, a recovery well (MW12) was installed to recover potential free product identified on a clay lens encountered at approximately 8 feet below ground surface (bgs).

Two soil samples were collected at each well and were analyzed for VOCs, SVOCs, and RCRA metals. Geotechnical samples were collected at each monitoring well. All of the monitoring wells were developed until the turbidity was less than or equal to 10 nephelometric turbidity units (NTUs). All wells were sampled using low-flow techniques. Groundwater samples collected from the monitoring wells were analyzed for VOCs, SVOCs, and RCRA metals. Conductivity, temperature, dissolved oxygen (DO), oxidation-reduction potential (Redox), and turbidity were measured in the field during sampling.

2.2 TOPOGRAPHY/PHYSIOGRAPHY/CLIMATE

FSMR occupies a low-lying, flat region in the coastal plain of Georgia. Surface elevations range from approximately 20 feet to 100 feet above mean sea level (amsl) within FSMR and generally decrease from northwest to southeast across the Installation. Terraces dissected by surface water drainages dominate the topography. The terraces are remnants of sea level fluctuations. The four terraces present within FSMR are the Wicomico, Penholoway, Talbot, and Pamlico (Metcalf and Eddy 1999).

The topography of the site is essentially flat. The surface elevation is approximately 68 feet amsl. The OWS is located in a small, grassy area that extends to the northwestern boundary of the motorpool's fence line, where a fenced storage area is located. The other three sides are comprised of a concrete vehicle parking area/road or the maintenance pad.

Fort Stewart has a humid, subtropical climate with long, hot summers. Average temperatures range from 50°F in the winter to 80°F in the summer. Average annual precipitation is 48 inches, with slightly more than half falling from June through September. Prolonged drought is rare in the area, but severe local storms (tornadoes and hurricanes) do occur. Under normal conditions wind speeds rarely exceed 5 knots, but gusty winds of more than 25 knots may occur during summer thunderstorms (Geraghty and Miller 1992).

2.3 SITE GEOLOGY

FSMR is located within the coastal plain physiographic province. This province is typified by southeastward-dipping strata that increase in thickness from 0 feet at the fall line (located approximately 155 miles inland from the Atlantic coast) to approximately 4,200 feet at the coast. State geologic records describe a probable petroleum exploration well (the No. 1 Jelks-Rogers) located in the region as having encountered crystalline basement rocks at a depth of 4,254 feet bgs. This well provided the most complete record for Cretaceous, Tertiary, and Quaternary strata.

The Cretaceous section is approximately 1,970 feet thick and is dominated by clastics. The Tertiary section is approximately 2,170 feet thick and is dominated by limestone, with a 175-foot-thick cap of dark green phosphatic clay. This clay is regionally extensive and is known as the Hawthorn Group. The interval from approximately 110 feet to the surface is Quaternary in age and composed primarily of sand with interbeds of clay or silt. This section is undifferentiated.

State geologic records contain information regarding a well drilled in October 1942, 1.8 miles north of Flemington at Liberty Field of Camp Stewart (now known as Fort Stewart). This well is believed to have been an artesian well located approximately 0.25 mile north of the runway at Wright Army Airfield within FSMR. The log for this well describes a 410-foot section, the lowermost 110 feet of which consisted predominantly of limestone, above which 245 feet of dark green phosphatic clay typical of the Hawthorn Group were encountered. The uppermost 55-foot interval was Quaternary-age interbedded sands and clays. The top 15 feet of these sediments were described as sandy clay.

2.4 SITE SOIL

Boring logs showing the types of soil encountered in soil screening probes, groundwater screening probes, and monitoring well boreholes during the Phase II RFI at SWMU 27F are provided in Appendix A of the revised final Phase II RFI report (SAIC 2000) and Attachment A of the revised final addendum to the revised final RFI report (SAIC 2001). Geological cross sections of the site, depicting the lithology and stratigraphy of the unconsolidated soil deposits beneath the site, as inferred from the soil borings are shown in cross sections A-A′ and B-B′, Figures 5 and 6, of the revised final addendum to the revised final Phase II RFI report (SAIC 2001). The cross sections indicate that the soil present across SWMU 27F consists of alternating layers of sand and silty to clayey sands.

2.5 SITE HYDROLOGY

Water level measurements were collected during the Phase I and Phase II RFIs. Groundwater was encountered at approximately 12 feet to 14 feet bgs in the monitoring wells during the Phase II RFI. The most recent and complete groundwater level measurements were collected in May 2001.

Potentiometric surface maps of the shallow and deep groundwater systems based on the water levels from May 2001 are provided in Figures 2-4 and 2-5, respectively. The shallow surficial groundwater flow direction across the site is to the southeast. The deep surficial groundwater flow direction is to the south to slight southeast. A slight groundwater high is located at MW17, which may be due to its being located in a grassy area and closer to a drainage ditch (potentially higher percolation). The hydraulic gradients of the shallow and deep surficial groundwater are 0.0009 foot/foot and 0.0014 foot/foot, respectively.

Both the shallow and deep surficial groundwater flow may intercept the man-made drainage ditch located approximately 450 feet to the southwest.

2.6 ECOLOGY

The habitat at SWMU 27F is classified as an "industrialized area with managed grassland." The site is located within the industrialized area and is comprised of approximately 0.01 acre (see Figure 2-3). The surface of this SWMU is primarily concrete and contains man-made structures; however, a small area of managed grass does exist between the concrete and the fence line (Figure 2-3).

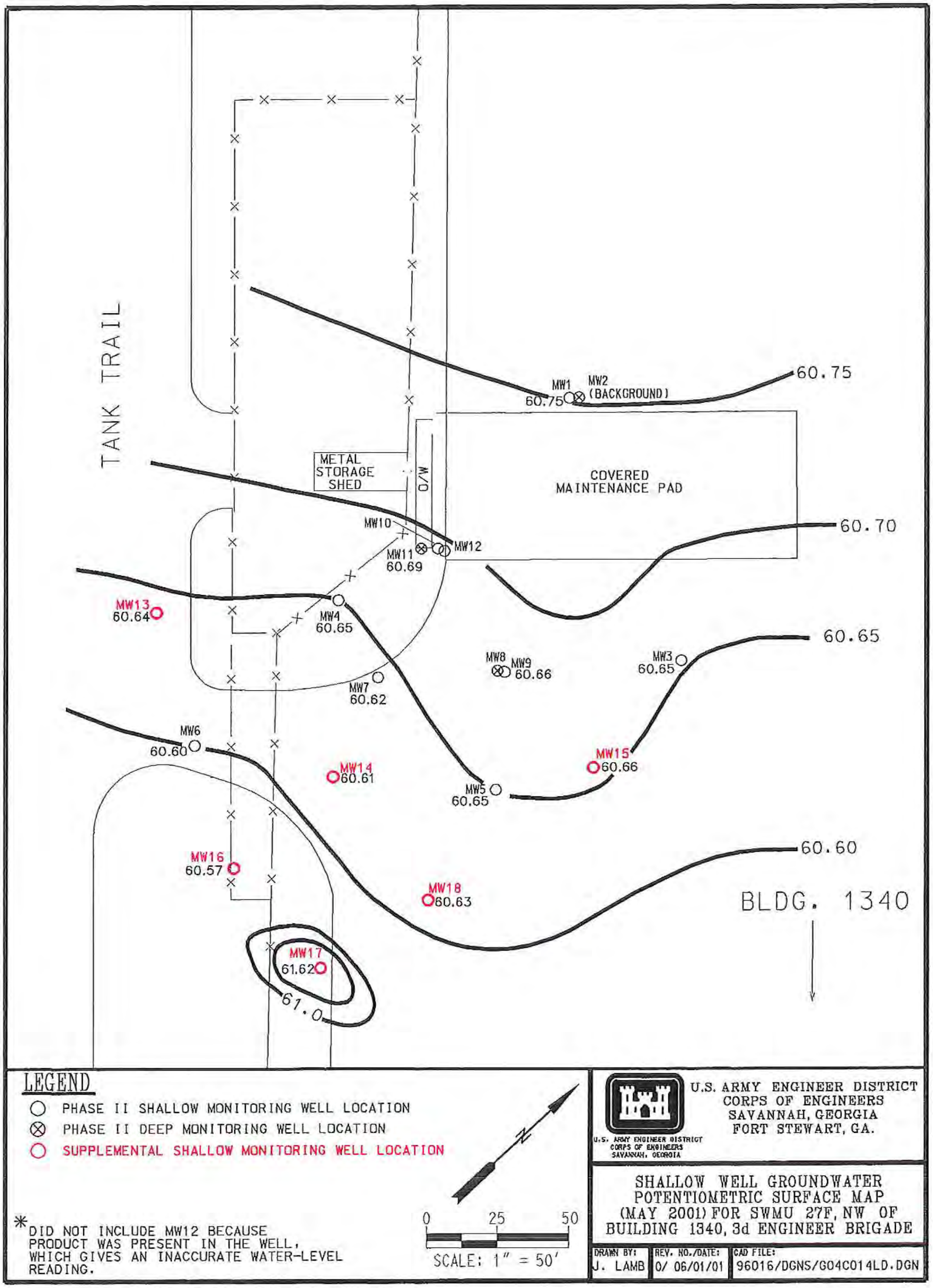

Figure 2-4. Groundwater Potentiometric Surface Map for Shallow Wells (May 2001), SWMU 27F, Northwest of Building 1340

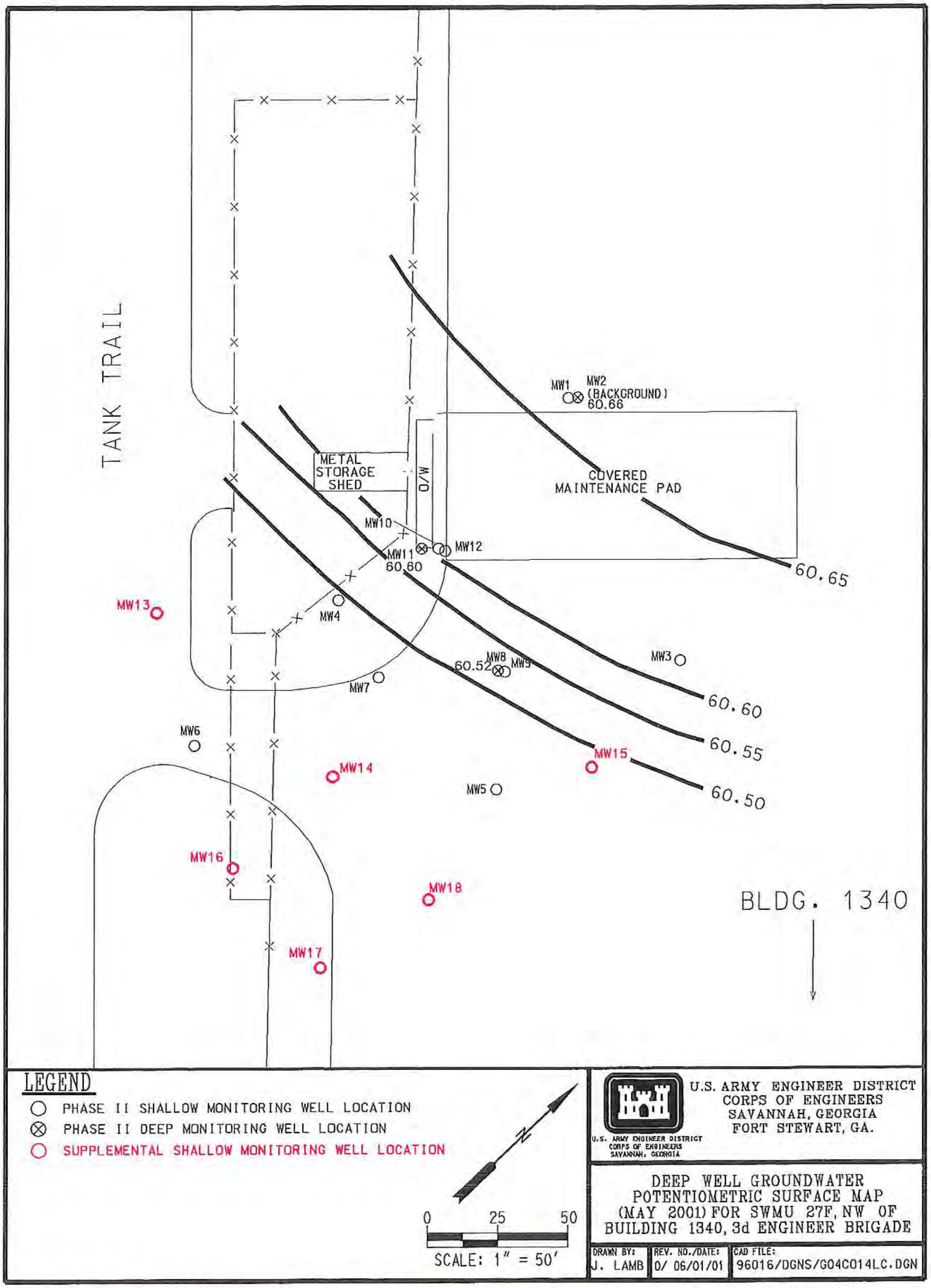

Figure 2-5. Groundwater Potentiometric Surface Map for Deep Wells (May 2001), SWMU 27F, Northwest of Building 1340

2.7 CONTAMINANT NATURE AND EXTENT

The results of chemical analyses performed during the Phase I and Phase II RFIs indicated that the soil and groundwater contain organic and metal contaminants at concentrations greater than their reference background concentrations. No surface water is present at this site.

The reference background criteria for SWMU 27F have been developed based on data from background samples collected across FSMR for SWMUs under Phase I and/or Phase II RFIs. In general, reference background samples were collected in each medium at locations upgradient or upstream of each site so as to be representative of naturally occurring conditions at the SWMUs under investigation. In addition, soil samples collected during the Phase I RFI were included in the background data set if they were determined to come from upgradient of the site and to be of sufficient quality to be representative of natural background conditions at FSMR. A summary of the sample locations by medium at each SWMU and the source of the data (Phase I and II RFI analytical data) are presented in Table 5-1 of the revised final Phase II RFI report (SAIC 2000).

EPA Region IV methodology (EPA 1995) was used as guidance for the development of the background data set for screening metals data. In cases in which enough samples (e.g., more than 20) are collected to define background, a background upper tolerance level can be calculated. In cases in which too few samples (e.g., fewer than 20) are collected to define background, background can be calculated as two times the mean background concentration (EPA 1995). Given that fewer than 20 background samples were collected for FSMR, the latter method was used for calculating reference background concentrations.

The reference background concentrations for surface soil, subsurface soil, and groundwater were calculated as two times the average concentration of all of the locations selected to be in the background data set. If a chemical was not detected at a site, then one-half the detection limit was used as the concentration when calculating the reference mean background concentration.

Inorganics were considered to be SRCs if their concentrations were above the reference background concentrations. Organics were considered to be SRCs if they were simply detected because organic constituents are considered to be anthropomorphic in nature.

Appendix G of the revised final Phase II RFI report (SAIC 2000) presents a summary of the background data as well as the two-times-mean background concentrations. Given the limited background data, the mean concentration established by the U.S. Geological Survey for soil in the eastern United States (USGS 1984) is also presented for comparative purposes. Because of the limited number of background samples, the screening value for background may be heavily skewed as a result of an outlier in the sampling data. The nature and extent of contamination by medium are summarized below. A tabular summary of SRCs by medium for the 3d Engineer Brigade, northwest of Building 1340, is presented in Table 2-1.

2.7.1 Surface Soil

Eleven surface soil samples were collected during the Phase II RFI. 2-Butanone was detected in four surface soil locations. 4-Methyl-2-pentanone was detected at MW4. Acetone was detected in four out of nine surface soil samples. Carbon disulfide was detected at MW3 and MW10. Toluene was detected at MW11. 2-Butanone, 4-methyl-2-pentanone, acetone, carbon disulfide, and toluene are considered to be SRCs in surface soil. Seventeen SVOCs (acenaphthene, anthracene, benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*g,h,i*)perylene, benzo(*k*)fluoranthene, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, chrysene, di-*N*-octyl phthalate, dibenzo(*a,h*)anthracene, fluoranthene, fluorene, indeno(*1,2,3-cd*)pyrene, phenanthrene, and pyrene) were detected in surface soil. All of the SVOCs, at

Table 2-1. Summary of Site-Related Contaminants, SWMU 27F, Northwest of Building 1340

	Maximum Concentration (mg/kg)			Maximum Concentration (μg/L)		
	Surface Soil	Subsurface Soil	Sediment	Groundwater Supplemental January 2001	Groundwater Phase II RFI November 1999	Surface Water
Volatile Organic Compounds						
1,1,1-Trichloroethane	ND	ND	NP	ND	5.2	NP
1,1-Dichloroethane	ND	ND	NP	ND	4.6	NP
2-Butanone	0.0105	0.0058	NP	10.6	40.2	NP
2-Hexanone	ND	ND	NP	ND	3.4	NP
4-Methyl-2-pentanone	0.0021	ND	NP	6.8	98.4	NP
Acetone	0.115	0.111[a]	NP	ND	ND	NP
Benzene	ND	0.0081	NP	61	141	NP
Carbon disulfide	0.0478	0.01	NP	ND	9	NP
Ethylbenzene	ND	1.68	NP	7	29.6	NP
Toluene	0.0218	ND	NP	ND	89	NP
Xylenes, total	ND	5.04	NP	38.5	137	NP
Semivolatile Organic Compounds						
2-Methylnaphthalene	ND	18.1	NP	31.9	10.8	NP
4-Methylphenol	ND	ND	ND	21.3	ND	ND
Acenaphthene	0.0425	1.12	NP	ND	ND	NP
Anthracene	0.492	0.393	NP	ND	ND	NP
Benzo(*a*)anthracene	3.94	ND	NP	ND	ND	NP
Benzo(*a*)pyrene	2.43	ND	NP	ND	ND	NP
Benzo(*b*)fluoranthene	2.88	ND	NP	ND	ND	NP
Benzo(*g,h,i*)perylene	0.885	ND	NP	ND	ND	NP
Benzo(*k*)fluoranthene	2.1	0.0541	NP	ND	ND	NP
Bis(2-ethylhexyl)phthalate	0.793	25.6	NP	ND	22.1	NP
Butyl benzyl phthalate	0.265	ND	NP	ND	ND	NP
Carbazole	ND	ND	ND	5.7	ND	ND
Chrysene	3.6	ND	NP	ND	ND	NP
Di-*N*-octyl phthalate	0.374	ND	NP	ND	ND	NP
Dibenzo(*a,h*)anthracene	0.543	ND	NP	ND	ND	NP
Diphenylamine	ND	2.81	NP	ND	ND	NP
Fluoranthene	10.5	0.3	NP	ND	ND	NP
Fluorene	0.0375	2.18	NP	2.1	ND	NP
Indeno(*1,2,3-cd*)pyrene	0.976	ND	NP	ND	ND	NP
Naphthalene	ND	4.49	NP	37.2	6.4	NP
Phenanthrene	1.18	5.23	NP	ND	2.4	NP
Pyrene	8.22	1.04	NP	ND	ND	NP
Metals						
Arsenic	4.4	BRBC	NP	ND	ND	NP
Barium	21.5	28.9	NP	BRBC	BRBC	NP
Cadmium	1.3	BRBC	NP	ND	ND	NP
Chromium	19.9	18.7	NP	7	7	NP
Lead	11.8	35.6	NP	BRBC	BRBC	NP
Mercury	BRBC	0.05	NP	ND	ND	NP
Selenium	1.4	BRBC	NP	ND	ND	NP

[a]Phase I RFI.

BRBC = Below reference background criteria.

ND = Not detected above reference background criteria.

NP = No pathway exists.

their maximum concentrations, were detected at MW10. Four of these SVOCs [benzo(*b*)fluoranthene, benzo(*g,h,i*)perylene, benzo(*k*)fluoranthene, and dibenzo(*a,h*)anthracene] were also detected in surface soil collected from MW11. MW10 and MW11 are a shallow/deep monitoring well pair located adjacent to one another. SVOCs were not detected at any other surface soil location. All of the SVOCs detected in surface soil are considered to be SRCs. Arsenic was detected at MW6 and MW9. Barium was detected in five of 11 surface soil samples. Cadmium was detected at MW4. Chromium was detected in seven of 11 surface soil samples. Lead was detected at a MW4, MW6, and MW9. Selenium was detected at MW9. Arsenic, barium, cadmium, chromium, lead, and selenium are considered to be SRCs in surface soil.

2.7.2 Subsurface Soil

Fifteen subsurface soil samples were collected during the Phase II RFI [see Figure 10 of the revised final addendum to the revised final Phase II RFI report (SAIC 2001)]. These samples were selected for analysis based on field headspace screening for VOCs. Because MW10 was located in an area of significant contamination, all the subsurface soil intervals to the water table (five) were analyzed for VOCs. 2-Butanone was detected at MW1, MW2, MW5, and MW10. Acetone was detected at MW1 (site background location). Benzene was detected at MW7, MW8, and MW9. Carbon disulfide was detected at MW1 and MW6. Ethylbenzene was detected in six out of 15 subsurface soil samples. Total xylenes were detected in six out of 15 subsurface soil samples. 2-Butanone, benzene, carbon disulfide, ethylbenzene, and total xylenes are SRCs in subsurface soil based on the Phase II RFI. Acetone is not an SRC in subsurface soil because it was detected at only the site background location. Twelve SVOCs [2-methylnaphthalene, acenaphthene, anthracene, benzo(*k*)fluoranthene, bis(2-ethylhexyl)phthalate, diphenylamine, fluoranthene, fluorene, naphthalene, phenanthrene, benzo(*b*)fluoranthene, and pyrene] were detected in subsurface soil. The majority of the detections were at locations MW10 and MW11. All of the SVOCs detected [with the exception of benzo(*b*)fluoranthene] are considered to be SRCs in subsurface soil based on the Phase II RFI. Benzo(*b*)fluoranthene is not an SRC in subsurface soil because it was detected at only the site background location. Barium, chromium, lead, and mercury were detected at concentrations above their respective reference background criteria and are considered to be SRCs in subsurface soil based on the Phase II RFI. Barium was detected at MW9. Chromium was detected above the reference background criterion in four of 11 subsurface soil samples. Lead was detected at MW4, MW6, and MW9. Mercury was detected at MW9.

2.7.3 Groundwater

Groundwater was evaluated using results from groundwater screening samples, vertical-profile samples, and monitoring wells. The groundwater was analyzed for VOCs, SVOCs, and RCRA metals.

2.7.3.1 Shallow groundwater monitoring wells

1,1,1-Trichloroethane; 1,1-dichloroethane; 2-butanone; 2-hexanone; and 4-methyl-2-pentanone were detected at only sample location GP9. Benzene was detected in eight of 27 shallow surficial groundwater samples. Six of the eight benzene detections were above the maximum contaminant level (MCL) of 5 μg/L. Carbon disulfide was detected at GP6 and GP7. Ethylbenzene was detected in nine of 27 shallow surficial groundwater samples. Toluene was detected at GP7 and GP9. Total xylenes were detected in 11 of 27 shallow surficial groundwater samples. Of the ten VOCs detected, only three (benzene, ethylbenzene, and total xylenes) were detected in shallow surficial groundwater from two of the eight shallow monitoring wells (MW9 and MW10). Benzene was detected at MW9 and MW10. Ethylbenzene was detected at MW10. Total xylenes were detected at MW9 and MW10. 1,1,1-Trichloroethane; 1,1-dichloroethane; 2-butanone; 2-hexanone; 4-methyl-2-pentanone; benzene; carbon disulfide; ethylbenzene; toluene; and total xylenes are SRCs in shallow surficial groundwater. Low concentrations of four SVOCs were detected in groundwater from the monitoring wells, primarily from MW10.

2-Methylnaphthalene was detected at MW3 and MW10. Bis(2-ethylhexyl)phthalate was detected in four of eight shallow surficial groundwater samples. Naphthalene was detected at MW3 and MW10. Phenanthrene was detected at MW10. 2-Methylnaphthalene, bis(2-ethylhexyl)phthalate, naphthalene, and phenanthrene are considered to be SRCs in shallow surficial groundwater. No RCRA metals were detected above reference background criteria in groundwater from the shallow surficial monitoring wells.

2.7.3.2 Deep groundwater monitoring wells

No VOCs were detected in the deep intervals of the vertical profiles or the deep surficial monitoring wells. No SVOCs were detected in the groundwater from the deep surficial monitoring wells. SVOC analysis was not performed on groundwater from the vertical profiles. Arsenic, chromium, lead, and selenium were detected above reference background criteria in MW2 (background location). Chromium was detected at MW8. Dissolved metals analysis was also performed on groundwater from MW2 and MW8. All of the filtered metals concentrations at MW2 and MW8 were either nondetect or below reference background criteria. Both locations had elevated turbidities [291 NTUs and 45.2 NTUs, respectively (see Table 6 of the revised final addendum [SAIC 2000] to the revised final Phase II RFI report [SAIC 2001]) during groundwater sampling, indicating colloids or particulates in the sample. Both deep monitoring wells extended into the Hawthorn confining (clay) layer, which is likely to be the source of the colloids/particulates and is probably the source of the elevated chromium. Chromium is the only RCRA metal SRC in deep surficial groundwater based on the Phase II RFI.

2.8 CONCLUSIONS AND RECOMMENDATIONS OF THE PHASE II RFI

The following presents the conclusions and recommendations from the revised final addendum (SAIC 2001) to the revised final Phase II RFI report for 16 SWMUs issued in June 2000.

Benzo(*a*)pyrene was identified as an HHCOC in surface soil. Benzo(*a*)pyrene was not identified as a CMCOPC, indicating that it is not likely to migrate to groundwater. The extent of benzo(*a*)pyrene in surface soil was confined to a single location near the OWS and the heavily used vehicle maintenance facility. The extent of benzo(*a*)pyrene in surface soil has been defined by the Phase II RFI, and no additional investigation and/or evaluation is required. A remedial level of 0.89 mg/kg was established for benzo(*a*)pyrene in surface soil. Remedial alternatives for benzo(*a*)pyrene in surface soil were to be evaluated in the CAP (the subject of this document).

Benzene and bis(2-ethylhexyl)phthalate were identified as HHCOCs in groundwater. The bis(2-ethylhexyl)phthalate concentration was believed to be the result of field or laboratory contamination. The MCLs for benzene (5 μg/L) and bis(2-ethylhexyl)phthalate (6 μg/L) were established as their remedial levels.

To further define the extent of potential groundwater contamination, Fort Stewart recommended the installation of the three to six new shallow monitoring wells downgradient of the potential source area and the resampling of the groundwater at all the existing monitoring wells prior to the development of the CAP. No soil samples were to be collected during the installation of the new monitoring wells. The groundwater samples were to be analyzed for VOCs and SVOCs to provide additional site data to fully define the extent of potential organic groundwater contamination. RCRA metals were not identified as either CMCOPCs or human health constituents of potential concern (HHCOPCs) at SWMU 27F, northwest of Building 1340; therefore, RCRA metals are not constituents of potential concern (COPCs) requiring further investigation and/or evaluation. The new data were originally to be submitted to GEPD as part of the CAP; however, the results were available earlier than expected and issued in a revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000).

2.9 SUPPLEMENTAL DATA EVALUATION

Groundwater samples were collected in January 2001 to comply with the recommendations of Section 10.9.8.2 of the revised final Phase II RFI report (SAIC 2000). Six shallow wells (MW13 through MW18) were installed (Figure 2-6) in accordance with the recommendations of the revised final Phase II RFI report (SAIC 2000). Thirteen shallow monitoring wells [six of which were installed in accordance with the recommendations of the final revised final Phase II RFI report (SAIC 2000)] and four deep monitoring wells were low-flow sampled in May 2001 as part of the supplemental data collection. The groundwater samples were analyzed for VOCs and SVOCs. In addition, MW12, the monitoring well installed above the clay layer that occurs at approximately 8 feet bgs, was checked for free product.

Free Product

Floating product was identified in one well, MW12. Approximately 0.05 foot of a thick, black, viscous material was indicated in MW12 during the measurement of the water level in May 2001. MW12 was installed to the top of the clay layer that occurs at approximately 8 feet bgs. The material was removed with an absorbent sock. The material does not readily recharge in MW12.

Shallow Groundwater Monitoring Wells

Five VOCs (2-butanone, 4-methyl-2-pentanone, benzene, ethylbenzene, and total xylenes) were detected in shallow groundwater at SWMU 27F. 2-Butanone was detected in one out of 13 shallow groundwater samples at a concentration of 10.6 μg/L in MW7. 4-Methyl-2-pentanone was detected at a concentration of 6.8 μg/L in MW7. Benzene was detected in four out of 13 shallow groundwater samples at concentrations of 2.4 μg/L at MW10, 5.8 μg/L at MW9, 31.4 μg/L at MW7, and 61 μg/L at MW14. Ethylbenzene was detected in two out of 13 shallow groundwater samples at concentrations of 4.3 μg/L and 7 μg/L at MW7 and MW14, respectively. Total xylenes were detected in five out of 13 shallow groundwater samples at concentrations ranging from 3.2 μg/L at MW10 to 38.5 μg/L at MW14. 2-Butanone, 4-methyl-2-pentanone, benzene, ethylbenzene, and total xylenes are considered to be SRCs in shallow groundwater at SWMU 27F. Benzene also exceeded its MCL of 5 μg/L.

Five SVOCs (2-methylnaphthalene, 4-methylphenol, carbazole, fluorene, and naphthalene) were detected in shallow groundwater at SWMU 27F. 2-Methylnaphthalene was detected in four out of 13 shallow groundwater samples at concentrations of 2.3 μg/L, 7.4 μg/L, 15.6 μg/L, and 31.9 μg/L at MW9, MW7, MW4, and MW14, respectively. 4-Methylphenol was detected at a concentration of 21.3 μg/L in MW7. Carbazole was detected at a concentration of 5.7 μg/L in MW14. Fluorene was detected at a concentration of 2.1 μg/L in MW14. Naphthalene was detected at concentrations of 3.6 μg/L, 3.8 μg/L, 11 μg/L, and 37.2 μg/L at MW9, MW18, MW4, and MW14, respectively.

The SRCs in groundwater identified from the supplemental data evaluation are presented in Table 2-1.

Deep Groundwater Monitoring Wells

No VOCs or SVOCs were detected in the deep groundwater at SWMU 27F.

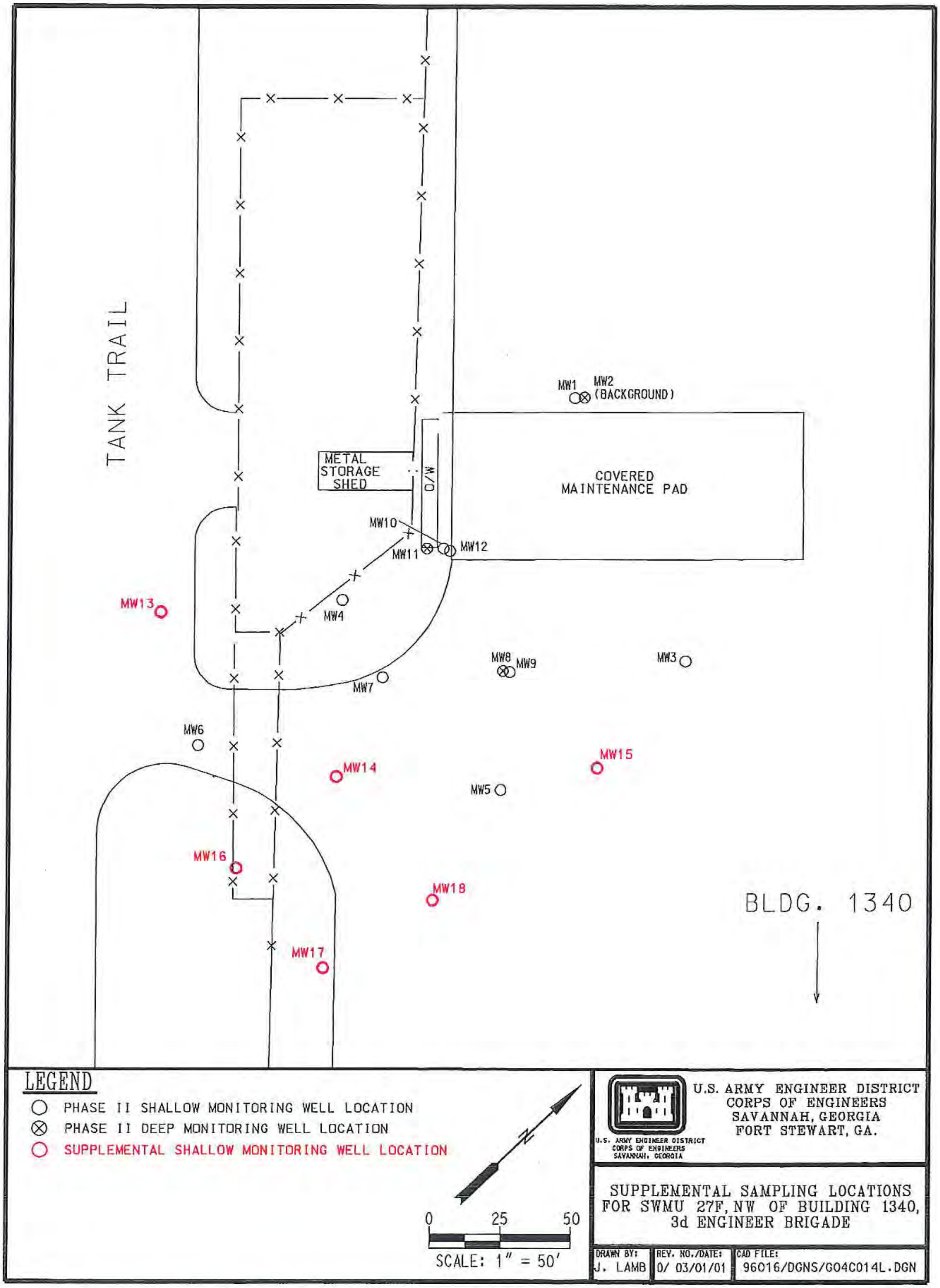

Figure 2-6. Supplemental Sampling Locations for SWMU 27F, Northwest of Building 1340

2.10 SITE-RELATED CONSTITUENTS FROM PHASE II AND SUPPLEMENTAL DATA EVALUATION

Additional soil data were not collected during the supplemental data investigation; therefore, the soil SRCs were identified during the Phase I and Phase II RFIs. SRCs for groundwater were determined using the most current groundwater characterization data (collected from monitoring wells during the supplemental data evaluation) (Table 2-1). The SRCs from surface and subsurface soil from the Phase I and Phase II RFIs and groundwater from the supplemental data evaluation were evaluated under fate and transport, human health preliminary risk evaluation (HHPRE), and ecological preliminary risk evaluation (EPRE).

2.11 CONTAMINANT FATE AND TRANSPORT

This section presents the site-specific components of the conceptual site model developed for SWMU 27F and describes the contaminant release mechanisms through the primary transport medium (groundwater). This section also discusses the fate and transport of contaminants at the site with respect to their leachability and natural attenuation. Chapter 6.0 of the revised final Phase II RFI report (SAIC 2000) presents a general discussion on the contaminant fate and transport for the 16 SWMUs. This section and Attachment E of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report provide a site-specific extension for SWMU 27F.

2.11.1 Generic Soil Screening Analysis

Contaminant fate and transport analysis provided an assessment of the potential migration pathways and transport mechanisms affecting the constituents at the site. In particular, the leachability of contaminants from soil to groundwater and their natural attenuation in groundwater were evaluated.

The site characterization identified inorganic and organic SRCs in surface soil and subsurface soil. Eight VOCs, 20 SVOCs, and seven metals were identified as SRCs in soil. These constituents were compared to EPA generic soil screening levels (GSSLs; EPA 1996a) to determine if these constituents might leach from soil into groundwater at concentrations exceeding groundwater standards [i.e., concentrations that exceed the MCL or, in the absence of an MCL, the risk-based concentration (RBC) for drinking water (EPA 1996b)].

The maximum concentration of benzo(*a*)anthracene exceeded its GSSL, and this constituent is considered to be a CMCOPC in surface soil [see Table 18 of the revised final addendum (SAIC 2001) to the revised final phase II RFI report (SAIC 2000)] at SWMU 27F, northwest of Building 1340.

2.11.2 Fate and Transport Modeling

Fate and transport modeling was performed to estimate the future concentrations of the preliminary CMCOPC [benzo(*a*)anthracene], HHCOPCs (2-methylnaphthalene, 4-methylphenol, benzene, carbazole, and naphthalene), and ecological constituents of potential concern (ECOPCs) (2-methylnaphthalene, 4-methylphenol, benzene, carbazole, and total xylenes) in groundwater at the surface water receptor location. The nearest surface water receptor is a man-made drainage ditch located approximately 450 feet south of the site. The results of the modeling are presented in Attachment E of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000).

Seasonal Soil Compartment (SESOIL) modeling indicated that benzo(*a*)anthracene will completely naturally attenuate before reaching the water table; therefore, benzo(*a*)anthracene was not evaluated in the baseline human health risk assessment (BHHRA).

Analytical Transient 1-, 2-, 3-Dimensional (AT123D) modeling was performed to estimate the exposure concentrations of the COPCs in the surface water receptor. The AT123D modeling results are presented in Table E-5 of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000). The modeling results indicate that none of the HHCOPCs will reach the receptor location; therefore, the predicted surface water exposure concentrations resulting from migration of groundwater COPCs are all zero. The modeling results predicted that none of the ECOPCs except carbon disulfide would reach the receptor location. The maximum concentration of carbon disulfide at the surface water receptor was estimated to be 0.00018 μg/L.

2.12 PRELIMINARY RISK EVALUATION

2.12.1 Human Health Preliminary Risk Evaluation

The HHPRE included a Step 1 risk evaluation to determine potential human health risks associated with the contaminants present at the site. HHCOPCs were defined as those constituents present at concentrations higher than their reference background criteria and higher than their respective risk-based or applicable or relevant and appropriate requirement–based screening criteria. The SRCs for surface soil, subsurface soil, and groundwater evaluated under the HHPRE are presented in Table 2-1. Based on the results of the preliminary risk assessment, the conclusions listed below were reached.

- Benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, dibenzo(*a,h*)anthracene, indeno(*1,2,3-cd*)pyrene, and arsenic are considered to be HHCOPCs in surface soil. There are no HHCOPCs in subsurface soil [see Table 19 of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000)].

- The maximum groundwater concentrations of 2-methylnaphthalene, 4-methylphenol, benzene, carbazole, and naphthalene exceeded their respective screening values; therefore, they are HHCOPCs in groundwater.

- A BHHRA was performed to quantitatively assess the risks associated with exposure to the HHCOPCs (2-methylnaphthalene, 4-methylphenol, benzene, carbazole, and naphthalene) in groundwater and [benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, dibenzo(*a,h*)anthracene, indeno(*1,2,3-cd*)pyrene, and arsenic] in surface soil.

2.12.2 Ecological Preliminary Risk Evaluation

Based on the results of the EPRE screening analysis, ECOPCs were identified in groundwater and surface soil. Those constituents identified as ECOPCs were further evaluated using realistic exposure factors, mean site concentrations, or predicted maximum groundwater discharge concentrations at downgradient surface water bodies. The results of the EPRE are summarized below.

- Benzene and total xylenes in groundwater are ECOPCs for aquatic biota if groundwater discharges to nearby surface water bodies with aquatic habitat because they were detected at concentrations exceeding the respective ecological screening values (ESVs). Three SVOCs (2-methylnaphthalene, 4-methylphenol, and carbazole) are ECOPCs by default because there are no ESVs. Fate and transport modeling (using the AT123D model) was performed to estimate the groundwater concentrations at the nearest surface water body to which groundwater might migrate. The ECOPCs in groundwater are unlikely to pose a hazard to aquatic biota because the predicted maximum discharge concentrations are 0 μg/L for all ECOPCs.

- There are no ECOPCs in groundwater at SWMU 27F, northwest of Building 1340, for terrestrial receptors.

- Cadmium, chromium, and lead in surface soil at SWMU 27F, northwest of Building 1340, are ECOPCs for terrestrial receptors because the preliminary hazard quotients (HQs) exceed one. There are no toxicity reference values (TRVs) for butyl benzyl phthalate and di-*N*-octyl phthalate, so they are ECOPCs by default. The supplemental risk calculations for these ECOPCs using surrogate toxicity benchmarks for the two SVOCs result in HQs of less than one for shrews and robins; therefore, cadmium, chromium, lead, butyl benzyl phthalate, and di-*N*-octyl phthalate in surface soil are unlikely to pose a risk to terrestrial receptors.

In summary, the revised final Phase II RFI report (SAIC 2000) concluded that there was no present ecological risk at SWMU 27F and that the site was unlikely to pose an ecological risk in the future.

2.13 BASELINE HUMAN HEALTH RISK ASSESSMENT

A BHHRA was performed to assess HHCOPCs in groundwater and soil around SWMU 27F. The COPCs addressed in the baseline risk assessment included the groundwater HHCOPCs 2-methylnaphthalene, 4-methylphenol, benzene, carbazole, and naphthalene and the surface soil HHCOPCs benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, dibenzo(*a,h*)anthracene, indeno(*1,2,3-cd*)pyrene, and arsenic.

No CMCOPCs were identified for this site.

2-Methylnaphthalene, 4-methylphenol, benzene, carbazole, and naphthalene were identified as HHCOPCs in groundwater. Groundwater at this site is not currently used for any purpose, and groundwater does not discharge to any nearby surface waters; therefore, no current receptors are being exposed to COPCs at this site. Potential future receptors include an Installation worker, a juvenile trespasser, and a resident. Benzene and carbazole are considered to be COCs in groundwater. The main risk driver is benzene in groundwater for the on-site Installation worker and carbazole for the on-site resident child and adult.

The risk drivers for the on-site Installation worker include arsenic (surface soil), benzo(*a*)pyrene (surface soil), dibenzo(*a,h*)anthracene (surface soil), and benzene (groundwater). With the exception of indeno(*1,2,3-cd*)pyrene, all of the HHCOPCs in surface soil are risk drivers for the on-site resident child and resident adult. Surface soil HHCOPCs do not present a significant risk to off-site receptors. The following constituents are considered to be COCs in surface soil: arsenic, benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, and dibenzo(*a,h*)anthracene.

Remedial levels were derived for benzene and carbazole in groundwater. Remedial levels were derived for arsenic, benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, and dibenzo(*a,h*)anthracene in surface soil.

Human Health Constituents of Concern. The selection of the recommended remedial levels for groundwater took into consideration the MCLs, risk-based remedial levels, and reference background concentrations of inorganics (Table 2-2). The MCL for benzene (5 μg/L) is the recommended remedial level for it in groundwater. The recommended remedial level for carbazole was 34.9 μg/L. Given that the recommended level for carbazole is higher than the maximum detected value of 5.7 μg/L, no further study and/or remediation is required for this constituent.

Table 2-2. Remedial Levels for Groundwater, SWMU 27F, Northwest of Building 1340

COC	Units	Maximum Detected Concentration	Risk-Based Remedial Levels ILCR 1×10^{-6}	Risk-Based Remedial Levels ILCR 1×10^{-5}	Maximum Contaminant Level	Quantification Limits
Benzene	μg/L	61	NA	NA	**5**	2
Carbazole	μg/L	5.7	3.5	**34.9**	ND	9.6

COC = Constituent of concern.
ILCR = Incremental lifetime cancer risk.
NA = Not applicable; remedial level for groundwater defaults to the maximum contaminant level.
ND = No data; this constituent does not have a maximum contaminant level.
Bold indicates values are recommended remedial levels.

The recommended remedial levels (Table 2-3) for the contaminants in surface soil are arsenic (10.12 mg/kg), benzo(*a*)pyrene (0.89 mg/kg), benzo(*a*)anthracene (8.93 mg/kg), benzo(*b*)fluoranthene (8.93 mg/kg), and dibenzo(*a,h*)anthracene (0.89 mg/kg). Given that the recommended remedial values for arsenic (10.12 mg/kg), benzo(*a*)anthracene (8.93 mg/kg), benzo(*b*)fluoranthene (8.93 mg/kg), and dibenzo(*a,h*)anthracene (0.89 mg/kg) are higher than their maximum detected values of 4.4 mg/kg, 3.94 mg/kg, 2.88 mg/kg, and 0.54 mg/kg, respectively, no further study and/or remediation is required for these constituents.

Table 2-3. Remedial Levels for Surface Soil, SWMU 27F, Northwest of Building 1340

COC	Units	Maximum Detected Concentration	Risk-Based Remedial Levels ILCR 1×10^{-6}	Risk-Based Remedial Levels ILCR 1×10^{-5}	Surface Soil Background Concentration
Arsenic	mg/kg	4.40	1.01	**10.12**	2.1
Benzo(*a*)anthracene	mg/kg	3.94	0.89	**8.93**	0
Benzo(*a*)pyrene	mg/kg	2.43	0.09	**0.89**	0
Benzo(*b*)fluoranthene	mg/kg	2.88	0.89	**8.93**	0
Dibenzo(*a,h*)anthracene	mg/kg	0.54	0.09	**0.89**	0

COC = Constituent of concern.
ILCR = Incremental lifetime cancer risk.
Bold indicates values are recommended remedial levels.

2.14 CONCLUSIONS AND ESTIMATED EXTENT OF CONTAMINATION

Benzo(*a*)pyrene in surface soil and benzene in groundwater were identified as COCs at SWMU 27F requiring remediation. The estimated areal extent of soil and groundwater contamination at SWMU 27F is presented in Figure 2-7.

Groundwater contamination is confined to the shallow surficial groundwater. Contaminants have not migrated to the deep surficial groundwater. A low volume of dark, viscous, oily free product has intermittently been identified at MW12, a well installed to the clay lens occurring at approximately 8 feet bgs.

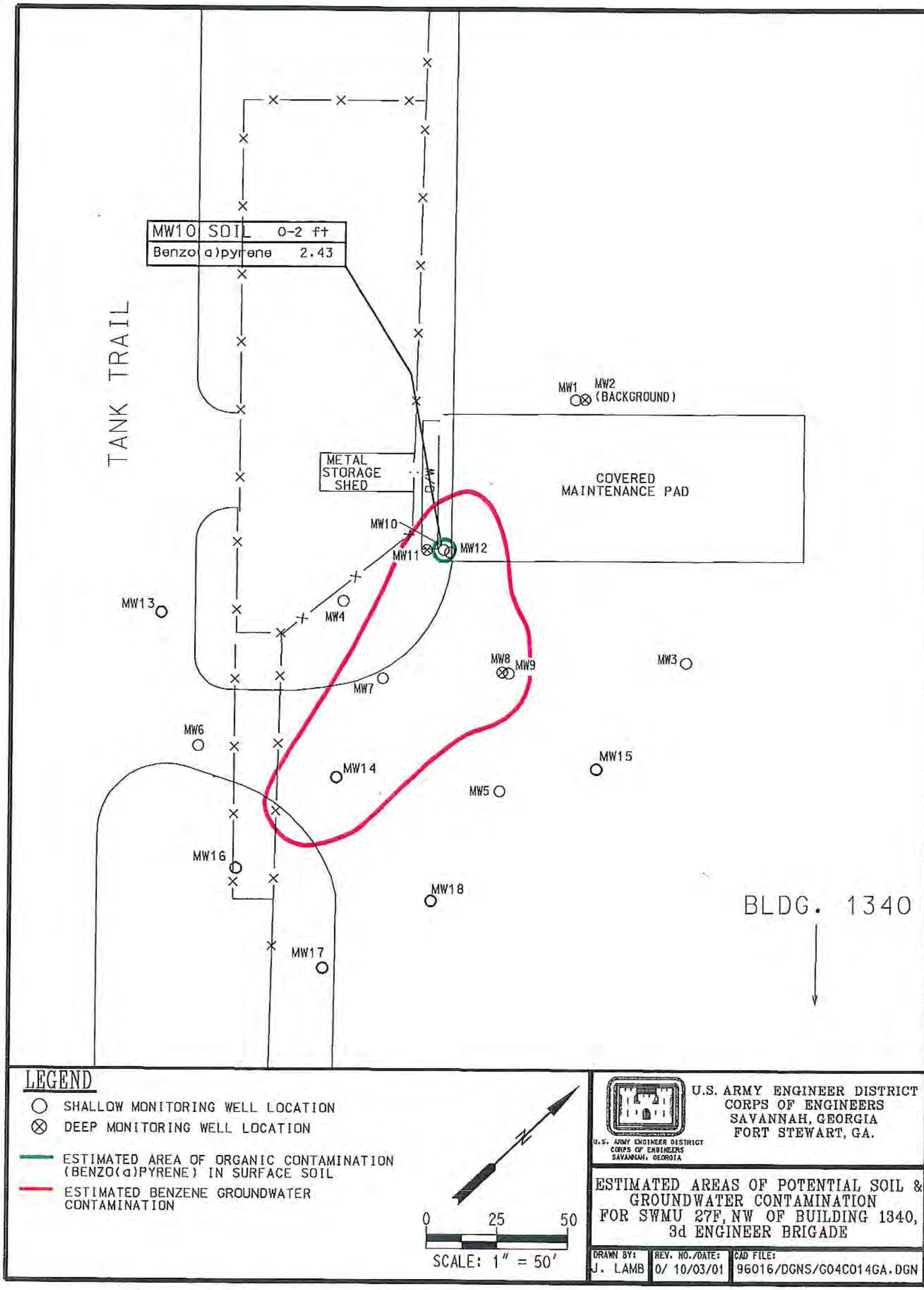

Figure 2-7. Estimated Areas of Potential Soil and Groundwater Contamination, SWMU 27F, Northwest of Building 1340

The extent of benzo(*a*)pyrene in surface soil was confined to a single location near the OWS and the heavily used vehicle maintenance facility. The contaminated soil is probably the result of spillage from past practices at the facility. Prior to the OWS's closure, containers (i.e., oil filters, oil cans/containers) were turned upside down on the OWS grate to remove residual product.

2.15 MODELING FOR EVALUATING MONITORED NATURAL ATTENUATION

Monitored natural attenuation involves long-term annual monitoring of the site for a certain period of time based on natural attenuation modeling. For SWMU 27F natural attenuation modeling was performed for benzo(*a*)pyrene in surface soil and benzene in groundwater. During that period of time, concentrations of the benzo(*a*)pyrene in surface soil and benzene in groundwater are predicted to decline to below their remedial levels, 0.89 mg/kg and 5 μg/L, respectively.

The SESOIL model was applied to benzo(*a*)pyrene to predict the decay of its concentration in soil as well as the concentration in the leachate migrating to the water table. The SESOIL modeling predicted the maximum concentration of benzo(*a*)pyrene in soil to be reduced to its remedial level within 26 months from the sampling event (i.e., October 1999). The leaching modeling results also indicated that benzo(*a*)pyrene is not expected to reach the water table within the 1,000 years simulation time, thereby degrading completely before reaching the water table.

The groundwater concentrations of benzene were predicted using the AT123D model, which predicts the distribution of constituents in groundwater and the transient spread of a chemical plume through a groundwater aquifer. Model calibration was performed by matching the highest concentration observed in MW14 in January 2001 and assuming a steady-state condition. Simulations were performed to predict the maximum benzene concentrations in the shallow surficial groundwater as a function of the downgradient distance from the source and also the time to achieve the remedial level in groundwater [i.e., 5 μg/L (MCL) as recommended in the BHHRA].

The results of the modeling indicate that the estimated timeframe needed for the maximum benzene concentration to degrade through natural attenuation to below its remedial level is approximately 6 years from January 2001. Therefore, it may be concluded that the estimated timeframe needed for monitored natural attenuation will be approximately 6 years from January 2001.

3.0 JUSTIFICATION AND PURPOSE OF CORRECTIVE ACTION

3.1 PURPOSE

EPA has established corrective action standards that reflect the major technical components that should be included with a selected remedy (EPA 1994). These include the following: (1) protect human health and the environment; (2) attain media cleanup standards set by the implementing agency; (3) control the source of the releases so as to reduce or eliminate, to the extent practicable, further releases that might pose a threat to human health and the environment; (4) comply with any applicable standards for management of wastes; and (5) other factors.

3.2 REMEDIAL RESPONSE OBJECTIVES

Due to the presence of benzene in groundwater and benzo(*a*)pyrene in soil at concentrations exceeding their respective remedial levels, corrective action is warranted at the 3d Engineer Brigade, northwest of Building 1340 (SWMU 27F). The remedial response objectives for SWMU 27F are to reduce the present concentrations of the site COCs in soil [benzo(*a*)pyrene] and groundwater (benzene) to the remedial levels presented in the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000).

In addition, 0.05 foot of a thick, black, viscous material was discovered in MW12, which was installed to the top of the clay layer that occurs at approximately 8 feet bgs, during the measurement of the water level in May 2001. The material was removed with an absorbent sock and does not readily recharge in MW12. The well will be monitored during the performance of the selected remedy to determine if the material represents an active source of potential contamination. Specific remedial alternatives were not evaluated for this material.

The selected remedy will provide the technology necessary to minimize levels of contaminants in the soil and groundwater and to achieve the best overall results with respect to such factors as effectiveness, implementability, and cost.

3.3 IDENTIFICATION OF REMEDIAL LEVELS

Remedial levels were derived for soil and groundwater COCs. The remedial level for benzo(*a*)pyrene in surface soil is protective of direct exposure of a current on-site Installation worker. The remedial levels for soil were based on an incremental lifetime cancer risk of 1×10^{-5}. The remedial level for benzene in groundwater is protective of direct exposure of hypothetical future residents to benzene in groundwater; however, it is recognized that groundwater is not used as a source of drinking water at this site and that future residential exposure is highly unlikely.

The remedial levels for soil and groundwater are presented in Table 3-1.

Table 3-1. Recommended Remedial Levels in Soil and Groundwater, SWMU 27F, Northwest of Building 1340

COC	Medium	Maximum Detected Concentration	Recommended Remedial Level
Benzo(*a*)pyrene	Surface soil	2.43 mg/kg	0.89 mg/kg
Benzene	Groundwater	61 µg/L	5 µg/L

COC = Constituent of concern.

4.0 SCREENING OF CORRECTIVE ACTIONS

This section identifies technologies applicable for the remediation of the 3d Engineer Brigade, northwest of Building 1340, and screens the technologies with respect to effectiveness, implementability, and cost. The technologies that are retained following screening are then combined into corrective action alternatives that address the COCs at SWMU 27F. These alternatives are then evaluated with respect to their times to implement and total life-cycle costs. Technologies for surface soil at SWMU 27F are screened separately from the groundwater technologies; however, the selected soil and groundwater technologies are combined and evaluated as potential corrective action alternatives for SWMU 27F.

4.1 SCREENING CRITERIA

The first step in the development of corrective action alternatives involves the identification and screening of technologies applicable to the site. The purpose of this step is to list and evaluate the general suitability of remedial technologies for meeting the stated corrective action objectives (see Section 3.2). The technologies are also evaluated for their general ability to protect human health and the environment.

Technologies that pass the initial screening phase will be retained for subsequent evaluation as corrective actions. The technologies are compared using three general criteria: effectiveness, implementability, and cost. An explanation of each criterion is provided below.

4.1.1 Effectiveness

This criterion evaluates the extent to which a corrective action reduces overall risk to human health and the environment. It also considers the degree to which the action provides sufficient long-term controls and reliability to prevent exposures at levels exceeding those protective of human and environmental receptors. Factors considered include performance characteristics and the ability to reduce contaminant concentration.

4.1.2 Implementability

This criterion evaluates the technical and administrative factors affecting implementation of a corrective action and considers the availability of services and materials required during implementation. Technical factors assessed include ease and reliability of initiating construction and operations, prospects for implementing any additional future actions, and adequacy of monitoring systems to detect failures. Technical feasibility considers the performance history of the technologies in direct applications or the expected performance for similar applications. Uncertainties associated with construction, operation, and performance monitoring are also considered.

Service and material considerations include equipment and operator availability and applicability or development requirements for prospective technologies. The availability of services and materials is addressed by considering the material components of the proposed technologies and the locations and quantities of those materials. Administrative factors include ease of obtaining permits, enforcing deed restrictions, or maintaining long-term control of the site.

Potentially applicable technologies for soil and groundwater are identified in Tables 4-1 and 4-2, respectively.

Table 4-1. Evaluation of Corrective Actions/Technologies for Soil, SWMU 27F, Northwest of Building 1340

Action/ Technology	Description	Effectiveness	Implementability	Costs
No Action	The "no action" alternative provides a baseline against which other actions can be compared. Under the no action alternative, the soil would be left "as is," without implementing any removal, treatment, or other mitigating actions to reduce existing or potential future exposure.	This alternative would not address the remedial response objectives of the site. This alternative does not provide protection of human health or the environment because attainment of remedial levels would not be confirmed.	There is no impediment to implementation of this alternative because no action would be taken.	There would be no cost associated with the no action alternative.
Institutional Controls	Technologies associated with institutional controls would reduce potential hazards by limiting exposure of humans to contaminated surface soil. Excavation permit restrictions would prohibit any construction at the site that might disturb the surface soil.	This technology alone would not meet the site objectives (i.e., remedial levels). Because the COCs are associated with surface soil, current on-site workers might be exposed to COCs.	Very few factors limit implementability of institutional controls. The property is not expected to be developed in the near future and will remain under federal ownership. This alternative is readily implementable.	Low; to establish soil use restrictions, approximately $5,000.
Natural Attenuation	This action would require the monitoring of contaminant levels to ensure that the mass of contamination was being reduced over time in accordance with OSWER Directive 9200.4-17P. Soil sampling would be performed to confirm that remedial levels had been achieved.	Natural attenuation through biodegradation of benzo(*a*)pyrene has been modeled for the site and would be effective. Modeling has indicated that it would require approximately 26 months from October 1999 (i.e., December 2001) to successfully meet the site objectives (i.e., achievement of soil remedial levels).	This alternative is readily implementable, and modeling has indicated that it would require until only December 2001 to achieve remedial levels. Soil sampling would be necessary to confirm that remedial levels have been achieved.	Low; potentially up to two surface soil sampling events to confirm that remedial levels have been achieved.
Bioventing	This treatment increases microbial degradation of organic contaminants in soil (unsaturated zone) using forced air as an oxygen source. A series of injection wells would be installed in the vadose zone, and air would be injected under a constant pressure to increase biodegradation of the contaminants.	This technology has been proven to be effective for organic contaminants in subsurface soil as long as the source is confined and limited. Contaminated soil at this site is located at the surface; therefore, short-circuiting may occur.	The equipment and technology for bioventing are readily available.	High capital and O&M costs.
Tilling	This alternative would involve tilling or physically aerating the surface soil by mechanical equipment and/or hand, with possible addition of nutrients or organic material over time to promote the biological degradation of the organic contaminants in the surface soil. Confirmatory soil samples would be collected to determine whether remedial levels had been met.	This technology has been proven to be effective for organic contaminants in surface soil. The effectiveness of the treatment is dependent on the ability to aerate soil in place at the level of contamination.	The equipment and technology for tilling are readily available; however, the small area and physical obstructions in the area make implementability difficult.	Low cost.

Table 4-1. Evaluation of Corrective Actions/Technologies for Soil, SWMU 27F, Northwest of Building 1340 (continued)

Action/ Technology	Description	Effectiveness	Implementability	Costs
Excavation	This alternative would involve physically removing/excavating the contaminated surface soil by hand or mechanical equipment. Confirmatory sampling would be taken to determine if the contamination had been removed to be below remedial levels. The excavation would be backfilled with clean soil. The contaminated soil would be properly disposed of off-site.	This alternative is highly effective. COCs would be removed, eliminating the potential for future exposure.	This alternative is readily implementable. The estimated area of contaminated surface soil is small and is located at the surface. Adequate disposal facilities are available to accept and treat the excavated soil.	Low cost; small estimated quantity located near the surface; minimal confirmatory sampling required.
Specialized Bacteria Addition	Specialized bacteria and nutrients in highly concentrated solutions and specific to biodegrading benzo(*a*)pyrene would be injected or mixed with the surface soil.	This technology has been proven to be effective for organic constituents if specific bacteria are available for the COC(s) and the site conditions are aerobic, a state that is conducive to biodegradation of SVOC contaminants.	Specialized bacteria and the equipment for application are readily available. The treatment is applicable to a relatively small site. The specialized bacteria would be injected or mixed into the surface soil to approximately 2 feet to 3 feet below ground surface. A UIC permit would be required for injection or mixing of specialized bacteria and nutrients.	Low; baseline sampling, followed by 1 month to treat and performance/ confirmatory soil sampling to evaluate the effectiveness of the specialized bacteria addition
Soil Sampling	Soil sampling would be used in conjunction with other alternatives to monitor the effectiveness of the remedial alternative.	This alternative is highly accurate in monitoring the effectiveness of a remedial alternative.	Highly implementable. Surface soil can easily and safely be sampled.	Low costs; costs depend on frequency of sampling.

COC = Constituent of concern.
O&M = Operations and maintenance.
OSWER = Office of Solid Waste and Emergency Response.
SVOC = Semivolatile organic compound.
UIC = Underground Injection Control.

Table 4-2. Evaluation of Corrective Actions/Technologies for Groundwater, SWMU 27F, Northwest of Building 1340

Action/ Technology	Description	Effectiveness	Implementability	Costs
No Action	The "no action" alternative provides a baseline against which other actions can be compared. Under the no action alternative, the groundwater would be left "as is," without implementing any removal, treatment, or other mitigating actions to reduce existing or potential future exposure.	This alternative would not address the remedial response objectives of the site. This alternative does not provide protection of human health or the environment because attainment of remedial levels would not be confirmed.	There is no impediment to implementation of this alternative because no action would be taken.	There would be no cost associated with the no action alternative.
Institutional Controls	Technologies associated with institutional controls would reduce potential hazards by limiting exposure of humans to contaminated groundwater. Groundwater use restrictions would prohibit the use of groundwater as a drinking water supply. Excavation permit restrictions would prohibit any construction at the site that might allow contact with groundwater.	This technology alone would not meet the site objectives (i.e., remedial levels). Assuming compliance with groundwater use restrictions, this technology would be effective and provide reliability with respect to eliminating human exposure to contaminated groundwater within the boundaries of the site. Use of surficial groundwater at this site for drinking water is unlikely.	Very few factors limit the implementability of institutional controls. The property is not expected to be developed in the near future and will remain under federal ownership. This alternative is readily implementable.	Low; to establish groundwater use restrictions, approximately $5,000.
Monitored Natural Attenuation	This action would require the monitoring of contaminant levels to ensure that the mass of contamination was being reduced over time in accordance with OSWER Directive 9200.4-17P. A total of 13 wells would be sampled annually or biannually for approximately 7 years starting in January 2001 (6 years monitored natural attenuation period plus 1 year added as a contingency) and analyzed for the COCs and natural attenuation parameters (e.g., methane, NO_2/NO_3). An additional one-time sampling event would be performed 1 year after the final annual event for confirmation sampling to determine if remedial levels had been met. Thirteen monitoring wells would be sampled annually and/or biannually, followed by confirmation sampling.	Natural attenuation through biodegradation has been modeled for the site and would be effective. This action would require approximately 6 years from January 2001 to successfully meet the site objectives (i.e., achievement of groundwater remedial levels). An additional year of annual sampling would be included as a contingency.	This alternative is readily implementable and would require only annual or biannual monitoring of a total of 13 wells at the site for approximately 7 years (1 year added as a contingency). In addition, confirmatory groundwater sampling (1 year after the completion of annual monitoring) would be required.	Low; monitoring of 13 wells for approximately 7 years would be required. In addition, confirmatory groundwater sampling (1 year after the completion of annual monitoring) would be required.

Table 4-2. Evaluation of Corrective Actions/Technologies for Groundwater, SWMU 27F, Northwest of Building 1340 (continued)

Action/ Technology	Description	Effectiveness	Implementability	Costs
Pumping and Treating	This corrective action involves pumping and treatment of groundwater to below remedial levels. Extraction wells would be installed in the shallow surficial groundwater. Low-flow pumping (3 gallons to 5 gallons per minute) would be used to extract groundwater. Groundwater would be treated using an activated carbon treatment system. Effluent from the treatment process would be discharged into the FSMR industrial wastewater treatment system.	This technology has been proven to be effective for a variety of contaminants as long as the source is confined and limited.	The equipment and technology for pumping and treating are readily available. A change in the FSMR NPDES permit may be required.	Moderate capital with potentially high O&M costs; O&M costs depend on duration of pumping required.
Specialized Bacteria Addition	Specialized bacteria and nutrients in highly concentrated solutions and specific to biodegrading the COCs would be injected upgradient and at selected points within the area of groundwater contamination. Specialized bacteria addition might be included as a part of any in situ biological remediation alternative, including monitored natural attenuation, to increase the in situ biological activity.	This technology has been proven effective for organic constituents if specific bacteria are available for the COC(s) and the site geochemical conditions are aerobic, a state that is conducive to biodegradation of petroleum contaminants.	Specialized bacteria and the equipment for application are readily available. The treatment is applicable to a relatively small site. Approximately 22 groundwater injection points would have to be installed. Baseline groundwater sampling would be required, followed by monthly performance monitoring of the site for 6 months. In addition, confirmatory sampling (1year after the completion of the performance evaluation of the bacterial application) would be required. A UIC permit would be required for injection of specialized bacteria and nutrients.	Low; monitoring of the 13 impacted wells for baseline sampling, 6 months of sampling to evaluate the performance of the specialized bacteria addition, and confirmatory sampling (1 year after performance sampling).

Table 4-2. Evaluation of Corrective Actions/Technologies for Groundwater, SWMU 27F, Northwest of Building 1340 (continued)

Action/ Technology	Description	Effectiveness	Implementability	Costs
Air Sparging	Air sparging involves injecting air under pressure into the subsurface to volatilize groundwater contaminants and to promote biodegradation by increasing subsurface oxygen concentrations. Groundwater sampling would be performed at the completion of the treatment to confirm that remedial levels had been achieved.	The technology has been proven to be effective for the volatile organic chemicals present at the site.	The equipment is readily available. Air injection system components would be operated for 2 or more years. Approximately 16 injection wells would have to be installed. Monitoring and maintenance of the wells would be required. A UIC permit would be required for injection of air.	Moderate; \$20 to \$50 per ton of saturated soil.
Enhanced Bioremediation (Pure Oxygen Injection)	Enhanced bioremediation is the enhancement of one aspect of natural attenuation. The activity of naturally occurring microbes is stimulated by injecting 98-percent-pure oxygen to enhance in situ biological degradation of organic contaminants. Nutrients or other additives may be used to encourage the natural biodegradation processes. Groundwater sampling would be performed at the completion of the treatment to confirm that remedial levels had been achieved.	This technology has been proven to be effective for volatile organic chemicals; site geochemical conditions are aerobic, a state that is conducive to biodegradation of benzene.	The equipment is readily available, and the treatment is applicable to a small site. Approximately 15 injection points would have to be installed. The bioremediation process might require continuous monitoring and maintenance to prevent plugging of injection wells by microbial growth or mineral precipitation. A UIC permit would be required for injection of oxygen and/or nutrients.	Moderate; similar to air sparging based on quote from manufacturer.

Table 4-2. Evaluation of Corrective Actions/Technologies for Groundwater, SWMU 27F, Northwest of Building 1340 (continued)

Action/ Technology	Description	Effectiveness	Implementability	Costs
Oxygen-Releasing Compounds	This treatment uses formulations that release oxygen when they contact water to promote biodegradation. These formulations would be injected into the groundwater to promote rapid degradation of organic contaminants. Groundwater sampling would be performed at the completion of the treatment to confirm that remedial levels had been achieved.	This technology has been proven to be effective for treatment of fuel- and solvent-related constituents, such as benzene, in groundwater.	The equipment and oxygen-releasing-compound formulation are readily available. Approximately 22 injection points would have to be installed. The time to reach MCLs would be only nominally shorter than that for natural attenuation. A UIC permit would be required for injection of a reagent.	High capital with minimal O&M costs.
Geo-Cleanse®	The Geo-Cleanse® process is an aggressive, pressurized injection of a concentrated hydrogen peroxide and ferrous iron catalyst (together known as Fenton's reagent) that generates a free radical hydroxyl that acts as the active oxidizing agent. Oxidation of an organic compound by Fenton's reagent is a rapid and exothermic (heat-producing) reaction. Groundwater sampling would be performed at the completion of the treatment to confirm that remedial levels had been achieved.	This treatment would be expected to provide accelerated performance over air sparging; however, more than one application might be required to achieve remedial levels. Chemical oxidation would temporarily destroy the natural bioremediation processes at the site.	This treatment would be compatible with any Geo-Cleanse® treatment for the organic contaminants. Approximately 20 injection points would have to be installed. The time to reach MCLs would be a matter of days. Violent reactions of chemicals would impact operations at the maintenance facility. A UIC permit would be required for injection of a reagent.	High; would require injection of a large volume of peroxide per injection point relative to the small contaminant mass.

Table 4-2. Evaluation of Corrective Actions/Technologies for Groundwater, SWMU 27F, Northwest of Building 1340 (continued)

Action/ Technology	Description	Effectiveness	Implementability	Costs
Groundwater Monitoring	Groundwater from strategically located monitoring wells would be sampled and the groundwater analyzed for COCs over time. Groundwater monitoring would be used in conjunction with other alternatives to monitor the effectiveness of the remedial alternative or the fate and transport of groundwater HHCOCs.	This alternative is highly effective at monitoring the potential migration of constituents and the effectiveness of a remedial alternative.	Highly implementable. A groundwater monitoring network consisting of 13 shallow and three deep surficial groundwater monitoring wells already exists at SWMU 27F.	Low capital costs; moderate O&M costs depending on frequency of sampling.

COC = Constituent of concern.
FSMR = Fort Stewart Military Reservation.
HHCOC = Human health constituent of concern.
MCL = Maximum contaminant level.
NPDES = National Pollutant Discharge Elimination System.
O&M = Operations and maintenance.
OSWER = Office of Solid Waste and Emergency Response.
SWMU = Solid waste management unit.
UIC = Underground Injection Control.

4.1.3 Cost

Relative costs are included for each corrective action technology to facilitate evaluation and comparison among the alternatives. Detailed cost estimates are not prepared at this screening stage. Typical cost estimating contingencies have been excluded from the relative costs.

4.2 EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES

Corrective action technologies were identified for benzo(*a*)pyrene in surface soil and benzene in groundwater. The technologies were evaluated using the screening criteria of effectiveness, implementability, and cost.

4.2.1 Surface Soil

Four general categories of corrective actions were identified for benzo(*a*)pyrene contamination in surface soil, which is limited to approximately 2 feet bgs: (1) no action, (2) institutional controls, (3) natural attenuation, and/or (4) active remediation. Confirmatory sampling would be required after implementation of the corrective action to determine if remedial levels had been achieved. The corrective actions representing active remediation of benzo(*a*)pyrene in soil that were evaluated included excavation, specialized bacteria addition, tilling, and bioventing. The technologies considered for benzo(*a*)pyrene in soil are presented in Table 4-1.

The no action alternative was not considered to be viable due to the need to ensure that benzo(*a*)pyrene in surface soil achieves its remedial levels. Institutional controls were not considered further as the sole remedial alternative because they are appropriate for this site only when combined with other technologies. Natural attenuation and excavation were retained as the only technologies for surface soil. Both can achieve remedial levels in a relatively short period of time. Tilling and bioventing were eliminated due to the small quantity of contamination and limited accessibility for implementation of each of these alternatives. Excavation was considered viable because of the small quantity of contaminated surface soil present and because it would eliminate the potential risk immediately upon implementation.

4.2.2 Groundwater

Four general categories of corrective actions were identified for benzene in groundwater: (1) no action, (2) institutional controls, (3) natural attenuation, and/or (4) active remediation. Thirteen monitoring wells are located at the site, with wells located within and completely encircling the benzene plume; therefore, the effectiveness of the selected treatment and potential migration of the contamination could be monitored. Consequently, if during the remediation any previously undetected COCs appeared in the groundwater at concentrations above the RBCs, the selected remedy could be modified to address them.

In addition to no action, institutional controls, and monitored natural attenuation, various corrective action technologies were identified for active remediation of benzene in groundwater, including air sparging, specialized bacteria addition, pumping and treating, the Geo-Cleanse® process, and enhanced bioremediation (pure oxygen injection). The corrective action technologies and the results of the screening for benzene in groundwater are described in Table 4-2.

The no action alternative was not considered to be a viable option due to the need to ensure that benzene concentrations in groundwater achieve remedial levels. Institutional controls were not considered further as the sole remedial alternative because they are appropriate for this site only when combined with other technologies such as monitored natural attenuation. Pump-and-treat technologies were not considered because of their relatively high cost to achieve remedial levels. Monitored natural attenuation, specialized bacteria addition, and enhanced bioremediation using pure oxygen injection were retained for further evaluation. Chemical oxidation was excluded from further consideration because of its very high cost, limited benefit over the other treatment technologies, and difficulty to implement.

4.3 CORRECTIVE ACTION ALTERNATIVES

Excavation and monitored natural attenuation were retained as the technologies to meet the remedial response objectives for benzo(*a*)pyrene in surface soil. Monitored natural attenuation, specialized bacteria addition, and enhanced bioremediation were retained as the technologies to meet the remedial levels for benzene in groundwater. The screened alternatives for surface soil and groundwater were combined to form remedial alternatives to meet the remedial response objectives for soil and groundwater at SWMU 27F. Three alternatives were identified for remediation of the soil and groundwater at the site.

The three alternatives are

- Alternative 1: monitored natural attenuation for surface soil and groundwater,
- Alternative 2: monitored natural attenuation for surface soil and specialized bacteria addition for groundwater, and
- Alternative 3: excavation for surface soil and enhanced bioremediation with oxygen injection for groundwater.

4.3.1 Evaluation Factors

Based on the results of the technology screening, each of the retained technologies is considered applicable to the site, implementable, and cost-effective; therefore, two primary evaluation factors were used in the selection of the preferred corrective action alternative: time to implement and life-cycle cost.

Time to Implement

The time required to implement the action is an important evaluation factor for this site. Preferably, the site would be remediated to meet remedial levels for soil and groundwater in the shortest possible time. For each alternative an estimate was made of the duration of any active remediation system or of the duration of any natural attenuation period. For all alternatives confirmatory soil and groundwater sampling would be performed following the remediation/attenuation period to verify that remedial levels in soil and groundwater had been met.

Life-Cycle Cost

The life-cycle cost estimates are budget estimates based on conceptual design and are to be used for comparison purposes. Costs are estimated for capital construction and for O&M. Cost estimates are derived from current information including vendor quotes, conventional cost estimating guides (e.g., Means 2001 and ECHOS 2001), and costs associated with similar projects. The actual costs of the project would depend on labor and material costs, site conditions, competitive market conditions, final project scope, and implementation schedule at the time that the corrective action was initiated. The life-cycle cost estimates have not been adjusted to present worth costs, and no escalation factors have been applied. Appendix B presents a summary of the life-cycle cost estimates for each alternative.

4.3.2 Evaluation of Corrective Action Alternatives

The soil and groundwater technologies were combined to form three corrective action alternatives to remediate the COCs at the site. The three corrective action alternatives are summarized in Table 4-3, along with the corresponding times to reach remedial levels and associated life-cycle costs. All of the alternatives would include the common features listed below.

- Monitoring of MW12 for sheen and/or free product and removal.
- Groundwater monitoring to track the effectiveness of the corrective action. The existing monitoring well network would provide adequate coverage for monitoring lateral and vertical conditions within the benzene plume. The wells associated with monitoring of the benzene plume include 13 shallow surficial wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18].
- Post-remediation confirmatory groundwater sampling to verify that groundwater remedial levels have been achieved.

The paragraphs that follow summarize the evaluation of the three corrective action alternatives for the benzo(*a*)pyrene in surface soil and benzene in groundwater with respect to the primary evaluation factors of time to implement and life-cycle cost.

Alternative 1: Monitored Natural Attenuation

Monitored natural attenuation would involve soil sampling for up to 3 years (1 year added as a contingency) and groundwater sampling for 7 years (1 year added as contingency) at 13 monitoring wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] beginning in calendar year (CY) 2002.

Modeling estimated that benzo(*a*)pyrene in surface soil would achieve its remedial level in 26 months from October 1999 (i.e., December 2001). In CY 2002 two surface soil samples would be collected from around MW10 using a hand auger and analyzed for SVOCs to confirm that remedial levels for benzo(*a*)pyrene had been achieved. If remedial levels for benzo(*a*)pyrene had not been achieved, then additional surface soil samples would be obtained in conjunction with the first biannual groundwater sampling event (CY 2004) discussed below. Only two soil sampling events would be expected. If benzo(*a*)pyrene was not detected above remedial levels during the initial soil sampling, then that sampling event would be considered to represent the final/confirmatory soil sampling.

The groundwater from the 13 wells would be sampled in CY 2002, followed by biannual (every 2 years) groundwater sampling for the next 6 years. Modeling estimated the time to reach remedial levels to be 6 years (monitored natural attenuation period) from January 2001. An additional year of natural attenuation time was added as a contingency.

The groundwater monitoring network would consist of 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18]. The baseline for beginning the natural attenuation period would be the groundwater results collected in January 2001. Figure 4-1 identifies the monitoring wells to be sampled at SWMU 27F.

Table 4-3. Corrective Action Alternatives, Implementation Time, and Costs for Remediation, SWMU 27F, Northwest of Building 1340

Corrective Action	Description	Time to Implement	Cost	Comments
Alternative 1: Monitored Natural Attenuation	This alternative would require the monitoring of contaminant levels in soil and groundwater and natural attenuation parameters in groundwater to ensure the reduction of contaminants through biodegradation and dispersion.	Modeling estimated that benzo(*a*)pyrene in surface soil will achieve its remedial level in 26 months from October 1999 (i.e., December 2001). The estimated time based on modeling for benzene to reach its remedial level in groundwater is approximately 6 years from January 2001. An additional year was added to the monitored natural attenuation period for benzene in groundwater as a contingency. Soil samples would be collected in CY 2002 and during the first biannual groundwater sampling event (if necessary) to confirm that soil remedial levels had been achieved. The monitored natural attenuation period was set for 7 years from CY 2001, including 1 year as a contingency. Thirteen wells would be sampled in CY 2002, followed by biannual sampling (every 2 years) for the next 6 years. Confirmation groundwater sampling would be performed 1 year after the monitored natural attenuation period. The total implementation time including final reporting would be 8.5 years.	Approximately $295,000 for two soil and four groundwater sampling events of 13 wells during natural attenuation period, followed by confirmatory groundwater sampling of 13 wells at 1 year after monitored natural attenuation period.	Least expensive, but longer time to implement.

Table 4-3. Corrective Action Alternatives, Implementation Time, and Costs for Remediation, SWMU 27F, Northwest of Building 1340 (continued)

Corrective Action	Description	Time to Implement	Cost	Comments
Alternative 2: Monitored Natural Attenuation for Soil and Specialized Bacteria Addition for Groundwater	As in Alternative 1, monitored natural attenuation would be used to achieve remedial levels for benzo(*a*)pyrene in soil. In addition, the action would require the installation of 22 groundwater injection wells, injection of specialized bacteria over 6 months (includes a 3-month contingency), and the monitoring of contaminant levels to ensure the reduction of contaminants in groundwater through biodegradation.	Modeling estimated that benzo(*a*)pyrene in surface soil will achieve its remedial level in 26 months from October 1999 (i.e., December 2001). The remedial levels for benzo(*a*)pyrene in surface soil would be achieved by natural attenuation within the implementation time for specialized bacteria addition. This alternative is easily implementable. Materials, equipment, and specialized bacteria to implement this alternative are easily obtainable. Specialized bacteria addition would be expected to reduce contaminants to below remedial levels in 6 months (includes a 3-month contingency). Confirmatory sampling would be performed 1 year after the final performance monitoring. Total implementation time would be approximately 26 months.	Approximately $429,000, including baseline sampling of 13 well locations, installation of 22 groundwater injection wells, bacterial injection for 6 months, monthly performance sampling of up to 13 wells for 6 months, confirmatory sampling of 13 wells (1 year after performance sampling), and up to two rounds of soil sampling to confirm that soil remedial levels have been achieved.	Relatively low-cost alternative and shorter time to implement than monitored natural attenuation and enhanced bioremediation.

Table 4-3. Corrective Action Alternatives, Implementation Time, and Costs for Remediation, SWMU 27F, Northwest of Building 1340 (continued)

Corrective Action	Description	Time to Implement	Cost	Comments
Alternative 3: Excavation for Soil and Enhanced Bioremediation (with Oxygen Injection) for Groundwater	The action would require excavation (and confirmatory sampling) of the benzo(*a*) pyrene–contaminated surface soil. Enhanced bioremediation would be used to promote biological degradation of benzene in groundwater. Pure oxygen would be injected into the groundwater. Fifteen oxygen injection wells would be installed with their screens approximately 10 feet below the water table.	Soil remedial levels would essentially be achieved upon excavation of the soil. Oxygen injection treatment would require approximately 12 months to reduce the COCs to remedial levels. Confirmatory groundwater sampling would be performed 12 months after oxygen injection treatment was complete, for a total implementation time of approximately 3 years (including system installation and final reporting).	Approximately $955,000 (monthly monitoring of 13 wells during treatment, treatment using 15 injection points, and confirmatory sampling after 12 months).	Most expensive.

COC = Constituent of concern.
CY = Calendar year.

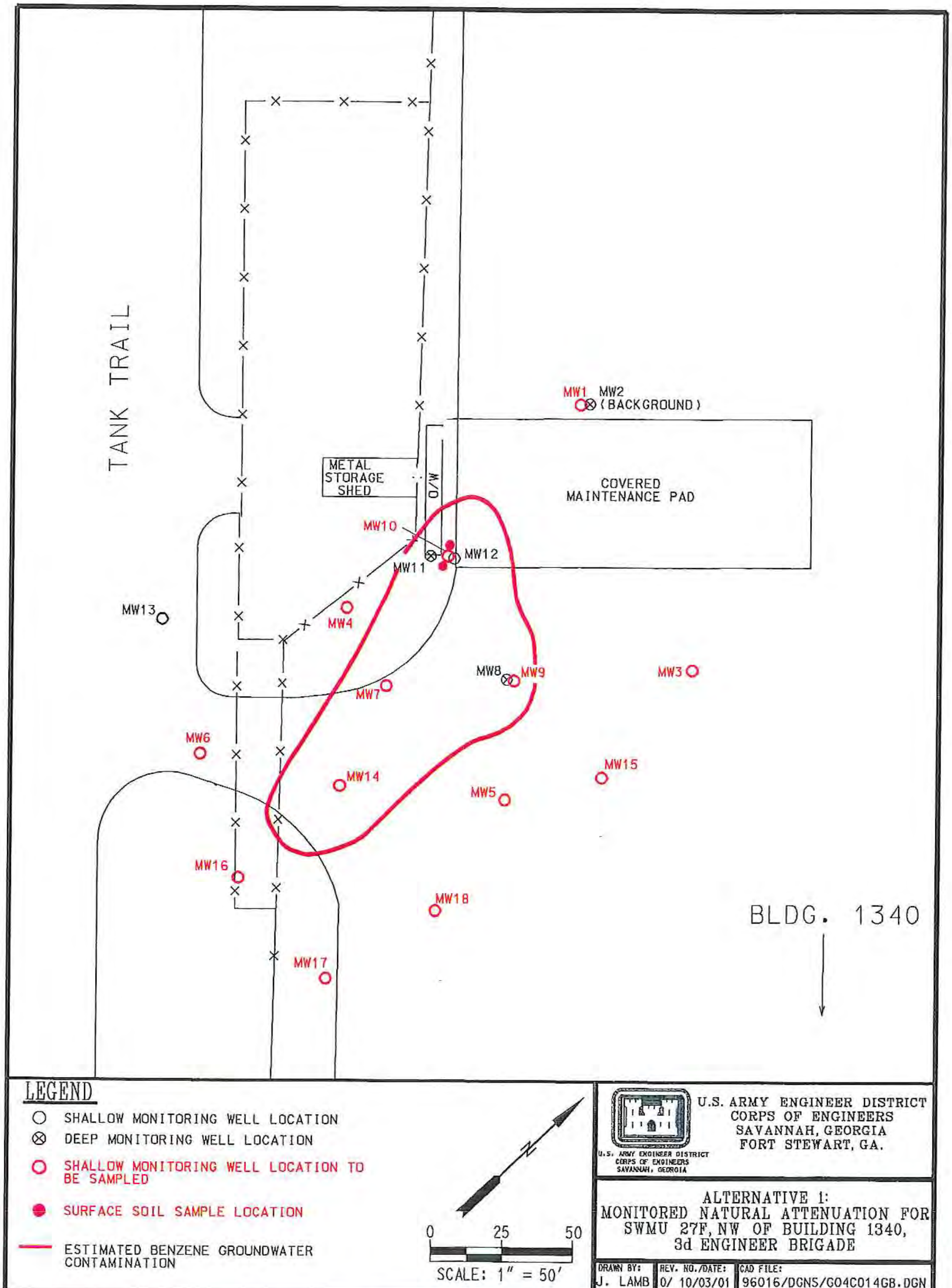

Figure 4-1. Alternative 1: Monitored Natural Attenuation for SWMU 27F, Northwest of Building 1340

The groundwater samples would be analyzed for VOCs, SVOCs, and natural attenuation parameters [i.e., methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron (field measurement)]. SVOCs were included in the analysis because they were detected in groundwater (but below RBCs) and because they are characteristic of the materials or waste disposed of at the now abandoned OWS, the presumed source of the contamination. During the 7 years, concentrations of benzene in groundwater are predicted to decline below its MCL of 5 µg/L at all monitoring well locations. One year following this monitored natural attenuation period, confirmation groundwater sampling would be conducted to verify that the concentrations of benzene had remained below its remedial level. The confirmatory groundwater sampling would be identical to the biannual groundwater sampling. The soil samples indicating benzo(*a*)pyrene levels below remedial levels would be considered the final/confirmatory soil samples.

CAP progress reports would be issued after each groundwater sampling event to provide the results of the sampling and the progress of the natural attenuation. The results of the surface soil sampling conducted in CY 2002 would be reported in the first CAP progress report. A total of four CAP progress reports (one for each of CYs 2002, 2004, 2006, and 2008) would be issued. If concentrations of COCs were detected below remedial levels after two consecutive monitoring events, FSMR would request that the sampling be discontinued and confirmatory sampling scheduled. A CAP completion report would be issued after the confirmatory sampling.

This would be the least expensive alternative, with a life-cycle cost of approximately $295,000, but would take the longest time (7 years, including 1 year for a contingency) from CY 2001 to implement. The 8.5 years from CY 2001 would include 7 years of monitored natural attenuation (1 year added as a contingency), 1 year for confirmatory groundwater sampling, and approximately 6 months for work plan development and final reporting.

Alternative 2: Monitored Natural Attenuation for Soil and Specialized Bacteria Addition for Groundwater

Natural attenuation modeling has estimated that it would require 26 months from October 1999 for benzo(*a*)pyrene in surface soil and 6 years from CY 2001 for benzene in groundwater to reach their respective remedial levels. The addition of specialized bacteria would be expected to reduce this natural attenuation period for benzene in groundwater to approximately 6 months, including a 3-month contingency (added because this technology has not been used at FSMR). The remedial level for benzo(*a*)pyrene would be achieved by natural attenuation during the implementation of the specialized bacteria addition for benzene in groundwater.

Two surface soil samples would be collected around MW10 using a hand auger and analyzed for SVOCs in CY 2002 to confirm that remedial levels for benzo(*a*)pyrene had been achieved. The soil sampling would be scheduled during one of the mobilizations for the implementation of specialized bacteria addition. If remedial levels for benzo(*a*)pyrene had not been achieved, then additional surface soil samples would be collected in conjunction with the confirmatory groundwater sampling event scheduled for 1 year after the completion of specialized bacteria addition. Only two soil sampling events would be expected.

Baseline groundwater sampling of 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] for VOCs and SVOCs would be performed to confirm the type and quantity of specialized bacteria to be added to groundwater.

Twenty-two 3/4-inch-inside-diameter (ID) polyvinyl chloride (PVC) injection wells with 10-foot screens would be installed upgradient and within the groundwater plume to approximately 10 feet below the water table (Figure 4-2). The baseline groundwater sampling would be used to confirm the type and

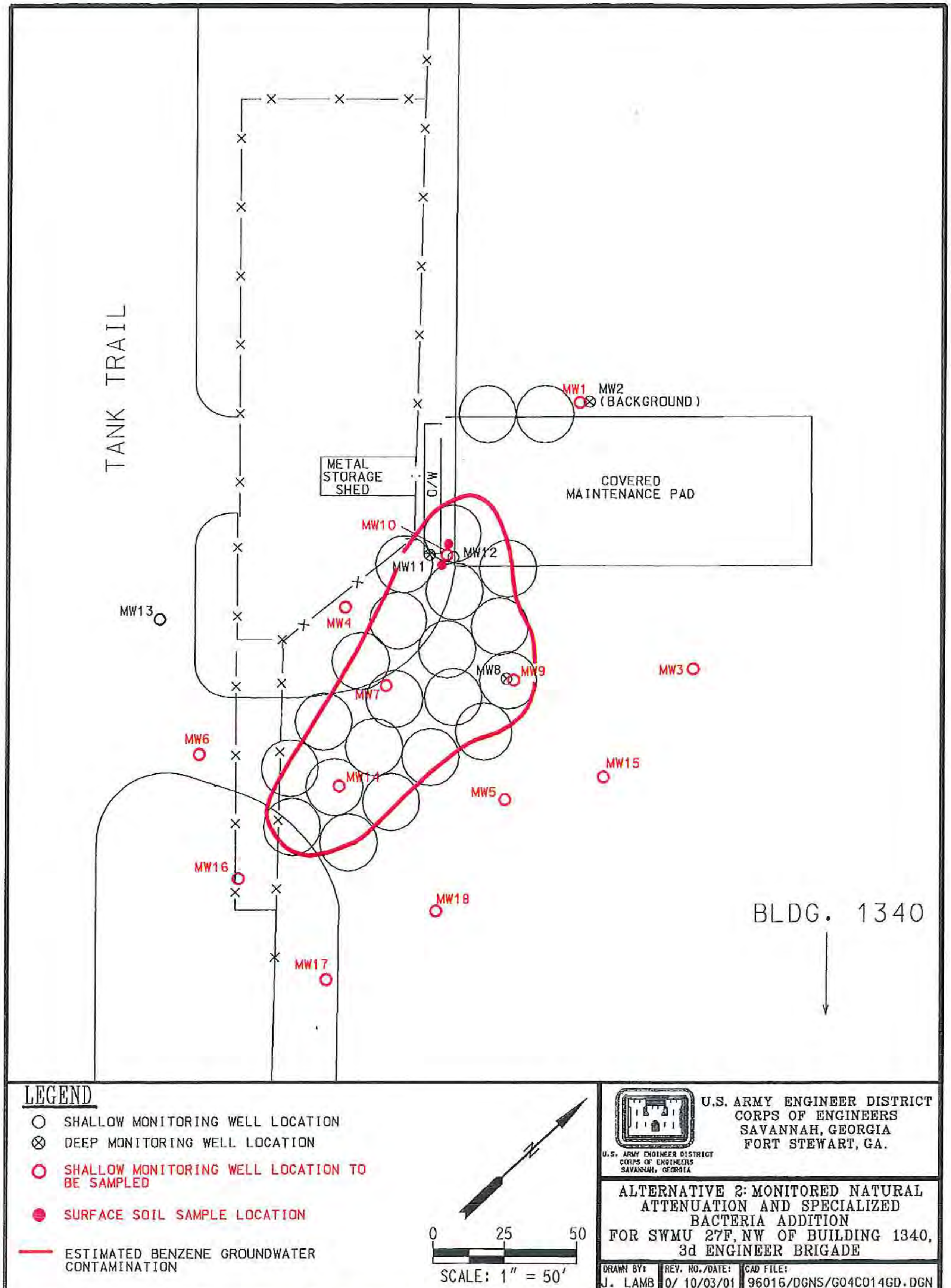

Figure 4-2. Alternative 2: Monitored Natural Attenuation and Specialized Bacteria Addition for SWMU 27F, Northwest of Building 1340

quantity of specialized bacteria to be added. In addition, field measurements of pH, Redox, turbidity, and DO would be taken at each monitoring well. Specialized bacteria specific to benzene (petroleum contaminants) would be added monthly for 6 months. Groundwater samples for VOCs, SVOCs, nitrate, phosphate, and field measurements would be collected monthly from the same 13 shallow surficial groundwater wells sampled for the baseline sampling to evaluate the performance of the specialized bacteria addition. Therefore, if the CY 2002 soil samples contained concentrations below the remedial level, soil samples would not be collected during confirmatory groundwater sampling.

Confirmatory soil sampling (if required) and groundwater sampling would be performed 1 year after completion of the specialized bacteria addition to verify that remedial levels had been achieved and maintained across the site. Confirmatory groundwater sampling would consist of sampling the 13 shallow surficial groundwater wells that were sampled for the baseline and performance sampling. The soil samples indicating benzo(*a*)pyrene concentrations below the remedial levels would be considered the final/confirmatory soil samples.

A CAP progress report would be issued after the completion of the specialized bacteria addition to report its performance. The results of the soil sampling would be discussed in the CAP progress report. A CAP completion report would be issued after the confirmatory sampling. The results of the final soil sampling (if necessary) would be discussed in the CAP completion report.

The total time from contract award to completion of the specialized bacteria addition alternative would be approximately 26 months (including work plan development, subcontracting, treatment, and final reporting). The estimated treatment time to achieve soil and groundwater remedial levels using the specialized bacteria addition alternative would be the shortest of all the alternatives. This alternative would have an estimated life-cycle cost of approximately $429,000.

Alternative 3: Excavation and Enhanced Bioremediation (Pure Oxygen Injection)

Excavation of the contaminated surface soil to approximately 2 feet bgs would be performed by hand and mechanical means. The area to be excavated would be the area that potentially received spills from the draining of oil containers and filters on the top of the OWS, which would include the area extending from the abandoned OWS to the southern end of the covered maintenance pad, estimated to encompass 150 square feet (Figure 4-3). Confirmatory samples would be collected from the four sides of the bottom of the excavation and analyzed for SVOCs on 24-hour turnaround. Depending on whether remedial levels in soil had been achieved, an additional 1 foot of soil might be excavated and up to four additional confirmatory soil samples collected. The excavation would be filled with clean backfill and seeded, with straw placed on the surface.

Initial baseline groundwater sampling would be performed to determine the present nature of the contamination and to confirm the appropriateness of the enhanced bioremediation design. The baseline sampling would consist of groundwater sampling of 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] for VOCs and SVOCs.

Approximately 15 oxygen injection points would be installed to treat the benzene plume. The groundwater injection wells would be of similar design to those presented in Alternative 2. The groundwater injection wells would be 3/4-inch-ID PVC with a 1-foot screen installed to approximately 10 feet below the water table. One oxygen generator capable of producing 80 standard cubic feet per hour of 90- to 95-percent-pure oxygen would be located at the site. The injection wells and all piping to the injection wells would be installed flush to the ground to allow access to the covered maintenance pad. Temporary fencing would be placed around the injection wells, surface piping, and oxygen generator located on the grass to

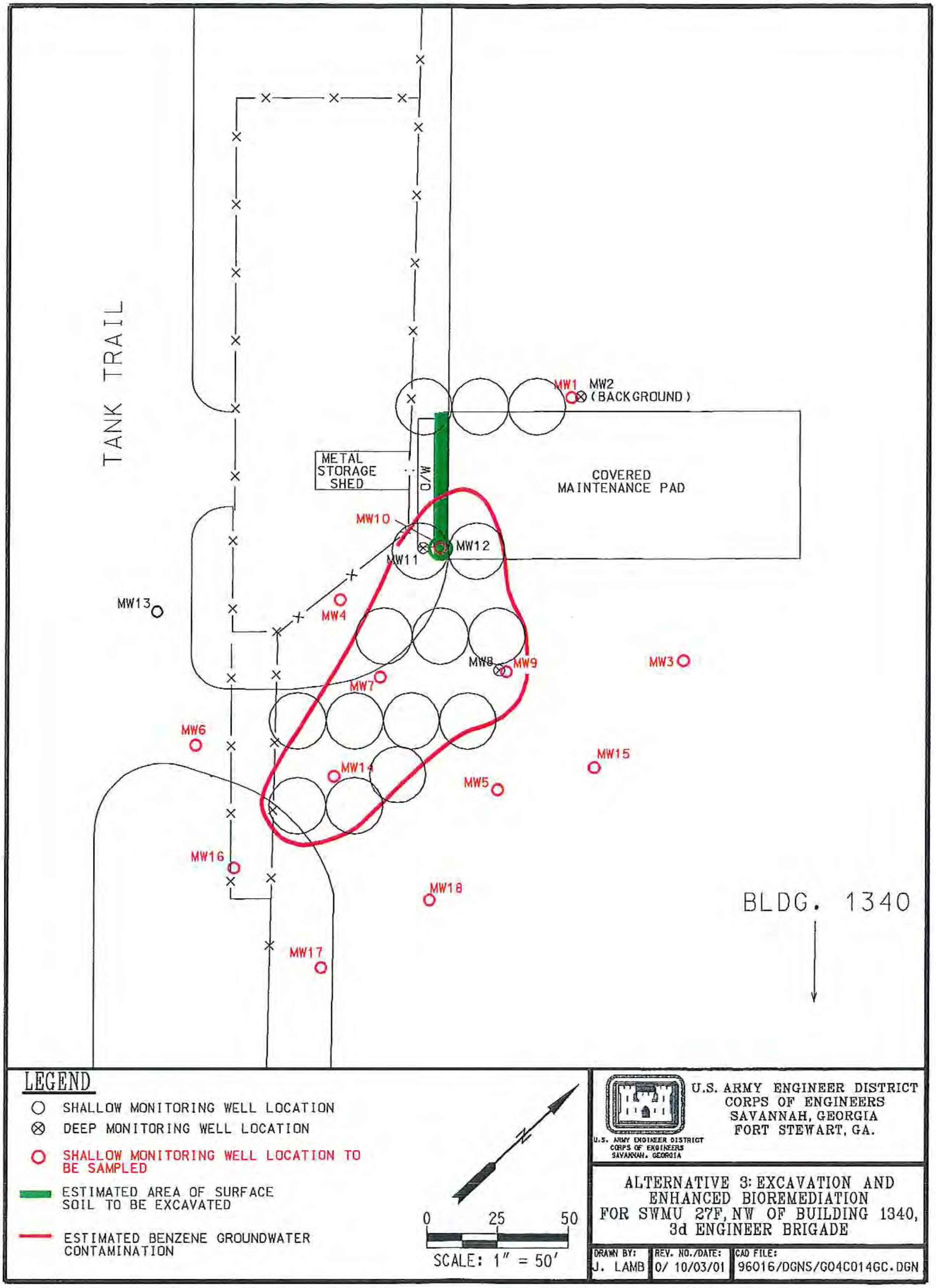

Figure 4-3. Alternative 3: Excavation and Enhanced Bioremediation for SWMU 27F, Northwest of Building 1340

the southeast to restrict unauthorized access to the area. The oxygen injection wells located in the concrete area entering the covered maintenance pad would be installed underground to allow access to the pad.

Treatment would consist of enhancing bioremediation by injection of 90- to 95-percent-pure oxygen and would continue until the concentration of benzene declined to a level below its MCL of 5 μg/L, estimated to require approximately 12 months, not including any contingency period. Groundwater monitoring would include monthly sampling of the same 13 monitoring wells to evaluate how the treatment was progressing. This active treatment period would be followed by confirmatory groundwater sampling (once after 1 year) to verify that the groundwater remedial levels had been met and maintained. The confirmatory sampling would be identical to the baseline and performance sampling previously discussed.

Two CAP progress reports would be issued: one after the excavation of the soil, installation of the injection wells, and startup and the other after an additional year to report the performance of the enhanced bioremediation alternative. If concentrations of COCs were detected at concentrations below remedial levels earlier than expected, FSMR would request that the injection and sampling be discontinued and confirmatory sampling scheduled. A CAP completion report would be issued after the confirmatory sampling.

This alternative would be more expensive than Alternatives 1 and 2, with a life-cycle cost estimated at approximately \$955,000. The time required for implementation would be approximately 3 years (including work plan development, subcontracting, installation, treatment, and final reporting).

5.0 CONCEPTUAL DESIGN AND IMPLEMENTATION PLAN

This section presents a conceptual design and plan for implementation of the selected corrective action alternative. Based on the available groundwater data and modeling results, a cost-effective corrective action has been selected that will reduce the COCs in soil and groundwater to the required remedial levels. The technology evaluation presented in Chapter 4.0 considered three different corrective action alternatives for the soil and groundwater based on the time needed to implement them and their life-cycle costs. Based on that evaluation, Alternative 1, monitored natural attenuation, has been selected for the soil and groundwater because of its acceptable implementation time and cost-effectiveness. An O&M Plan for this alternative is presented in Appendix C.

5.1 SELECTED CORRECTIVE ACTION

The selected corrective action alternative for treatment of soil and groundwater is monitored natural attenuation. In addition, implementation of institutional controls (i.e., land use controls) would be required for the duration of the monitored natural attenuation alternative to establish the activities that are permitted at the site during the natural attenuation period (i.e., until site remedial levels have been achieved).

5.1.1 Justification for Selection of Corrective Action

Monitored natural attenuation has been selected for remediation of soil and groundwater because it will effectively achieve the remedial levels in a reasonable period of time and will do so cost-effectively. Modeling indicated that monitored natural attenuation will achieve remedial levels for benzo(*a*)pyrene in surface soil in 26 months from October 1999, the date of the highest detected surface soil concentration. The predicted natural attenuation period has already elapsed (i.e., till December 2001). Confirmatory soil sampling at the location of the previously highest detected surface soil concentration of benzo(*a*)pyrene will confirm that the contaminated soil has been remediated. Excavation might provide a higher degree of reliability than monitored natural attenuation and less uncertainty but at a higher cost.

Monitored natural attenuation is expected to achieve the groundwater remedial levels in less than 6 years from January 2001; however, an additional year will be added to the natural attenuation period as a contingency. Confirmatory groundwater sampling and analysis will be conducted 1 year after completion of the monitored attenuation period to provide additional assurance that concentrations of COCs do not exceed their remedial levels. Other corrective action alternatives, such as specialized bacteria addition or enhanced bioremediation with pure oxygen injection, might provide a higher degree of reliability and less uncertainty in their effectiveness than monitored natural attenuation, but they would cost substantially more to achieve the remediation goals.

Monitored natural attenuation is appropriate for addressing benzo(*a*)pyrene in soil and benzene in groundwater at SWMU 27F. No significant soil source of contamination exists. Appendix D lists considerations for the selection of monitored natural attenuation for benzo(*a*)pyrene in soil and benzene in groundwater in accordance with the guidance of OSWER Directive 9200.4-17P (EPA 1999).

Justification for the selection of this corrective action alternative is provided in the following evaluations of effectiveness, implementability, and cost.

Effectiveness. The selected corrective action will be effective in protecting human health and the environment. Based on the conclusions of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report (SAIC 2000), there is no current human health or ecological risk associated with the soil or groundwater contaminants at SWMU 27F. Soil does represent a risk to the on-site Installation worker, and remediation by natural attenuation will eliminate the source of potential future risk to future residents. Potential exposure to groundwater is extremely unlikely because the shallow groundwater is not a viable source of drinking water. The selected alternative will achieve the remedial level within a relatively short timeframe (less than 1 year for soil and less than 6 years for groundwater), thereby effectively eliminating any potential future risk. The selected alternative will not require long-term O&M beyond the natural attenuation monitoring period and 1-year confirmatory sampling period; therefore, it will provide long-term reliability. Short-term risks to human health or the environment will be minimal because attenuation will occur in situ. No air emissions or surface water discharges will be associated with the selected corrective action from the treatment of groundwater. Potential exposure of remediation workers to contaminants will be limited. Minimal exposure could result during sampling events; however, any exposure will be minimized and kept below acceptable levels through the use of proper protective clothing and strict adherence to the project-specific health and safety plan.

The time required to achieve remedial levels for benzo(a)pyrene in soil was estimated by modeling to be 26 months from October 1999 (i.e., December 2001). In groundwater the time required to degrade benzene from a maximum of 61 μg/L (January 2001 at MW14) to its MCL of 5 μg/L has been estimated to be 6 years from January 2001 (see Appendix A).

Implementability. The selected corrective action is readily implementable. Modeling estimated that the remedial level for benzo(*a*)pyrene in surface soil will be achieved in 26 months from October 1999 (i.e., December 2001). Confirmatory soil sampling at the location of the previously highest detected surface soil concentration of benzo(*a*)pyrene will confirm that the contaminated soil has been remediated.

Modeling indicated that the remedial levels for benzene in groundwater will be achieved in a relatively short period of time (within 6 years). As a contingency an additional 1 year will be added to the natural attenuation period estimated by modeling. Confirmatory sampling will be performed 1 year after the natural attenuation period, resulting in a total of 8.5 years (including final reporting) to complete the alternative. The selected corrective action will use monitoring of VOC and SVOC concentrations to ensure that the remedial level for the site is being met. A detailed project implementation schedule is presented in the conceptual design later in this section.

Cost. The estimated total life-cycle cost of operations, maintenance, and confirmatory sampling for the selected corrective action is $295,000. Monitored natural attenuation is the least expensive alternative and will require 8.5 years from January 2002 to achieve the remedial levels. Costs estimated for the other corrective action alternatives were much higher than those for monitored natural attenuation, ranging from $429,000 to $955,000.

5.2 CONCEPTUAL DESIGN

The conceptual design and cost estimate presented in this section are based on the subsurface stratigraphy information presented on the drilling logs, the most recent contaminant chemistry for the soil and groundwater, and past experience with similar remediation systems.

5.2.1 Establishment of Institutional Controls

Land-use requirements will be implemented and enforced by Fort Stewart DPW at SWMU 27F as part of the corrective action. The land-use restrictions will prohibit the following within the identified boundaries of SWMU 27F:

- all activities that may result in disturbance of surface and subsurface soil and/or substantially interfere with implementation of the selected remedial alternative except for those activities associated with maintenance/demolition/repair of SWMU 27F or adjacent facilities and their associated utilities;

- use of groundwater beneath the subject property except for the installation of groundwater monitoring wells and/or potentially wells required for remediation of the groundwater (i.e., extraction or injection wells);

- hunting and recreational activities; and

- all construction within the property boundaries except for those activities associated with maintenance of the facility, soil and/or groundwater sampling, implementation of the selected alternative, or potential abandonment and/or demolition of the facility.

These land-use restrictions will be enforced at SWMU 27F until remedial levels are achieved and SWMU 27F is formally closed under RCRA.

FSMR has no plans for transferring the SWMU 27F area from federal ownership; however, if in the future (i.e., prior to remedial levels being achieved) the SWMU 27F site is to be released from federal ownership, GEPD will be notified, and the CAP will be amended. Appropriate land-use controls (if any) related to the future property transfer will be evaluated and documented in the amended CAP. The purchase agreement(s) and deed recordation or lease agreement will reference this CAP and other environmental documents that contain the rationale for the restrictions. As required by the U.S. Department of Defense policy "Responsibility for Additional Environmental Cleanup after Transfer of Property," the property disposal agent will ensure that the transfer documents for real property reflect the land-use controls. All applicable and appropriate state land-use control management systems in effect at the time of transfer will also be implemented.

5.2.2 Monitored Natural Attenuation of Surface Soil

Modeling estimated that benzo(*a*)pyrene in surface soil will achieve its remedial level in 26 months from October 1999 (i.e., December 2001). Two surface soil samples will be collected around MW10 [the surface soil sample location indicating the highest concentration of benzo(*a*)pyrene] in CY 2002. The soil samples will be collected using a hand auger and analyzed for SVOCs to confirm that remedial levels for benzo(*a*)pyrene have been achieved. If remedial levels for benzo(*a*)pyrene have not been achieved, then additional surface soil samples will be collected in conjunction with the first biannual groundwater sampling event (CY 2004). Only two soil sampling events are expected to be required. When benzo(*a*)pyrene is no longer detected above remedial levels in the surface soil samples, then that sampling event will represent the final one. No confirmatory samples will be required for soil.

5.2.3 Monitored Natural Attenuation of Groundwater

The conceptual design includes groundwater sampling to monitor the performance of natural attenuation and confirmatory sampling to confirm that remedial levels have been achieved in groundwater. The monitoring well locations were selected (1) to encircle the locations of the maximum detected groundwater concentrations of the benzene and (2) to have wells located on the upgradient as well as the downgradient side of the plume to ensure detection of benzene and possibly other COCs identified in the future.

The start (baseline) of the natural attenuation period will be considered to be January 2001, the date of the latest complete round of groundwater samples at SWMU 27F (see Section 2.9). During the monitored natural attenuation period, 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] will be sampled to verify that benzene concentrations are declining, that the concentrations of other COCs not detected to date have continued to be below remedial levels and are not increasing with time, and that active biodegradation is occurring. In addition, the water level and potential free product would be measured in MW12, the monitoring well installed to the clay layer approximately 8 feet bgs. The first monitoring event will be performed in CY 2002. Samples will be analyzed at an off-site laboratory for VOCs, SVOCs, and natural attenuation parameters [methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron (field analysis)]. Field measurements to be made will include DO, temperature, Redox, conductivity, and pH. Biannual (every 2 years) groundwater sampling events will be performed for the final 6 years of the natural attenuation period, resulting in a total of four groundwater sampling events over the 7-year natural attenuation period.

Based upon the results of groundwater modeling, the monitored natural attenuation period is expected to be 6 years in duration; however, an additional 1 year has been added as a contingency. If groundwater monitoring over two consecutive sampling periods indicates that benzene in groundwater is at concentrations below remedial levels or nondetect and if the other potential COCs in groundwater are nondetect, Fort Stewart can elect to request approval from GEPD for the discontinuation of the annual sampling and for groundwater confirmatory sampling to be performed 1 year from the date of the last groundwater sampling event. With the concurrence of GEPD, the confirmatory sampling will then be performed and the results used to determine if monitored natural attenuation has achieved the remedial goals in groundwater.

Completion Criteria. Monitored natural attenuation of surface soil will be considered complete when surface soil samples indicate that benzo(*a*)pyrene concentrations are below remedial levels. Monitored natural attenuation for benzene in groundwater will be considered complete upon attaining a maximum benzene concentration in groundwater in each of the wells below the remedial level, as measured during the groundwater monitoring event. However, groundwater monitoring might continue for the full 7 years (6-year monitored natural attenuation period plus 1-year contingency) to ensure that the groundwater remedial levels are maintained. As discussed under Section 5.2.2, if groundwater monitoring over two consecutive sampling events indicates benzene in groundwater at concentrations below its remedial level and if no other potential COCs are detected, Fort Stewart can elect to request of GEPD that the sampling be discontinued and that groundwater confirmatory sampling be performed 1 year from the date of the last groundwater sampling event. With the concurrence of GEPD, the confirmatory sampling will then be performed and the results used to determine if monitored natural attenuation has achieved the remedial goals in groundwater.

If benzene is detected in groundwater at concentrations above its remedial level after 6 years or if COCs that have not been detected in groundwater to date are detected and show an increasing trend, the remedial action will be reevaluated to determine whether the attenuation period should be extended or whether more aggressive remedial technologies should be applied. Confirmation groundwater sampling will be conducted 1 year after the end of the monitored natural attenuation period to verify that groundwater remedial levels for benzene have been achieved and maintained. Thirteen groundwater monitoring wells at SWMU 27F will be sampled once, 1 year following the completion of monitored natural attenuation. Samples will be collected from each of the wells and analyzed for VOCs and SVOCs.

5.2.4 Well Abandonment

With the concurrence of GEPD, the groundwater monitoring wells will be abandoned when the completion criteria indicate that groundwater concentrations are below remedial levels. Upon approval by GEPD, 14 monitoring wells (MW1 through MW18) will be properly abandoned. The abandonment of the monitoring wells will include just grouting of the wells to the ground surface because they are flush-mounted wells.

5.3 OPERATIONS AND MAINTENANCE PLAN

Appendix C presents the O&M Plan for the selected remedial alternatives. O&M activities will include monitoring of contamination trends in groundwater starting in CY 2002, followed by biannual (every 2 years) sampling throughout the estimated 7-year monitored natural attenuation period (6 years plus 1 year contingency) plus one confirmatory sampling event 1 year following completion.

5.4 LIFE-CYCLE COST ESTIMATE

The total life-cycle cost estimate for the selected alternatives for the monitored attenuation alternative is $295,000 (see Appendix B for the cost components). Table 5-1 summarizes the life-cycle costs estimated for remediation of groundwater. Capital costs, including indirect costs, are estimated to be $20,000 and include engineering services (work plan, site safety and health plan, contracting/procurement, permitting, and baseline monitoring). The O&M costs, including indirect costs, are estimated to be approximately $180,000. The total costs of monitored natural attenuation for groundwater are estimated to be $295,000, including contingencies, management, health and safety, and contractor profit.

Table 5-1. Estimated Cost for Selected Alternative for SWMU 27F, Northwest of Building 1340

Site	Capital Costs	O&M	Other[a]	Total
SWMU 27F	$20,000	$180,000	$95,000	$295,000

[a]Includes construction management, contingency, health and safety, and contractor profit.

5.5 IMPLEMENTATION SCHEDULE

Implementation of the corrective action will begin once approval of this CAP is received from GEPD. It is anticipated that the final corrective action work plan (including appropriate reviews by the Army) will be completed within 3 months after approval of the CAP.

The soil and groundwater monitoring for CY 2002 will be conducted during the same field mobilization.

Based on the groundwater modeling results presented in Appendix A, the required monitoring time for monitored natural attenuation of groundwater is expected to be approximately 6 years. An additional year will be added to the monitored natural attenuation period estimated by modeling as a contingency, for a total of 7 years. Confirmatory sampling for groundwater will be conducted 1 year following the monitored natural attenuation period to verify that remedial levels have been achieved and maintained in groundwater. Remediation should, therefore, be complete within approximately 7 years. A CAP Completion Report will be prepared and submitted to GEPD for review within 4 months of the completion of the confirmatory sampling. FSMR will abandon the monitoring wells within 90 days of

GEPD approval of the CAP Completion Report. The expected implementation schedule is presented in Figure 5-1.

5.2 REPORTS

5.2.1 Corrective Action Plan Progress Report

A CAP progress report will be prepared after each groundwater sampling event during the 7-year monitored natural attenuation period. These reports will summarize the sampling and analytical results of each groundwater monitoring event. The results of the soil and groundwater monitoring for CY 2002 will be presented in the first CAP progress report. An analysis of trends and effectiveness of the corrective action will be presented. The need for any contingent action (extending or decreasing the natural attenuation period, implementing active remediation, etc.) will also be discussed, as required.

A checklist is presented in the O&M Plan (Appendix C) that summarizes the items to be addressed in each CAP progress report.

5.2.2 Corrective Action Completion Report

A final CAP Completion Report will be prepared following the completion of the corrective action and confirmatory sampling (1 year after the natural attenuation period). The CAP Completion Report will summarize the corrective measures taken at the site, provide a summary of sampling data, and give results of the confirmation groundwater sampling.

5.3 IMPLEMENTATION PLAN

Upon approval of this CAP by GEPD, Fort Stewart will request funding, procure a contractor for implementing the corrective actions, and implement the specified actions. A corrective action work plan will be prepared to guide implementation of the corrective action but will not require GEPD review or approval. Any revisions required to the O&M Plan (Appendix C) or the implementation schedule (Figure 5-1) that become apparent during preparation of the work plan will be submitted to GEPD for concurrence. Substantive changes in the remediation approach or schedule will require that the public be provided with an opportunity for review and comment, in accordance with the Fort Stewart Hazardous Waste Facility Permit. No other submittals will need to be provided to GEPD prior to implementation of the selected corrective action.

As discussed in Section 5.5, progress reports will be prepared during the corrective action and submitted to GEPD for review and approval. Upon completion of the corrective action, a CAP Completion Report will also be prepared and submitted to GEPD for review and approval.

Activity ID	Original Duration	
SWMU 27F CORRE...	2475.0d	SWMU 27F CORRECTIVE ACTION PLAN, FT STEWART, GA
SWMU 27F. TASK 1...	60.0d	SWMU 27F. TASK 1 CONTRACT NEGOTIATIONS
A1000	0.0d	NTP CAP Approved
A1010	60.0d	Contract Negotiations
SWMU 27F. TASK 2...	90.0d	SWMU 27F. TASK 2 WORKPLAN
A1020	30.0d	Draft Workplan
A1030	0.0d	Submit Draft Workplan
A1040	30.0d	Review by Fort Stewart & USACE of Draft Workplan
A1050	30.0d	Final Workplan
A1060	0.0d	Submit Final Workplan
SWMU 27F. TASK 3...	1860.0d	SWMU 27F. TASK 3 MONITORED NATURAL ATTENUATION
A1070	15.0d	Mobilization and Sampling
A1080	5.0d	1st Bi Annual Groundwater and Soil Sampling
A1090	5.0d	2nd Bi Annual Groundwater Sampling
A1100	5.0d	3rd Bi Annual Groundwater Sampling
A1110	5.0d	Confirmatory Sampling
SWMU 27F. TASK 4...	1695.0d	SWMU 27F. TASK 4 CORRECTIVE ACTION PLAN PROGRESS REPORT
A1120	225.0d	First Bi Annual CAPP Report
A1130	60.0d	Draft CAPP Report
A1140	0.0d	Submit Draft CAPP Report
A1150	30.0d	Review by Ft Stewart & USACE of Draft CAPP Report
A1160	30.0d	Final CAPP Report
A1165	0.0d	Submit Final CAPP Report
A1170	45.0d	Review by GEPD, Fort Stewart, USACE of Final
A1180	30.0d	Corrected Final CAPP Report
A1190	0.0d	Submit Corrected Final CAPP Report
A1200	30.0d	Approval by GEPD, Fort Stewart, USACE
A1210	225.0d	2nd Bi Annual CAPP Report
A1220	60.0d	Draft CAPP Report
A1230	0.0d	Submit Draft CAPP Report
A1240	30.0d	Review by Ft Stewart & USACE of Draft CAPP Report
A1250	30.0d	Final CAPP Report
A1255	0.0d	Submit Final CAPP Report
A1260	45.0d	Review by GEPD, Fort Stewart, USACE of Final
A1270	30.0d	Corrected Final CAPP Report
A1280	0.0d	Submit Corrected Final CAPP Report
A1290	30.0d	Approval by GEPD, Fort Stewart, USACE
A1300	225.0d	3rd Bi Annual CAPP Report
A1310	60.0d	Draft CAPP Report
A1320	0.0d	Submit Draft CAPP Report
A1330	30.0d	Review by Ft Stewart & USACE of Draft CAPP Report
A1340	30.0d	Final CAPP Report
A1345	0.0d	Submit Final CAPP Report
A1350	45.0d	Review by GEPD, Fort Stewart, USACE of Final
A1360	30.0d	Corrected Final CAPP Report
A1370	0.0d	Submit Corrected Final CAPP Report
A1380	30.0d	Approval by GEPD, Fort Stewart, USACE
SWMU 27F. TASK 5...	315.0d	SWMU 27F. TASK 5 CORRECTIVE ACTION PLAN COMPLETION REPORT
A1390	60.0d	Draft CAPC Report
A1400	0.0d	Submit Draft CAPC Report
A1410	30.0d	Review by Ft Stewart & USACE of Draft CACP Report
A1420	30.0d	Final CAPC Report
A1430	0.0d	Submit Final CAPC Report
A1440	45.0d	Review by GEPD, Fort Stewart, USACE of Final
A1450	30.0d	Corrected final CAPC Report
A1460	0.0d	Submit Corrected Final CAPC Report
A1470	30.0d	Approval by GEPD, Fort Stewart, USACE
A1480	0.0d	Approved Corrected Final CAPC Report
A1490	0.0d	ABANDONMENT OF MONITORING WELLS

Baseline
Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

Start Date: 22-Feb-02
End Date: 01-Dec-08
Data Date: 22-Feb-02
Run Date: 22-Feb-02

CORRECTIVE ACTION SCHEDULE
SWMU 27F
FORT STEWART, GA

SAIC

Figure 5-1. Corrective Action Schedule, SWMU 27F, Northwest of Building 1340

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APPENDIX A

FATE AND TRANSPORT MODELING

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A.1 INTRODUCTION

Monitored natural attenuation is appropriate as a remedial approach only when it can be demonstrated to be capable of achieving a site's remedial objectives within a reasonable timeframe. To determine whether monitored natural attenuation is an appropriate remedy for soil and groundwater contamination at Solid Waste Management Unit (SWMU) 27F, northwest of Building 1340, Fort Stewart, Georgia, fate and transport modeling was performed to show if contaminants present in soil and groundwater could be effectively remediated by natural attenuation processes. The following sections summarize the modeling performed for evaluating natural attenuation as an alternative for the Corrective Action Plan at SWMU 27F.

A.2 MODELING APPROACH

A brief summary of the modeling approach is presented below.

1. Develop the conceptual model for each distinct flow path, including contaminated soil, the groundwater plume, the flow path direction and characteristics, and the receptor location.

2. Perform leachate modeling using the Seasonal Soil Compartment (SESOIL) Model [if there is a source of constituents of concern (COCs) in soil], and calculate the soil-to-leachate dilution attenuation factor (DAF) (i.e., $DAF_{S\text{-}L} = C_S/C_L$, where C_S is the maximum soil concentration at the source and C_L is the predicted maximum leachate concentration).

3. Using the results from the leachate modeling, perform saturated flow and contaminant transport modeling using the Analytical Transient 1-, 2-, 3-Dimensional (AT123D) Model to predict the maximum groundwater concentration ($C_{GWS,P}$) beneath the source, and compare to the observed maximum concentration in the groundwater ($C_{GWS,O}$) beneath the source.

4. Perform steady-state saturated flow and contaminant transport modeling using AT123D modeling to predict the maximum concentration of the COCs at the receptor location, using either the existing groundwater plume (if $C_{GWS,O} > C_{GWS,P}$) or the predicted concentration at the source (if $C_{GWS,O} < C_{GWS,P}$), and calculate the lateral flow and transport DAF (e.g., $DAF_{GWS\text{-}GWR} = C_{GWS}/C_{GWR}$, where C_{GWR} is the predicted maximum concentration at the receptor location and C_{GWS} is the concentration of groundwater at the source) (i.e., either $C_{GWS,O}$ or $C_{GWS,P}$).

5. Perform leachate modeling using SESOIL and saturated flow modeling using the AT123D model in conjunction with source removal to estimate the minimum time required that would limit the concentrations in groundwater to maximum contaminant levels (MCLs) or risk-based concentrations for compounds that do not have MCLs.

6. Perform saturated flow and contaminant transport modeling using AT123D model to predict the maximum concentration over time in conjunction with source remediation to identify a reasonable timeframe for the monitored natural attenuation alternative.

A.3 MODELS SELECTED

A.3.1 SESOIL MODELING

The SESOIL model was used to simulate the vertical transport of contaminants from the source areas down through the vadose zone to the shallow groundwater (water table). SESOIL is a one-dimensional, vertical-transport code for the unsaturated soil zone and is designed to simultaneously model water transport and pollutant fate. The program was originally developed by the U.S. Environmental Protection Agency (Bonazountas and Wagner 1981; Bonazountas and Wagner 1984) and has been extensively modified to enhance its capabilities (Hetrick et al. 1989; Hetrick et al. 1986; Hetrick and Travis 1988).

The SESOIL model defines the "soil compartment" as a soil column extending from the ground surface through the unsaturated zone to the water table. Processes are simulated in SESOIL in both the hydrologic cycle and pollutant cycle, each of which is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, infiltration, soil–water content, evapotranspiration, and groundwater recharge. The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A contaminant in SESOIL can partition in up to four phases (liquid, adsorbed, air, and pure).

The SESOIL model is well recognized and accepted by the scientific community using soil–chemical fate models. Some of the attributes of SESOIL that make the program particularly attractive and suitable for the vadose zone soil leaching at this site are listed below.

- SESOIL has been extensively validated and shown to work under a number of scenarios. The model has also been used for similar applications in other parts of the country and is capable of providing the information required for this study (Bonazountas, Wagner, and Goodwin 1982; Hetrick 1984; Watson and Brown 1985; Hetrick et al. 1986; Melancol, Pollard, and Hern 1986; Hetrick and Travis 1988; Hetrick et al. 1989; Hetrick, Luxmoore, and Tharp 1993).

- SESOIL has the advantage of fewer input requirements and faster run times compared to more complex unsaturated zone models, while still maintaining considerable resolution of the pollutant front in both time and space.

- The model can be divided into as few as two and as many as four layers, with as many as ten sublayers in each of the layers. This compartmental nature of the model allows for user-specified tailoring to suit a particular site.

A.3.2 AT123D MODELING

The AT123D model is a well-known and commonly used analytical groundwater pollutant fate and transport model. This model was developed by Yeh (1981) and has since been updated by GSC (1996). The model computes the spatial–temporal concentration distribution of chemicals in the aquifer system and predicts the transient spread of a chemical plume through a groundwater aquifer. The fate and transport processes accounted for in AT123D are advection, dispersion, adsorption/retardation, and decay. This model can be used as a tool for estimating the dissolved concentration of a chemical in three dimensions in the groundwater resulting from a mass release (i.e., continuous, instant, or depleting source) over a source area (i.e., point, line, area, or volume source).

A.4 PARAMETERS

The hydrologic parameters used in the modeling are based on findings from previous investigations. The parameters are selected such that they are representative values and account for the variability in the hydraulic system and the most likely conditions within that variability. Time-varying model runs are performed using the representative values. The chemical-specific model parameters include solubility in water, organic carbon partition coefficient, Henry's Law constant, soil–water distribution coefficient, diffusion coefficients in air and water, and first-order decay constant. These are literature-based parameters, and a conservative approach was always used for selecting the values of these parameters. The chemical parameters used in the modeling are presented in Table 6-2 of the revised final Phase II Resource Conservation and Recovery Act facility investigation (RFI) report for 16 SWMUs produced by Science Applications International Corporation in April 2000. As an example the input parameters for the observed benzene concentration (61 μg/L) AT123D file are presented as an attachment to this appendix.

A.5 MODEL APPLICATION AND RESULTS

Both SESOIL (for the unsaturated zone) and AT123D (for the saturated zone) were used to model the COCs. The SESOIL and AT123D models were used to determine whether monitored natural attenuation is appropriate as a remedial alternative for achieving the site's remedial objectives within a reasonable timeframe for soil and groundwater COCs. SESOIL outputs were used in the AT123D model to predict the present groundwater concentration of soil COCs only if the predicted leachate concentration exceeded its groundwater remedial levels. AT123D–predicted present groundwater concentrations were then compared to observed groundwater concentrations. Evaluation of natural attenuation was based on the maximum concentrations between either the AT123D–predicted concentration or the observed groundwater concentration. For benzene, the only COC in groundwater, the AT123D model was developed by calibrating the observed maximum concentration of benzene in the latest sampling event.

A.5.1 MODELING OF BENZENE

Because benzene was not detected in soil at concentrations exceeding its soil remedial level, leachate modeling using SESOIL was not necessary. During the last sampling event (January 2001), groundwater concentrations of benzene were observed to be 61 μg/L (MW14), 31.4 μg/L (MW7), and 5.8 μg/L (MW9). Fate and transport modeling using AT123D was performed to calibrate the source and to predict the groundwater concentration below the source. The benzene plume was considered to have originated from a source between MW7 and MW14. The maximum observed groundwater concentration data from MW14, MW7, and MW9 were used to calibrate this plume. Simulations were performed to predict the future concentrations of benzene in the groundwater. Results of this modeling indicate that benzene from the site is not expected to be of potential concern at the nearest receptor location. Figure A-1 presents the AT123D–predicted concentrations of benzene over time at various well locations. These results indicate that the groundwater concentration beneath the source will be reduced to below its remedial level by natural attenuation processes within 6 years from calendar year (CY) 2001 (Figure A-1). The remedial level of 5 μg/L for benzene was recommended in the baseline human health risk assessment for SWMU 27F [see Table 54 of the addendum for SWMU 27F: 3d Engineer Brigade, northwest of Building 1340 (SAIC 2001) to the revised final Phase II RFI Report for 16 SWMUs (SAIC 2000)]. The concentration will be reduced to below the remedial level within 60 feet of the source (Table A-1). Also,

Figure A-1. AT123D-Predicted Concentration of Benzene in Groundwater for SWMU 27F

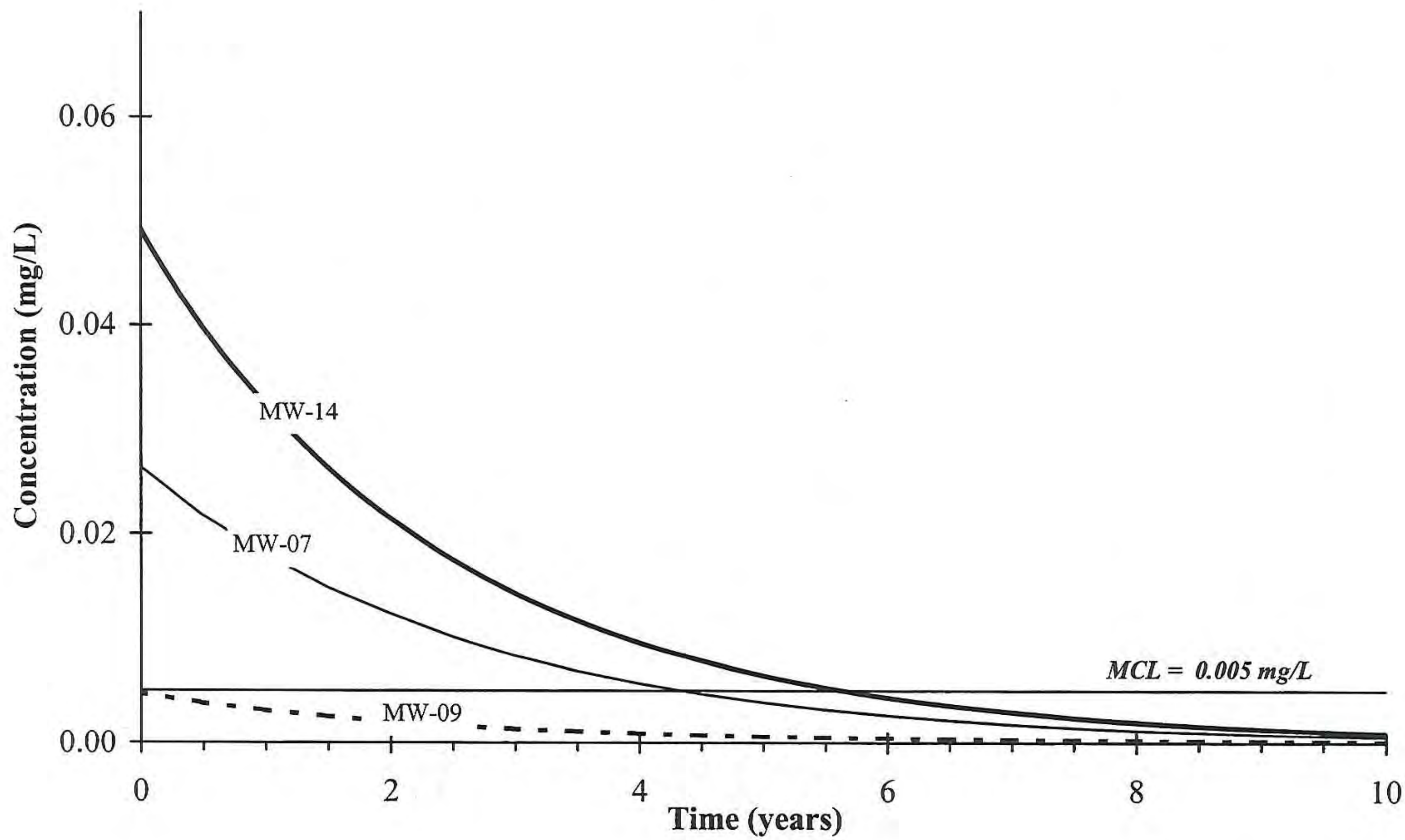


Table A-1. Dilution and Attenuation Factors, SWMU 27F

Distance to Receptor (feet)	Predicted Maximum Concentration of Benzene in Groundwater (mg/L)	DAF
0.00	6.10E-02	1.00
3	5.79E-02	1.05
7	5.44E-02	1.12
10	5.20E-02	1.17
13	4.77E-02	1.28
16	4.31E-02	1.42
20	3.83E-02	1.59
26	2.89E-02	2.11
36	1.71E-02	3.57
52	5.73E-03	10.6
69	1.80E-03	33.9
85	5.70E-04	107
102	1.80E-04	338.9
118	6.00E-05	1,017
135	1.80E-05	3,389
167	2.00E-06	30,500
200	2.15E-07	283,721

the groundwater concentration of benzene beneath the source will be reduced to below its remedial level by natural attenuation processes within 6 years (from CY 2001) (Figure A-2).

Site-specific DAFs between the source and hypothetical/actual receptor locations were developed. The DAF is a numerical value that represents an attempt to mathematically quantify the natural physical, chemical, and biological processes (e.g., advection-dispersion, sorption-retardation, biodegradation, and volatilization) that result in the decrease of a chemical concentration in an environmental medium. In simple terms, the DAF is the ratio of the chemical concentration at the source (or the point of origin) to the concentration at the exposure point. The DAF reflects the natural attenuation concepts outlined in the American Society for Testing and Material's risk-based corrective action protocol (ASTM 1995). Based on the modeling results, the estimated DAF for benzene at the man-made drainage ditch approximately 450 feet south of the site is infinite, suggesting that contaminants will not reach the drainage ditch. There is no downgradient water supply well screened in the surficial groundwater (above the Hawthorn Layer) near SWMU 27F. The confining layer for the Principal Artesian Aquifer is phosphatic clay of the upper Hawthorn Group with a very low permeability (10^{-8} cm/sec). The confining layer ranges from 60 feet to 80 feet in thickness at Fort Stewart. It is improbable that benzene would reach the Principal Artesian Aquifer from SWMU 27F.

Remedial alternatives for the identified plume were studied. The alternatives are presented in Figure A-3. The concentration-versus-time plots as a function of percent removal (F) of the source are shown. Here removal refers to the reduction of the maximum concentration at the source by F%. The results of the modeling indicate the estimated timeframes needed for the benzene concentration to degrade to below its remedial level are approximately 6 years, 5 years, 4 years, and 2.5 years from CY 2001 for F values of 0%, 25%, 50%, and 75%, respectively. The F=0% corresponds to the no-action scenario.

Figure A-2. Natural Attenuation of Benzene in Groundwater below the Source as a Function of Percent Removal (F%) Using AT123D for SWMU 27F

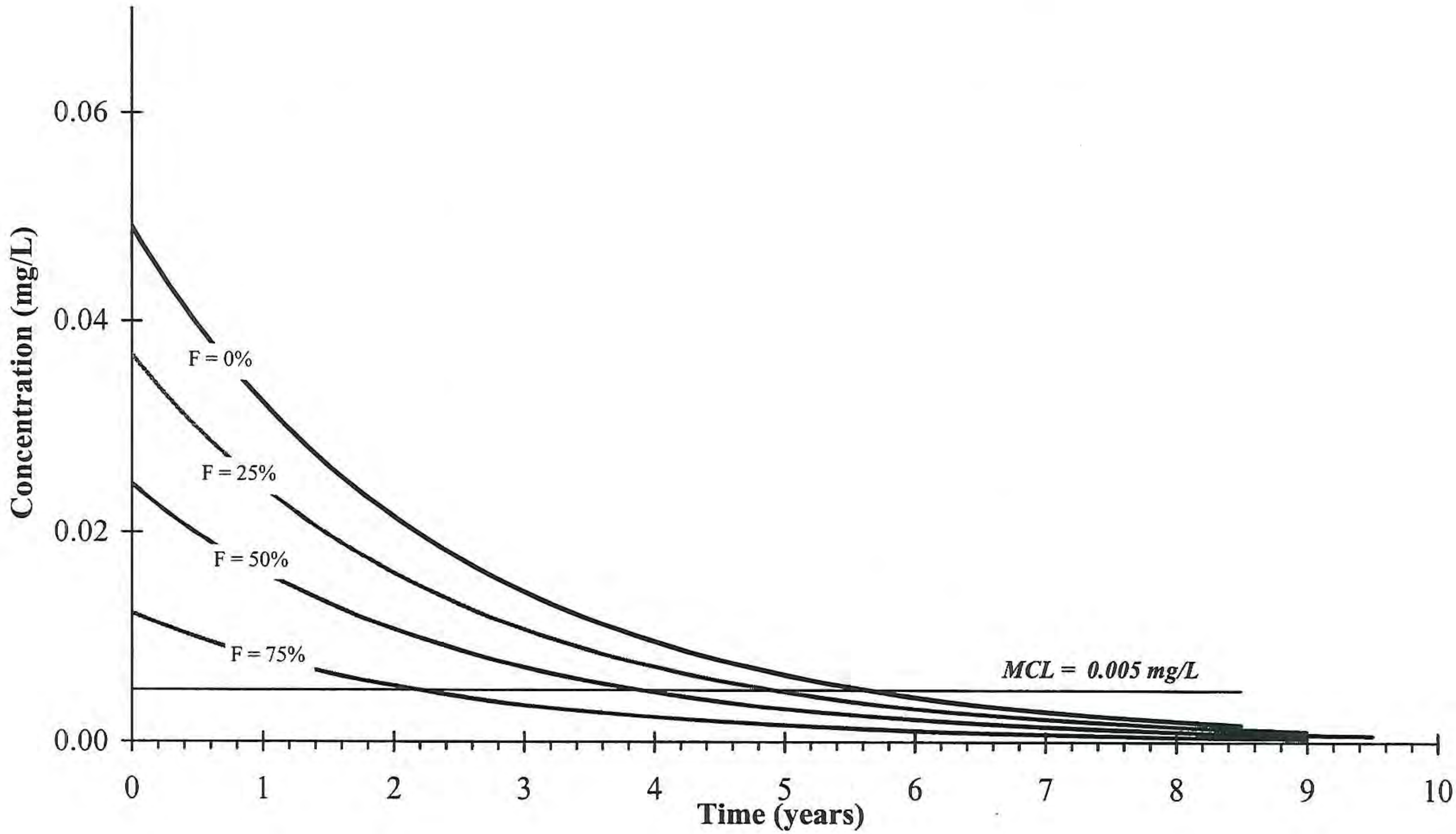
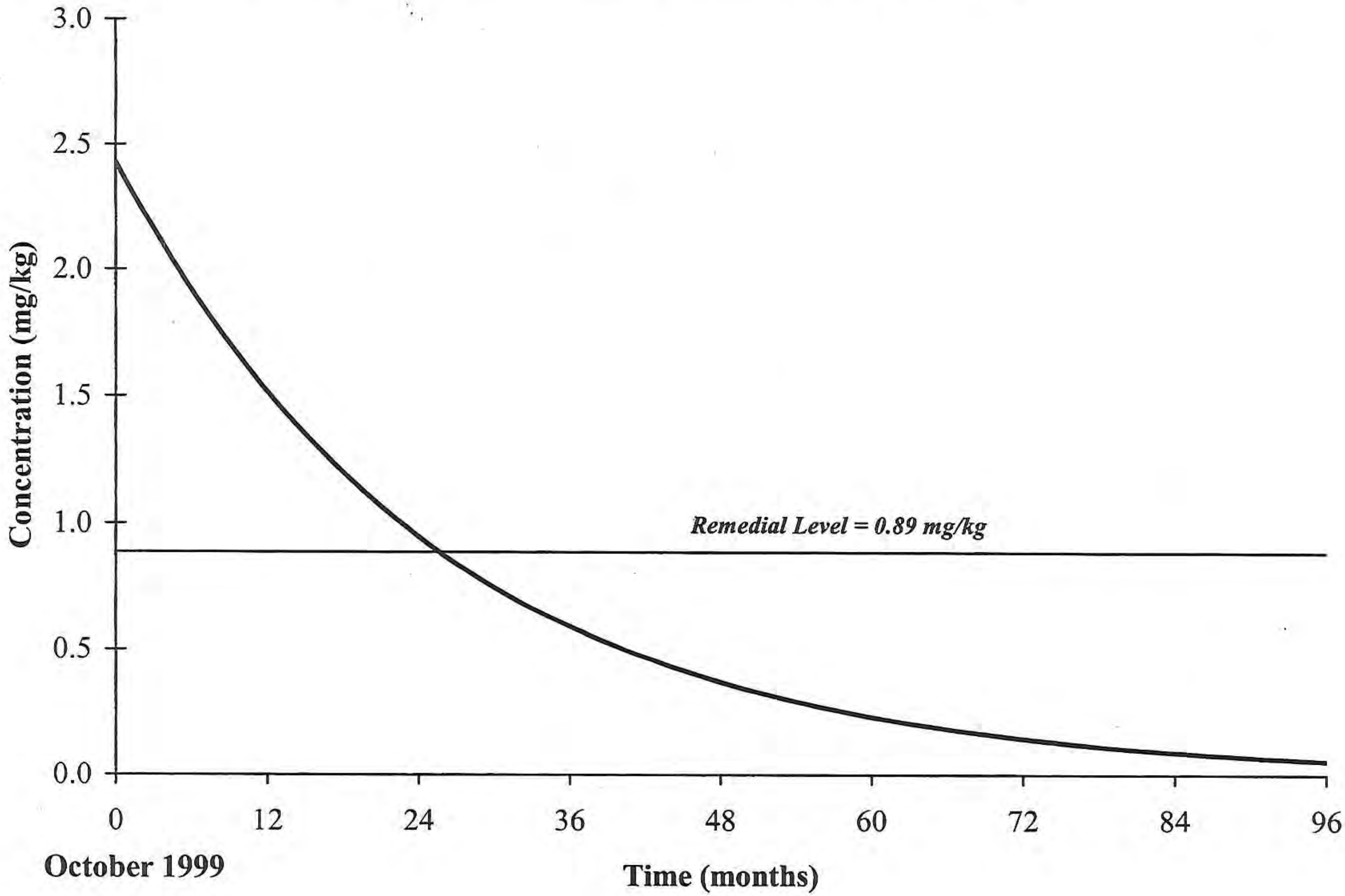


Figure A-3. SESOIL-Predicted Maximum Soil Concentration of Benzo(a)pyrene Based on Initial Contaminant Loading from SWMU 27F



A.5.2 MODELING OF BENZO(*A*)PYRENE

The maximum surface soil concentration (2.43 mg/kg) of benzo(*a*)pyrene exceeded its remedial level (0.89 mg/kg); therefore, benzo(*a*)pyrene was selected for natural attenuation modeling using the SESOIL leachate model. SESOIL modeling results indicate that the soil concentration of benzo(*a*)pyrene will be reduced to below its remedial level within 26 months from October 1999 (Figure A-3). It was also predicted that benzo(*a*)pyrene will completely degrade before reaching the water table. The biodegradation rate constants for benzo(*a*)pyrene in the unsaturated zone were taken from literature (Howard et al. 1991). A conservative approach was used to select the biodegradation rate for this constituent.

A.6 CONCLUSIONS AND SUMMARY

Constituent-specific conclusions of the natural attenuation modeling are presented below.

- The estimated timeframes needed for the benzene concentration to degrade to below its remedial level are approximately 6 years, 5 years, 4 years, and 2.5 years from CY 2001 for F values of 0%, 25%, 50%, and 75%, respectively.
- The results of the SESOIL modeling indicate the estimated timeframe needed for the benzo(*a*)pyrene soil concentration to degrade to below its remedial level as the result of natural attenuation is approximately 26 months from October 1999.

Although the model predicts up to 6 years from CY 2001 will be required for natural attenuation of benzene to achieve the remedial levels, the assumptions used by the model are conservative; therefore, the time required to attenuate is likely to be overestimated. Groundwater monitoring over time is an appropriate method for measuring and confirming the performance of natural attenuation.

A.7 LIMITATIONS/ASSUMPTIONS

Based upon the data available, a conservative approach was used that might overestimate the contaminant concentrations in the groundwater. Listed below are important assumptions used in this analysis.

- The use of K_d and R_d to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid- and solution-phase concentrations and that the relationship is linear and reversible.
- The most conservative biodegradation rates for benzene and benzo(*a*)pyrene from available literature were used.
- Flow and transport in the vadose zone are one-dimensional (i.e., only in the vertical direction).
- The initial condition is disregarded in the vadose zone modeling.
- Flow and transport are not affected by density variations.

- Liquid-phase dispersion in the vadose zone is neglected.
- The aquifer is homogenous and isotropic.
- The areal distribution of soil contamination in the vadose zone is not considered; instead, the maximum concentration is used throughout the soil column.
- A steady-state contaminant loading source to the aquifer is assumed for lateral transport.

The inherent uncertainties associated with using these assumptions must be recognized. It is also important to note that the major geochemistry of the plume will change over time and be affected by multiple solutes that are present at the site and any potential future releases, if they occur. Projected organic concentrations in the aquifer are probably highly conservative due to the use of a steady-state source and a conservative, literature-based decay rate.

A.8 REFERENCES

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AT123D OUTPUT FILE FOR SWMU 27F

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SWMU 27F Benzene

NO. OF POINTS IN X-DIRECTION	6
NO. OF POINTS IN Y-DIRECTION	5
NO. OF POINTS IN Z-DIRECTION	1
NO. OF ROOTS: NO. OF SERIES TERMS	400
NO. OF BEGINNING TIME STEP	145
NO. OF ENDING TIME STEP	259
NO. OF TIME INTERVALS FOR PRINTED OUT SOLUTION	6
INSTANTANEOUS SOURCE CONTROL = 0 FOR INSTANT SOURCE	1
SOURCE CONDITION CONTROL = 0 FOR STEADY SOURCE	0
INTERMITTENT OUTPUT CONTROL = 0 NO SUCH OUTPUT	1
CASE CONTROL = 1 THERMAL, = 2 FOR CHEMICAL, = 3 RAD	2

AQUIFER DEPTH, = 0.0 FOR INFINITE DEEP (METERS)	0.1524E+02
AQUIFER WIDTH, = 0.0 FOR INFINITE WIDE (METERS)	0.0000E+00
BEGIN POINT OF X-SOURCE LOCATION (METERS)	0.0000E+00
END POINT OF X-SOURCE LOCATION (METERS)	0.1100E+02
BEGIN POINT OF Y-SOURCE LOCATION (METERS)	-0.7000E+01
END POINT OF Y-SOURCE LOCATION (METERS)	0.7000E+01
BEGIN POINT OF Z-SOURCE LOCATION (METERS)	0.0000E+00
END POINT OF Z-SOURCE LOCATION (METERS)	0.2000E+01

POROSITY	0.2000E+00
HYDRAULIC CONDUCTIVITY (METER/HOUR)	0.5500E-01
HYDRAULIC GRADIENT	0.9000E-03
LONGITUDINAL DISPERSIVITY (METER)	0.1500E+02
LATERAL DISPERSIVITY (METER)	0.5000E+01
VERTICAL DISPERSIVITY (METER)	0.3000E+01
DISTRIBUTION COEFFICIENT, KD (M**3/KG)	0.5589E-03
HEAT EXCHANGE COEFFICIENT (KCAL/HR-M**2-DEGREE C)	0.0000E+00

MOLECULAR DIFFUSION MULTIPLY BY POROSITY (M**2/HR)	0.3530E-05
DECAY CONSTANT (PER HOUR)	0.4012E-04
BULK DENSITY OF THE SOIL (KG/M**3)	0.1690E+04
ACCURACY TOLERANCE FOR REACHING STEADY STATE	0.1000E-02
DENSITY OF WATER (KG/M**3)	0.1000E+04
TIME INTERVAL SIZE FOR THE DESIRED SOLUTION (HR)	0.7300E+03
DISCHARGE TIME (HR)	0.8760E+05
WASTE RELEASE RATE (KCAL/HR), (KG/HR), OR (CI/HR)	0.7340E-05

RETARDATION FACTOR	0.5723E+01
RETARDED DARCY VELOCITY (M/HR)	0.4325E-04
RETARDED LONGITUDINAL DISPERSION COEF. (M**2/HR)	0.6518E-03
RETARDED LATERAL DISPERSION COEFFICIENT (M**2/HR)	0.2193E-03
RETARDED VERTICAL DISPERSION COEFFICIENT (M**2/HR)	0.1328E-03

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.0000E+00 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00
X

Y	-2.	0.	9.	10.	11.	100.
20.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
11.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1051E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00
X

Y	-2.	0.	9.	10.	11.	100.
20.	0.227E-04	0.271E-04	0.384E-04	0.380E-04	0.373E-04	0.000E+00
11.	0.285E-02	0.362E-02	0.524E-02	0.506E-02	0.482E-02	0.000E+00
10.	0.481E-02	0.621E-02	0.903E-02	0.867E-02	0.820E-02	0.000E+00
5.	0.385E-01	0.533E-01	0.790E-01	0.739E-01	0.678E-01	0.000E+00
0.	0.455E-01	0.626E-01	0.926E-01	0.869E-01	0.799E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1095E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00
X

Y	-2.	0.	9.	10.	11.	100.
20.	0.187E-04	0.222E-04	0.314E-04	0.312E-04	0.307E-04	0.000E+00
11.	0.235E-02	0.295E-02	0.426E-02	0.414E-02	0.397E-02	0.000E+00
10.	0.399E-02	0.506E-02	0.732E-02	0.708E-02	0.675E-02	0.000E+00
5.	0.323E-01	0.434E-01	0.638E-01	0.603E-01	0.560E-01	0.000E+00
0.	0.381E-01	0.510E-01	0.748E-01	0.709E-01	0.660E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1139E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00
X

Y	-2.	0.	9.	10.	11.	100.
20.	0.154E-04	0.182E-04	0.258E-04	0.256E-04	0.253E-04	0.000E+00
11.	0.195E-02	0.241E-02	0.347E-02	0.338E-02	0.326E-02	0.000E+00
10.	0.330E-02	0.413E-02	0.595E-02	0.578E-02	0.555E-02	0.000E+00
5.	0.269E-01	0.353E-01	0.516E-01	0.492E-01	0.462E-01	0.000E+00
0.	0.317E-01	0.415E-01	0.605E-01	0.579E-01	0.544E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1183E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.127E-04	0.150E-04	0.211E-04	0.211E-04	0.208E-04	0.000E+00
11.	0.161E-02	0.197E-02	0.282E-02	0.277E-02	0.268E-02	0.000E+00
10.	0.272E-02	0.337E-02	0.484E-02	0.473E-02	0.456E-02	0.000E+00
5.	0.223E-01	0.288E-01	0.418E-01	0.402E-01	0.380E-01	0.000E+00
0.	0.263E-01	0.338E-01	0.491E-01	0.472E-01	0.448E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1226E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.105E-04	0.123E-04	0.173E-04	0.173E-04	0.171E-04	0.000E+00
11.	0.133E-02	0.161E-02	0.230E-02	0.226E-02	0.220E-02	0.000E+00
10.	0.225E-02	0.276E-02	0.395E-02	0.387E-02	0.375E-02	0.000E+00
5.	0.185E-01	0.234E-01	0.339E-01	0.328E-01	0.313E-01	0.000E+00
0.	0.218E-01	0.275E-01	0.398E-01	0.385E-01	0.368E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1270E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.867E-05	0.101E-04	0.142E-04	0.142E-04	0.141E-04	0.000E+00
11.	0.109E-02	0.132E-02	0.188E-02	0.185E-02	0.181E-02	0.000E+00
10.	0.186E-02	0.226E-02	0.322E-02	0.317E-02	0.308E-02	0.000E+00
5.	0.153E-01	0.191E-01	0.275E-01	0.268E-01	0.257E-01	0.000E+00
0.	0.180E-01	0.225E-01	0.324E-01	0.315E-01	0.302E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1314E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.716E-05	0.833E-05	0.117E-04	0.117E-04	0.116E-04	0.000E+00
11.	0.902E-03	0.108E-02	0.154E-02	0.152E-02	0.149E-02	0.000E+00
10.	0.153E-02	0.185E-02	0.263E-02	0.259E-02	0.253E-02	0.000E+00
5.	0.126E-01	0.156E-01	0.224E-01	0.219E-01	0.211E-01	0.000E+00
0.	0.148E-01	0.184E-01	0.263E-01	0.257E-01	0.248E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1358E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.591E-05	0.685E-05	0.963E-05	0.965E-05	0.960E-05	0.000E+00
11.	0.745E-03	0.888E-03	0.126E-02	0.125E-02	0.122E-02	0.000E+00
10.	0.126E-02	0.151E-02	0.215E-02	0.213E-02	0.208E-02	0.000E+00
5.	0.104E-01	0.128E-01	0.183E-01	0.179E-01	0.173E-01	0.000E+00
0.	0.123E-01	0.150E-01	0.215E-01	0.210E-01	0.204E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1402E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.489E-05	0.564E-05	0.792E-05	0.794E-05	0.792E-05	0.000E+00
11.	0.614E-03	0.728E-03	0.103E-02	0.102E-02	0.101E-02	0.000E+00
10.	0.104E-02	0.124E-02	0.176E-02	0.174E-02	0.171E-02	0.000E+00
5.	0.858E-02	0.104E-01	0.149E-01	0.146E-01	0.142E-01	0.000E+00
0.	0.101E-01	0.123E-01	0.175E-01	0.172E-01	0.168E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1445E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.404E-05	0.465E-05	0.652E-05	0.655E-05	0.653E-05	0.000E+00
11.	0.507E-03	0.598E-03	0.845E-03	0.841E-03	0.830E-03	0.000E+00
10.	0.859E-03	0.102E-02	0.144E-02	0.143E-02	0.141E-02	0.000E+00
5.	0.707E-02	0.854E-02	0.122E-01	0.120E-01	0.117E-01	0.000E+00
0.	0.834E-02	0.101E-01	0.143E-01	0.141E-01	0.138E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1489E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.334E-05	0.383E-05	0.537E-05	0.540E-05	0.539E-05	0.000E+00
11.	0.418E-03	0.491E-03	0.693E-03	0.691E-03	0.683E-03	0.000E+00
10.	0.709E-03	0.836E-03	0.118E-02	0.118E-02	0.116E-02	0.000E+00
5.	0.583E-02	0.700E-02	0.994E-02	0.983E-02	0.963E-02	0.000E+00
0.	0.687E-02	0.824E-02	0.117E-01	0.116E-01	0.113E-01	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1533E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.276E-05	0.316E-05	0.442E-05	0.445E-05	0.445E-05	0.000E+00
11.	0.345E-03	0.404E-03	0.569E-03	0.568E-03	0.563E-03	0.000E+00
10.	0.585E-03	0.687E-03	0.969E-03	0.966E-03	0.956E-03	0.000E+00
5.	0.481E-02	0.574E-02	0.814E-02	0.806E-02	0.792E-02	0.000E+00
0.	0.567E-02	0.675E-02	0.957E-02	0.949E-02	0.933E-02	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1577E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.228E-05	0.261E-05	0.365E-05	0.367E-05	0.368E-05	0.000E+00
11.	0.285E-03	0.332E-03	0.467E-03	0.467E-03	0.464E-03	0.000E+00
10.	0.483E-03	0.565E-03	0.796E-03	0.795E-03	0.787E-03	0.000E+00
5.	0.397E-02	0.471E-02	0.666E-02	0.662E-02	0.651E-02	0.000E+00
0.	0.468E-02	0.554E-02	0.784E-02	0.779E-02	0.767E-02	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1621E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.188E-05	0.215E-05	0.301E-05	0.303E-05	0.304E-05	0.000E+00
11.	0.235E-03	0.273E-03	0.384E-03	0.385E-03	0.382E-03	0.000E+00
10.	0.399E-03	0.465E-03	0.654E-03	0.654E-03	0.649E-03	0.000E+00
5.	0.327E-02	0.386E-02	0.546E-02	0.543E-02	0.536E-02	0.000E+00
0.	0.386E-02	0.455E-02	0.643E-02	0.640E-02	0.632E-02	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1664E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.156E-05	0.178E-05	0.248E-05	0.250E-05	0.251E-05	0.000E+00
11.	0.194E-03	0.225E-03	0.316E-03	0.317E-03	0.315E-03	0.000E+00
10.	0.329E-03	0.382E-03	0.537E-03	0.538E-03	0.535E-03	0.000E+00
5.	0.270E-02	0.317E-02	0.448E-02	0.446E-02	0.441E-02	0.000E+00
0.	0.318E-02	0.374E-02	0.527E-02	0.526E-02	0.520E-02	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1708E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.129E-05	0.147E-05	0.205E-05	0.207E-05	0.207E-05	0.000E+00
11.	0.161E-03	0.185E-03	0.260E-03	0.261E-03	0.260E-03	0.000E+00
10.	0.272E-03	0.315E-03	0.442E-03	0.443E-03	0.441E-03	0.000E+00
5.	0.223E-02	0.261E-02	0.368E-02	0.367E-02	0.364E-02	0.000E+00
0.	0.263E-02	0.307E-02	0.433E-02	0.432E-02	0.428E-02	0.000E+00

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1752E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.107E-05	0.121E-05	0.169E-05	0.171E-05	0.172E-05	0.390E-14
11.	0.133E-03	0.153E-03	0.214E-03	0.215E-03	0.215E-03	0.567E-13
10.	0.225E-03	0.259E-03	0.364E-03	0.365E-03	0.364E-03	0.686E-13
5.	0.184E-02	0.215E-02	0.302E-02	0.302E-02	0.300E-02	0.133E-12
0.	0.217E-02	0.253E-02	0.356E-02	0.356E-02	0.353E-02	0.164E-12

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1796E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.883E-06	0.100E-05	0.140E-05	0.141E-05	0.142E-05	0.156E-13
11.	0.110E-03	0.126E-03	0.176E-03	0.177E-03	0.177E-03	0.240E-12
10.	0.186E-03	0.214E-03	0.299E-03	0.301E-03	0.300E-03	0.292E-12
5.	0.152E-02	0.177E-02	0.248E-02	0.248E-02	0.247E-02	0.571E-12
0.	0.179E-02	0.208E-02	0.292E-02	0.293E-02	0.291E-02	0.708E-12

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1840E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X Y	-2.	0.	9.	10.	11.	100.
20.	0.731E-06	0.827E-06	0.115E-05	0.117E-05	0.117E-05	0.312E-13
11.	0.906E-04	0.104E-03	0.145E-03	0.146E-03	0.146E-03	0.503E-12
10.	0.153E-03	0.176E-03	0.247E-03	0.248E-03	0.248E-03	0.613E-12
5.	0.125E-02	0.145E-02	0.204E-02	0.205E-02	0.204E-02	0.121E-11
0.	0.148E-02	0.171E-02	0.240E-02	0.241E-02	0.240E-02	0.150E-11

STEADY STATE SOLUTION HAS NOT BEEN REACHED BEFORE FINAL SIMULATING TIME

DISTRIBUTION OF DISSOLVED CHEMICALS IN PPM AT 0.1883E+06 HRS
(ADSORBED CHEMICAL CONC. = 0.5589E+00 * DISSOLVED CHEMICAL CONC.)

Z = 0.00

X						
Y	188340.	0.	9.	10.	11.	100.
20.	0.605E-06	0.684E-06	0.952E-06	0.963E-06	0.970E-06	0.511E-13
11.	0.749E-04	0.856E-04	0.120E-03	0.121E-03	0.121E-03	0.860E-12
10.	0.127E-03	0.145E-03	0.203E-03	0.205E-03	0.205E-03	0.105E-11
5.	0.104E-02	0.120E-02	0.168E-02	0.168E-02	0.168E-02	0.209E-11
0.	0.122E-02	0.141E-02	0.198E-02	0.199E-02	0.198E-02	0.261E-11

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APPENDIX B

COST ESTIMATE SUMMARIES FOR CORRECTIVE ACTION ALTERNATIVES

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APPENDIX B

Cost Estimate Summaries for Remedial Action Alternatives

		Alternative 1 Monitored Natural Attenuation	Alternative 2 Specialized Bacterial Injection	Alternative 3 Oxygen Injection
1.0	**Capital Costs**			
1.1	**Engineering Services**			
1.1.1	Work Plan/SSHP and Remedial Design	$15,405	$20,342	$20,342
1.1.2	Contracting/Procurement	$0	$0	$0
1.1.3	Permitting	$0	$2,471	$2,033
1.1.4	Construction Oversight for Monitoring Well Installation	$0	$0	$0
1.1.5	Construction Oversight for Extraction/Injection Installation	$0	$0	$0
1.1.6	Construction Oversight for System Startup	$0	$0	$18,741
1.1	**Total Costs for Engineering Services**	**$15,405**	**$22,813**	**$41,117**
	Approximate Costs	**~$15,000**	**~$23,000**	**~$41,000**
1.2	**System Installation**			
1.2.1	Site Preparation and Mobilization/Demobilization			
1.2.1.1	Locate Underground Utilities	$0	$818	$1,635
1.2.1.2	Define Grid Layout	$0	$1,251	$2,502
1.2.1.3	Baseline Groundwater Monitoring	$0	$15,533	$15,533
1.2.1.4	Baseline Soil Monitoring	$0	$0	$0
1.2.1	**Total Costs for Site Preparation and Mobilization/Demobilization**	**$0**	**$17,602**	**$19,671**
1.2.2	Monitoring Well Installation	$0	$0	$0
1.2.3	Extraction/Injection and Equipment Installation	$0	$63,911	$291,042
1.2.4	Excavation and Disposal of Soil	$0	$0	$6,271
1.2.5	Project Closeout	$4,688	$6,008	$5,500
1.2	**Total Costs for System Installation**	**$4,688**	**$87,521**	**$322,484**
1.0	**Total Capital Costs**	**$20,093**	**$110,335**	**$363,601**
	Approximate Costs	**~$20,000**	**~$110,000**	**~$364,000**
2.0	**System Maintenance**			
2.1	Groundwater Monitoring	$103,525	$127,148	$235,224
2.2	Confirmatory Soil Analysis	$0	$0	$3,408
2.3	Post Remediation Soil Analysis	$1,704	$1,704	$0
2.4	Operations and Maintenance for System Maint.	$0	$21,485	$517
2.5	Reports	$75,000	$30,000	$45,000
2.0	**Total Costs for System Maintenance**	**$180,229**	**$180,337**	**$284,149**
	Approximate Costs	**~$180,000**	**~$180,000**	**~$284,000**
	Subtotal Project Costs	**$200,322**	**$290,672**	**$647,749**
	Construction Mgmt. (10% of subtotal)	$20,032	$29,067	$64,775
	Contingency (20% of subtotal)	$40,064	$58,134	$129,550
	Health and Safety (7.5% of subtotal)	$15,024	$21,800	$48,581
	Contractor Profit (10% of subtotal)	$20,032	$29,067	$64,775
	Total Project Costs	**$295,476**	**$428,741**	**$955,430**
	Approximate Costs	**~$295,000**	**~$429,000**	**~$955,000**

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APPENDIX C

OPERATIONS AND MAINTENANCE PLAN

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C.1 INTRODUCTION/PURPOSE

This plan presents preliminary procedures for the operations and maintenance (O&M) of the groundwater monitoring system for monitored natural attenuation of groundwater contamination at the 3d Engineer Brigade, Northwest of Building 1340 [Solid Waste Management Unit (SWMU) 27F)], Fort Stewart, Georgia. This O&M Plan is based upon attenuation factors as understood at this time. If actual performance indicates a change is appropriate, then a revised/updated O&M Plan will be submitted to the Georgia Environmental Protection Division (GEPD). Substantive changes in the remediation approach or schedule will require that the public be provided with an opportunity for review and comment in accordance with the Fort Stewart Hazardous Waste Permit HW-045 (S&T).

Surface soil and groundwater at SWMU 27F is contaminated with benzo(*a*)pyrene and benzene, respectively. The surface soil contamination [0 feet to 2 feet below ground surface (bgs)] is confined to a small area around MW10 (Figure C-1). The extent of benzene in groundwater as of January 2001 is presented in Figure C-1. Corrective action is required to reduce the benzo(*a*)pyrene and benzene concentrations to below the remedial level presented in the GEPD–approved revised final addendum to the Phase II Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) report for 16 SWMUs prepared by Science Applications International Corporation in June 2001. The selected corrective action consists of monitored natural attenuation of the soil and groundwater. A description of the system components is presented in Chapter 5.0 of the Corrective Action Plan (CAP) and includes the points listed below.

- Soil sampling around MW10, the surface soil location indicating the highest concentration of benzo(*a*)pyrene from previous sampling. The soil samples will be collected using a hand-auger and analyzed for semivolatile organic compounds (SVOCs) starting in calendar year (CY) 2002 and if necessary also in CY 2004.

- Groundwater sampling of 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] starting in CY 2002 and continuing biannually (every 2 years) for the next 6 years. The groundwater samples would be analyzed for volatile organic compounds (VOCs), SVOCs, and natural attenuation parameters [i.e., methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron (field analysis)].

- Confirmatory groundwater sampling and analysis. The confirmatory sampling will be performed 1 year following completion of the remediation (i.e., monitored natural attenuation) and would be identical to the biannual groundwater sampling.

C.2 TRAINING

Personnel who participate in field activities during monitoring are subject to the training requirements presented in Table C-1. Casual visitors, such as package deliverers, who access only the staging areas of the site, are not subject to these training requirements. Personnel will also be subject to the requirements specified in this O&M Plan, the Sampling and Analysis Plan (SAP) (as contained within the project-specific work plan), and the project Site Safety and Health Plan (SSHP). The Site Supervisor will be responsible for (1) assessing qualifications and determining skill needs of personnel; (2) ensuring that appropriate training is provided to personnel and that the training (classroom, reading assignments, or on-the-job) is completed; and (3) forwarding training records for personnel to a Central Records Facility. Health and safety–related documentation will also be maintained in on-site project files, in accordance with the SSHP.

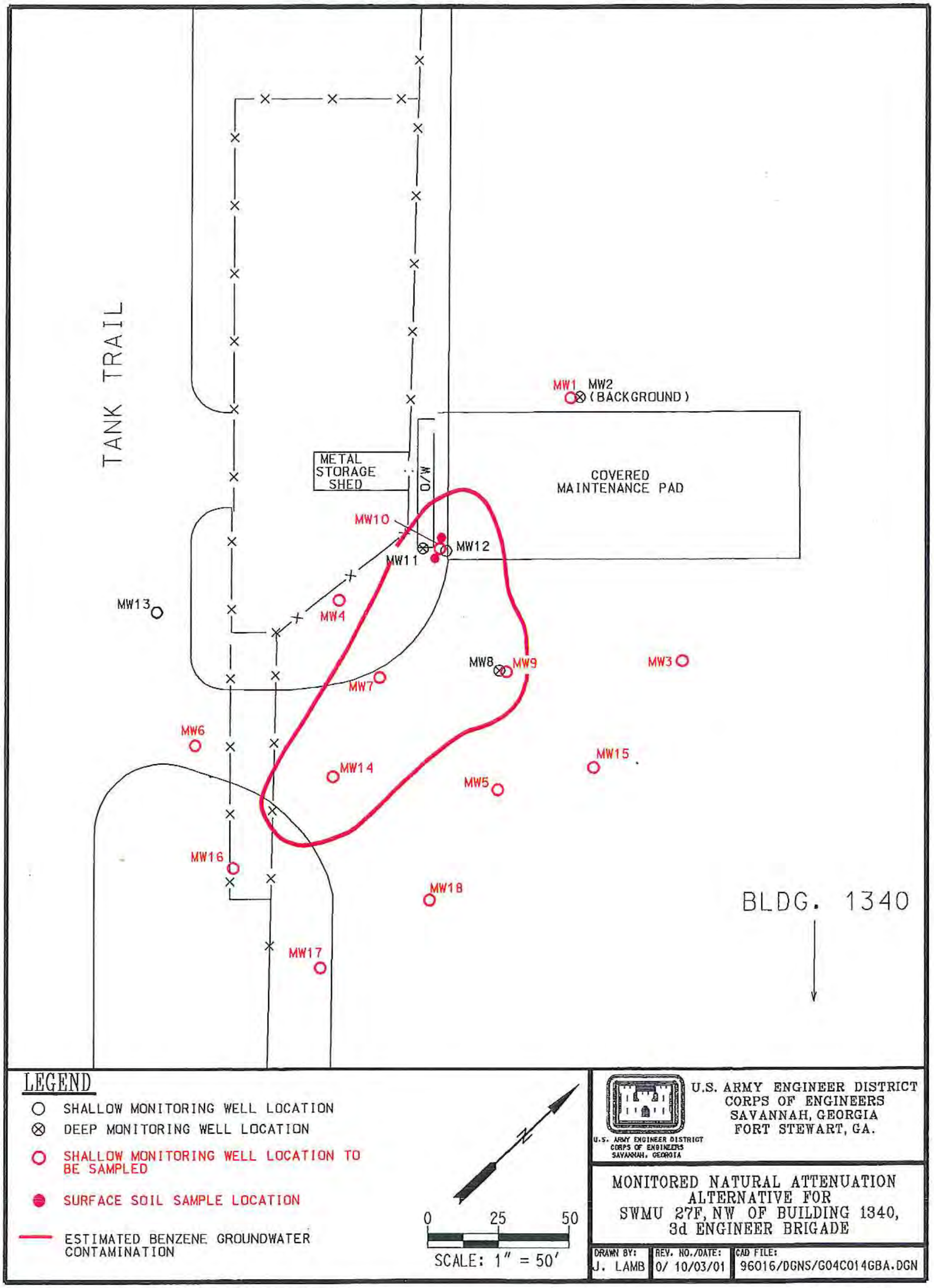

Figure C-1. Monitored Natural Attenuation Alternative for SWMU 27F, Northwest of Building 1340

Table C-1. Training Requirements, SWMU 27F

Training	Type	Remediation Worker	Groundwater Monitoring Worker	Site Supervisor
Health and Safety Training				
Site Safety and Health Plan	Reading	✓	✓	✓
Hazardous Waste Safety (40 hours)	Classroom	✓	✓	✓
Hazardous Waste Safety Annual Refresher (8 hours)	Classroom	✓	✓	✓
Hazardous Waste Safety Supervisor's Training (8 hours)	Classroom			✓
General Hazard Communication Training (contained in 40- and 8-hour courses)	Classroom	✓	✓	✓
Respiratory Protection Training (required only if respirators are worn; contained in 40-hour course)	Classroom	✓	✓	✓
Hearing Conservation Training (contained in 40- and 8-hour courses)	Classroom	✓	✓	✓
Pre-Entry Briefing (including site-specific hazards communication)	OJT	✓	✓	✓
Safety Briefing (daily and whenever conditions or tasks change)	OJT	✓	✓	✓
First Aid/CPR (standard Red Cross or equivalent)	Classroom	At least 2 workers		
Quality Assurance Training				
O&M Plan	Reading	✓	✓	✓
Sampling and Analysis Plan (with addendum)	Reading	✓	✓	✓
Quality Assurance Project Plan, including applicable quality assurance program elements	Reading	✓	✓	✓
General criteria, including applicable codes, standards, and regulations, and the purpose, scope, and implementation of manuals, instructions, and procedures	Reading	✓	✓	✓
Job responsibilities and authority	Reading	✓	✓	✓
Quality Assurance Administrative Procedures	Reading	✓	✓	✓
Quality Assurance Technical Procedures for sampling and analysis	Reading	✓	✓	✓
Demonstration of proficiency for task-specific procedures and equipment	OJT	✓	✓	✓

CPR = Cardiopulmonary resuscitation.
O&M = Operations and maintenance.
OJT = On-the-job training.
✓ = Required training.

C.3 WASTE MANAGEMENT PRACTICES

Wastes generated by operation of the corrective action will be managed in accordance with RCRA requirements and the investigation-derived waste section of the SAP, as contained in the project-specific work plan. The types of waste expected to be generated are monitoring well purge waters, decontamination fluids, and sanitary waste (uncontaminated compactible and miscellaneous trash). Materials that can be effectively reused, recycled, or decontaminated in the field are not waste materials.

Decontamination and monitoring well purge waters will be stored in drums or poly tanks. The drums or poly tanks will be transported to a staging area for temporary storage. Analytical data gathered from grab samples collected directly from filled drums or poly tanks will be used to characterize liquid wastes. One grab sample will be collected from each filled drum or poly tank and submitted to an off-site laboratory for analysis for VOCs, pH, oil and grease, and phenols. The analytical data reported for the grab samples, the quantity to be released, and the date of the release will be submitted to the Fort Stewart Directorate of Public Works (DPW) water engineer for evaluation.

The water engineer will determine if the liquid waste can be released into the Fort Stewart Industrial Wastewater Treatment Plant on a case-by-case basis using In-Stream Water Quality Standards and facility National Pollutant Discharge Elimination System permit requirements as the disposal criteria. In the event that the Fort Stewart DPW water engineer rejects release of the liquid waste into either of the treatment plants, the contents of the subject poly tank will be transferred into 55-gallon, 17E, closed-top drums for disposal off-site. Based upon the results of the analytical data, the material will be transported to either a permitted RCRA Subtitle D or Subtitle C facility located off the Installation for disposal. The material will be disposed of in accordance with all applicable U.S. Environmental Protection Agency (EPA), U.S. Department of Transportation, and state of Georgia regulations. Containerized hazardous waste will be transported off-site for disposal within 90 days of receipt of sample data indicating that the waste is hazardous.

Sanitary wastes that are noncontaminated will be bagged and placed in a sanitary waste dumpster for disposal at the permitted sanitary landfill in Savannah, Georgia. No free liquids or hazardous substances will be placed in the dumpster.

C.4 SYSTEM OPERATION

Modeling estimated that benzo(*a*)pyrene in surface soil will achieve its remedial level in 26 months from October 1999 (i.e., December 2001). Concentrations of SVOCs will be monitored in CY 2002 and if necessary in CY 2004 in conjunction with groundwater monitoring (see below). Two surface soil samples will be collected around MW10 [the surface soil location indicating the highest concentration of benzo(*a*)pyrene] in CY 2002. If remedial levels for benzo(*a*)pyrene have not been achieved, then additional surface soil samples will be collected in conjunction with the first biannual groundwater sampling event (CY 2004).

Concentrations of VOCs and SVOCs and natural attenuation parameters in groundwater will be monitored throughout the monitored natural attenuation period, expected to be 6 years in duration from January 2001. However, an additional 1 year will be added to the monitored natural attenuation period as a contingency. The operational strategy for monitored natural attenuation involves collecting data on a regular basis to check the continuity of trends. Groundwater sampling of 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] will start in CY 2002 and continue biannually (every 2 years) for the next 6 years. The groundwater samples will be analyzed for VOCs, SVOCs, and natural attenuation parameters [i.e., methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron (field analysis)]. The initial conceptual site model will periodically be updated to include results of these monitored natural attenuation data. This updated model will then be used as a basis for any change in groundwater monitoring system operation.

Confirmatory sampling of groundwater will be conducted 1 year following the end of the natural attenuation period. The analysis of groundwater will be same as that conducted during the biannual groundwater sampling.

C.5 SAMPLING AND ANALYSIS

Sampling of soil and groundwater will be conducted to evaluate the effectiveness of the natural attenuation alternative. The start (baseline) for benzo(*a*)pyrene in surface soil will be considered to be October 1999, the date of the detection of the most elevated concentration of that constituent. Surface soil samples will be collected around MW10 [the surface soil location indicating the highest concentration of benzo(*a*)pyrene] in CY 2002, to confirm that the remedial levels have been achieved. If remedial levels have not been achieved, then additional surface soil samples will be collected in conjunction with the first biannual groundwater sampling event (CY 2004). Only two soil sampling events are expected to be required. Once benzo(*a*)pyrene is no longer detected at concentrations above remedial levels in the surface soil samples, then the soil samples from that soil sampling event will be considered to represent the final soil samples. No confirmatory samples will be required for soil.

The start (baseline) of the natural attenuation period for benzene in groundwater will be considered to be January 2001, the latest complete round of groundwater sampling at SWMU 27F (see Section 2.9 of the CAP). Sampling of groundwater will be conducted throughout the remediation period to verify the effectiveness of the corrective measures. Sampling of groundwater will be performed 1 year after the completion of the monitored natural attenuation period to confirm that the remedial levels in groundwater have been achieved.

All information, data, and resulting decisions will be technically sound, statistically valid, and properly documented by following the Quality Assurance Project Plan (QAPP), as contained in the project-specific work plan. The QAPP will document all monitoring procedures, sampling, field measurements, and sample analyses performed during these activities. Appropriate quality assurance, quality control, and chain-of-custody procedures will be followed in accordance with the U.S. Army Corps of Engineers' *Requirements for the Preparation of Sampling and Analysis Plans* (EM200-1-3), EPA's *Requirements for Quality Assurance Project Plans for Environmental Data Operations* (QA/R-5), and EPA's *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (QAMS-005/80). Detailed sampling and analysis procedures will be developed in conjunction with the Corrective Action Work Plan. Groundwater sampling will be performed using low-flow sampling techniques.

C.5.1 BASELINE SAMPLING PROCEDURES

The start (baseline) of the natural attenuation period for benzo(*a*)pyrene in surface soil will be considered to be October 1999, the date of the detection of the most elevated concentration of benzo(*a*)pyrene at SWMU 27F. The start (baseline) of the natural attenuation period for benzene in groundwater will be considered to be January 2001, the latest complete round of groundwater sampling at SWMU 27F. No baseline soil or groundwater sampling will be required.

C.5.2 SOIL MONITORING DURING MONITORED NATURAL ATTENUATION

Modeling estimated that benzo(*a*)pyrene in surface soil will achieve its remedial level in 26 months from October 1999 (i.e., December 2001). Two surface soil samples will be collected around MW10 [the surface soil location indicating the highest concentration of benzo(*a*)pyrene] in CY 2002 (Figure C-1). The soil samples will be collected using a hand-auger and analyzed for SVOCs to confirm that the remedial levels for benzo(*a*)pyrene have been achieved. If remedial levels have not been achieved, then additional surface soil samples will be collected in conjunction with the first biannual groundwater sampling event (CY 2004) discussed in Section 5.2.3 of the CAP. Only two soil sampling events are expected to be required. Once benzo(*a*)pyrene is no longer detected at concentrations above remedial levels in the surface soil samples, then the samples from that soil sampling event will be considered to represent the final soil samples. No confirmatory samples will be required for soil.

C.5.3 GROUNDWATER MONITORING DURING MONITORED NATURAL ATTENUATION

Results of modeling predict a 6-year (from 2001) monitored natural attenuation period. During the monitored natural attenuation period, 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] will be sampled to verify that benzene concentrations are declining, that the concentrations of other constituents of concern (COCs) not detected to date have continued to be below remedial levels and are not increasing with time, and that active biodegradation is occurring. In addition, the water level and potential free product will be measured in all the wells (MW1 through MW18) at SWMU 27F, including MW12, the monitoring well installed to the clay layer approximately 8 feet below ground surface. Measurement of free product will be immediately reported to the Fort Stewart Military Reservation Directorate of Public Works, and appropriate removal measures will be taken. The free product at MW12 does not readily accumulate in the well and is easily removed with an absorbent sock.

The first monitoring event will be performed in CY 2002. Biannual (every 2 years) groundwater sampling events will be performed for the final 6 years of the natural attenuation period, resulting in a total of four groundwater sampling events over the 7-year natural attenuation period.

Groundwater will be collected from the monitoring wells using low-flow techniques. The groundwater will be analyzed for VOCs and SVOCs. In addition, groundwater will be analyzed for natural attenuation parameters [methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron (field analysis)] as shown in Table C-2. Samples will be analyzed at an off-site laboratory using then-current SW-846 methods. Field parameters will be measured at the time of groundwater sampling and will include turbidity, dissolved oxygen, temperature, oxidation-reduction potential, conductivity, and pH.

C.5.4 CONFIRMATION SAMPLING

No confirmation samples will be required for surface soil. Once benzo(*a*)pyrene is no longer detected at concentrations above remedial levels in the surface soil samples, then the samples from that soil sampling event will be considered to represent the final soil samples.

Confirmation groundwater sampling and analysis will be conducted once (1 year following completion of the natural attenuation period) to verify that groundwater remedial levels have been met and maintained. Confirmation sampling will be similar to the biannual sampling (see Section C.5.2). Thirteen shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] will be sampled. Samples will be analyzed at an off-site laboratory for VOCs and SVOCs using then-current SW-846 methods. Analysis of natural attenuation parameters will not be required for confirmatory sampling because remedial levels will have already been achieved in groundwater following the monitored natural attenuation period. Field parameters will be measured at the time of sampling and will include turbidity, dissolved oxygen, temperature, oxidation-reduction potential, conductivity, and pH.

Table C-2. Soil and Groundwater Monitoring for Monitored Natural Attenuation, SWMU 27F

Sampling Endeavor	Soil Locations to be Sampled	Analytical Parameters for Soil	Groundwater Wells to be Sampled	Analytical Parameters for Groundwater
CY 2002 soil and groundwater sampling	Two surface soil locations around MW10	SVOCs	MW1, MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18	VOCs, SVOCs, methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron
Biannual monitoring (every 2 years after CY 2002 soil and groundwater sampling)	Two surface soil locations around MW10[a]	SVOCs	MW1, MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18	VOCs, SVOCs, methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron
Confirmation sampling (1 year after last biannual monitoring event)	None[b]		MW1, MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18	VOCs and SVOCs

[a]Soil sampling may not be necessary if remedial levels have been achieved by CY 2002 sampling.
[b]Confirmatory soil sampling will be considered either CY 2002 or CY 2004 (if necessary).
CY = Calendar year.
SVOC = Semivolatile organic compound.
VOC = Volatile organic compound.

C.6 CORRECTIVE ACTION COMPLETION CRITERIA

The purpose of the corrective action is to achieve remedial levels in soil and groundwater at the site. The remedial levels, as defined in the RFI report, are listed in Table C-3.

Table C-3. Summary of Remedial Levels, SWMU 27F

Contaminant of Concern	Groundwater Remedial Level (μg/L)	Soil Remedial Level (mg/kg)
Benzene	5.0	NA
Benzo(*a*)pyrene	NA	0.89

NA = Not applicable.

Monitored natural attenuation for benzo(*a*)pyrene in surface soil will be considered complete when soil sampling indicates that benzo(*a*)pyrene concentrations are below its remedial level of 0.89 mg/kg.

Monitored natural attenuation for benzene in groundwater will be considered complete following 7 years of sampling, provided the concentration of benzene in groundwater is below 5 μg/L and no additional never-before-detected COCs have been detected in the groundwater. Confirmatory groundwater sampling will be conducted 1 year following the monitored natural attenuation period to verify that the groundwater remedial levels have been maintained.

C.7 SYSTEM DECOMMISSIONING

Upon satisfactory completion of the confirmatory groundwater sampling (see Section C.5.2.3) and acknowledgment from the regulators that the corrective action is complete, the groundwater monitoring system will be decommissioned. The groundwater monitoring wells will be plugged and abandoned by filling the casings with a cement and bentonite grout mixture.

C.8 O&M CONTINGENCY PROCEDURES

The results of the soil and groundwater sampling and analysis will be evaluated in CAP Progress Report. In particular, an analysis of the trends in the rate of decline in contaminant concentrations will be performed. The conceptual site model will be modified, as appropriate. If trends do not match predicted modeled behavior, then contingent actions will be considered, including revising the computational model to correlate to the new data, extending or reducing the predicted duration of the monitored natural attenuation period, or implementing active remediation. Specific alternatives for active remediation (such as use of specialized bacteria addition, or enhanced biodegradation through injection of oxygen and/or nutrients) would be evaluated at that point in time. Table C-4 lists the contingency actions that may be considered for monitored natural attenuation of the benzene plume.

Table C-4. Troubleshooting Guide for Monitored Natural Attenuation, SWMU 27F

<table>
<tr><th>Problems/Triggers</th><th>Considerations</th><th>Potential Solutions</th></tr>
<tr><td>Benzene concentrations in groundwater from MW7, MW9, or MW14 increase at least 10 percent for two consecutive sampling events.</td><td>Transient may be migrating through aquifer; an undiscovered source of contaminant may be present; additional release may have occurred.</td><td rowspan="4">Modify conceptual site model.

Revise the Analytical Transient 1-, 2-, 3-Dimensional numerical model.

Extend (or reduce) the duration of monitored natural attenuation.

Evaluate active remediation:
• specialized bacteria addition or
• enhanced biodegradation through injection of oxygen and/or nutrients.</td></tr>
<tr><td>Benzene concentrations in wells other than MW7, MW9, and MW14 increase to a level exceeding 5 μg/L.</td><td>Groundwater flow direction may have changed; additional release may have occurred; analytical error may have occurred.</td></tr>
<tr><td>Benzene concentrations in MW7, MW9, and MW14 are greater than (less than) the predicted concentration by more than 25 percent for two consecutive sampling events.</td><td>Rate of attenuation may be slower (faster) than predicted; additional release may have occurred.</td></tr>
<tr><td>Other COCs are detected in groundwater.</td><td>Distribution coefficients may be higher than those used in the model (i.e., COCs delayed in reaching groundwater by strong sorption); groundwater flow direction shift may move a previously undetected plume to intersect a well; additional release may have occurred; analytical error may have occurred.</td></tr>
</table>

Table C-4. Troubleshooting Guide for Monitored Natural Attenuation, SWMU 27F (continued)

Problems/Triggers	Considerations	Potential Solutions
Previously undetected VOC is found in well.	Transient may be moving through aquifer; previously undetected source may exist in soil; additional release may have occurred; analytical error may have occurred.	
Land use or groundwater use changes at the SWMU 27F	Remediation objectives or timeframe may no longer be appropriate for new use.	

COC = Constituent of concern.
SWMU = Solid waste management unit.
VOC = Volatile organic compound.

C.9 OPERATIONS AND MAINTENANCE SCHEDULE

The anticipated schedule for O&M is summarized in Table C-5.

Table C-5. Operations and Maintenance Schedule, SWMU 27F

O&M Activity	Frequency	Duration
Baseline soil and groundwater sampling	Already performed (represented by soil sampling performed October 1999 and groundwater monitoring performed January 2001)	One-time event
Soil sampling during monitored natural attenuation period	CY 2002 and CY 2004 (if necessary)	CY 2002 and CY 2004 (if necessary)
Groundwater sampling during monitored natural attenuation	CY 2002 and biannually thereafter	CY 2002 and biannually (every 2 years) for 6 years
Site inspection and maintenance	CY 2002 and biannually thereafter	CY 2002 and biannually thereafter
Confirmatory soil sampling	None	Soil sampling performed during CY 2002 and CY 2004 represents confirmatory soil sampling
Confirmatory groundwater sampling	Once, 1 year after completion of monitored natural attenuation	One-time event

CY = Calendar year.

C.10 DATA MANAGEMENT AND REPORTING DOCUMENTATION

A data management system will be maintained throughout the corrective action to accumulate, archive, and control project data. The data and operational information will be used to prepare CAP progress reports and the final CAP completion report. The types of data to be maintained in the data management system include those listed below.

- Monitoring and laboratory data, including sample location, date and time of collection, chain of custody, laboratory, test method, analytical results, detection limits, and associated quality control sample results.
- Personnel, maintenance, and inspection records, including logbooks, maintenance checklists, or repairs.

C.10.1 CORRECTIVE ACTION PLAN PROGRESS REPORT

A CAP progress report will be prepared after each groundwater sampling event during the 7-year monitored natural attenuation period. These reports will summarize the sampling and analytical results of each groundwater monitoring event. The results of the soil sampling and groundwater monitoring for CY 2002 will be presented in the first CAP progress report. An analysis of trends and effectiveness of the corrective action will be presented. The need for any contingent action (extending or decreasing the natural attenuation period, implementing active remediation, etc.) will also be discussed, as required.

A checklist is presented in Attachment C-1 to this O&M Plan summarizing the items to be addressed in each CAP progress report.

C.10.2 CORRECTIVE ACTION PLAN COMPLETION REPORT INFORMATION

A final CAP completion report will be prepared following the completion of the corrective action and confirmation sampling. The CAP completion report will summarize the corrective measures taken at the site, provide a summary of sampling data, and give results of the confirmation groundwater sampling events.

ATTACHMENT C-1

Corrective Action Plan Progress Report Checklist
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart, Georgia

Progress Report Section	Baseline Sampling Event	Semiannual Monitored Natural Attenuation Sampling	Confirmatory Sampling Event
Work accomplished (description of significant activities)	• Date of sampling and analysis	• Dates of sampling and analysis, including well inspections • Any monitoring well system maintenance performed	• Date of sampling and analysis
Problems encountered	• Summary of any problems encountered • Actions taken to rectify problems	• Summary of any problems encountered • Actions taken to rectify problems	• Summary of any problems encountered • Actions taken to rectify problems
Analysis of trends	• Baseline to establish point of departure for analysis of trends	• Comparison of groundwater analytical results to predicted performance	• Comparison of results of groundwater analysis to remedial levels • Summary of any deviations noted
Communications/contacts	• Summaries of visitors to the site • Summaries of major contacts or communications with GEPD, the local community, or others	• Summaries of visitors to the site • Summaries of major contacts or communications with GEPD, the local community, or others	• Summaries of visitors to the site • Summaries of major contacts or communications with GEPD, the local community, or others
Conclusions and recommendations	• Included in each CAP report	• Completion of monitored natural attenuation period, if remedial levels have been met • Need for contingent action (e.g., continued monitored natural attenuation, contingent active remediation) if remedial levels have not been met	• Need for contingent action if remedial levels exceeded

CAP = Corrective Action Plan.
GEPD = Georgia Environmental Protection Division.

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APPENDIX D

IMPLEMENTATION CHECKLIST FOR MONITORED NATURAL ATTENUATION OF CONSTITUENTS OF CONCERN

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Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart, Georgia

ROLE OF MONITORED NATURAL ATTENUATION	
Source Control	• There is no significant recoverable free petroleum product (NAPL) at SWMU 27F. Approximately 0.05 foot of a thick, black, viscous material was found in MW12 during the measurement of the water level in May 2001. MW12 was installed to the top of the clay layer that occurs at approximately 8 feet bgs. The material was removed with an absorbent sock. The material does not readily recharge in MW12. • Benzo(*a*)pyrene was identified as an HHCOC in a very limited and small quantity in the surface soil (0 feet to 2 feet bgs) around MW10. • No CMCOCs were identified in the surface or subsurface soil. • Benzene was identified as an HHCOC in groundwater. • No other source control measures are needed to control the long-term threat of release because there is no principal-threat waste at the SWMU 27F site.
Restoration of Groundwater	• Groundwater will be restored to "beneficial use" through reduction of benzene concentrations to less than the remedial level that was developed based on its MCL in the BHHRA [revised final addendum (SAIC 2001) to the revised final Phase II RFI report for 16 SWMUs (SAIC 2000)]. Benzene is the only constituent in groundwater identified as an HHCOC. Groundwater at this site is not used as a source of drinking water, and exposure of a future resident is highly unlikely. • The timeframe is reasonable for restoration of groundwater to this beneficial use. Results of modeling predict that the benzene concentrations in groundwater will decline to below the remedial levels in just 6 years from January 2001. This timeframe is reasonable compared to the 2 years to 3 years predicted for active remediation systems. • Further migration of the plume will be prevented. Modeling has predicted that lateral migration of contamination is unlikely. This prediction has been proven correct because there are sampling points farther downgradient (at the edge of the plume) that indicate no benzene contamination. Benzene has not been detected in the deep surficial groundwater. In addition, vertical migration below the surficial groundwater is unlikely because there is a clay layer (Hawthorn layer) located approximately 45 feet bgs. • Exposure to contaminated groundwater will be prevented through continuation of groundwater use restrictions and excavation permit restrictions at SWMU 27F. Groundwater at this site is not used as a source of drinking water. • Further reduction in risk will occur as contaminant concentrations in groundwater continue to decline due to biodegradation, advection, and dispersion.
Soil Remediation	Benzo(*a*)pyrene was indicated as a potential slight risk to an on-site Installation worker and a future on-site resident. The extent of benzo(*a*)pyrene in surface soil was confined to a single location near the closed OWS and the heavily used vehicle maintenance pad. The contaminated soil is probably the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to closure. Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999. The small amount of benzo(*a*)pyrene does not represent a significant threat to human health.
Public Involvement	The public will be provided with an opportunity for review and comment on the CAP in accordance with the Fort Stewart Hazardous Waste Facility Permit. The public will also be provided with an opportunity for review and comment on any substantive changes in the remediation approach or schedule that might arise during implementation of the corrective action.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

ROLE OF MONITORED NATURAL ATTENUATION (CONTINUED)	
Protective of Human Health and the Environment	MNA is protective of human health and the environment at SWMU 27F. Based on the conclusions in Chapter 10 of the revised final addendum (SAIC 2001) to the revised final RFI report for 16 SWMUs (SAIC 2000), there is no current human health or ecological risk associated with benzene in groundwater. Benzo(*a*)pyrene was indicated as a possible slight risk to an on-site Installation worker and a future on-site resident Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999. Potential future exposure is unlikely because the shallow surficial groundwater is not a viable source of drinking water at FSMR. Attainment of the remedial levels will effectively eliminate any potential future risk.
Capable of Achieving Remedial Objectives	The remedial objective is to attain media cleanup standards for COCs in surface soil and groundwater. Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001,respectively, thereby achieving remedial objectives.
Capable of Achieving Objectives in Reasonable Timeframe	Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively. This timeframe is reasonable compared to the 2.5 years to 3 years predicted for active remediation systems.
Demonstrated Effectiveness	• MNA has been demonstrated to be effective through technical analysis of modeling of soil (SESOIL model analysis) and groundwater (AT123D model analysis) as well as of geochemical data. • Performance monitoring will include soil and groundwater sampling to demonstrate the effectiveness of MNA. Performance monitoring of surface water is not necessary at SWMU 27F because there are no surface water pathways. • Contingency (backup) measures are identified in the O&M Plan to ensure attainment of remedial objectives. Contingency measures include extension of monitoring and evaluation of active remediation alternatives (i.e., addition of specialized bacteria to enhance natural biodegradation or active injection of oxygen, and/or nutrients into the groundwater).
DEMONSTRATION OF EFFICACY	
Site-Specific Characterization: Conceptual Site Model	Former releases of petroleum-related constituents from probable spills and releases from the OWS and its piping and adjacent vehicle maintenance pad located at SWMU 27F have resulted in contamination of soil and groundwater. Groundwater contaminated with benzene at concentrations exceeding its MCL extends from the southwest edge of the vehicle maintenance pad to 125 feet downgradient (southwest). The groundwater contamination is limited to the upper portion of the surficial groundwater. The extent of benzo(*a*)pyrene in surface soil was confined to a single location near the closed OWS and the heavily used vehicle maintenance pad. The contaminated soil is probably the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to closure. Floating product was identified in one well, MW12. Approximately 0.05 foot of a thick, black, viscous material was indicated in MW12 during the measurement of the water level in May 2001. MW12 was installed to the top of the clay layer that occurs at approximately 8 feet bgs. The material was removed with an absorbent sock. The material does not readily recharge in MW12 and is not considered to be a significant source of NAPLs.
Nature and Distribution of Contamination in Groundwater	Benzene contamination is confined to an oblong plume approximately 125 feet in length and to the shallow surficial groundwater. Benzene has not been detected in the deep surficial groundwater wells. Monitoring of shallow surficial wells since 1999 has shown decreasing benzene concentrations in the wells near the former source (MW10) and downgradient of the potential source (MW9 and MW7). No other COCs have been identified in the most recent groundwater data (January 2001).

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

DEMONSTRATION OF EFFICACY (CONTINUED)	
Nature and Distribution of Contaminant Sources	The potential source of the groundwater contamination is the piping from the floor drains at the vehicle maintenance pad to the OWS. The piping is believed to be broken. The floor drains have been plugged and are no longer used. The source of the benzo(*a*)pyrene in surface soil was confined to a single location near the OWS and the heavily used vehicle maintenance pad. The contaminated soil is believed to be the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to closure of the OWS.
Potential Risk or Impacts to Receptors	Benzo(*a*)pyrene was indicated as a possible slight risk to an on-site Installation worker and a future on-site resident. The risk to the on-site Installation worker from benzo(*a*)pyrene is 1.62E-05, which is slightly above the target risk value of 1E-06. The site is not planned for a future residential site. Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999. There is no current significant human health or ecological risk associated with exposure to benzene in groundwater. Potential future exposure is unlikely because the shallow groundwater is not a viable source of drinking water at FSMR. Attainment of the remedial levels for COCs will effectively eliminate any potential future risk for all the probable scenarios, as outlined in the BHHRA. No surface water is present at the site.
Proximity of Receptors	Surficial groundwater is not used as a source of drinking water. The underlying Principal Artesian (Floridan) Aquifer is the primary source of drinking water in the vicinity of FSMR. The closest surface water body is a man-made drainage ditch approximately 450 feet south of the site. The drainage ditch receives miscellaneous drainage and surface water runoff form the northwestern side of the garrison area and discharges into Mill Creek approximately 2,400 feet to the west.
Quantitative Understanding of Source Mass	The source of the benzo(*a*)pyrene in surface soil is confined to a single location near the closed OWS and the heavily used vehicle maintenance pad. The contaminated soil is believed to be the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to closure of the OWS. Groundwater contaminated with benzene at concentrations exceeding its MCL extends from the southwest edge of the vehicle maintenance pad to 125 feet downgradient (southwest). The groundwater contamination is limited to the upper portion of the surficial groundwater.
Groundwater Flow	The shallow surficial groundwater flow direction across the site is to the southeast. The deep surficial groundwater flow direction is to the south to slight southeast. A slight groundwater high is located at MW17, which may be due to its being located in a grassy area and closer to a drainage ditch (potential higher percolation). The hydraulic gradients of the shallow and deep surficial groundwater are 0.0009 foot/foot and 0.0014 foot/foot, respectively. Recharge is by precipitation. The aquifer consists of widely varying amounts of sand and silty sands. A clay layer ranging in thickness of approximately 2 feet to 4 feet occurs at approximately 8 feet bgs at SWMU 27F. The groundwater at SWMU 27F will be able to be adequately monitored through the existing monitoring well network. The existing monitoring well network consists of 17 monitoring wells (four deep and 13 shallow surficial wells) located upgradient, downgradient, and within the benzene plume.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

DEMONSTRATION OF EFFICACY (CONTINUED)	
Contaminant Phase Distribution and Partitioning	Floating product was identified in one well, MW12. Approximately 0.05 foot of a thick, black, viscous material was indicated in MW12 during the measurement of the water level in May 2001. MW12 was installed to the top of the clay layer that occurs at approximately 8 feet bgs. The material was removed with an absorbent sock. The material does not readily recharge in MW12 and is not considered to be a significant source of NAPLs. The soil-to-groundwater partitioning was evaluated using the SESOIL model. No CMCOCs are present in soil at SWMU 27F.
Rates of Biological and Nonbiological Transformation	Natural attenuation has been demonstrated to be effective through technical analysis of modeling of soil (SESOIL analysis) and groundwater (AT123D analysis). The models accounts for fate and transport processes of advection, dispersion, adsorption/retardation, and biological decay. Biological transformation has been simulated assuming conservative biodegradation, literature-based values. Direct measurement of the nutrients, electron donors, or microbial population present has not been made.
Variation in Factors with Time	The OWS was closed in 2001. The closure consisted of placing plywood over the metal grates covering the OWS and plugging the drains located at the adjacent, covered maintenance pad. Approximately 0.05 foot of free product was discovered in MW12 in May 2001 and removed using an absorbent sock. The free product does not readily accumulate in MW12. The potential presence of significant undiscovered additional free product at the site during the MNA period may impact the time estimated by modeling. However, this is unlikely because significant free product has not been measured to date in any of the monitoring wells.
Site-Specific Analysis: Estimated Rate of Attenuation	The rates of natural attenuation of benzo(*a*)pyrene in surface soil were modeled using SESOIL. The rates of natural attenuation of benzene in groundwater have been simulated using AT123D modeling.
Anticipated Time Required to Achieve Remedial Objectives	Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively. This timeframe is reasonable compared to the 2.5 years to 3 years predicted for active remediation systems.
Lines of Evidence (Three Tiers of Information)	The efficacy of MNA at SWMU 27F is evidenced by means of two of the three tiers of information: monitoring trends and hydrogeologic and geochemical data analysis. These lines of evidence provide sufficient confidence in the rate of attenuation and the anticipated time required to achieve remediation objectives. 1. Monitoring of shallow surficial wells since 1999 has shown decreasing benzene concentrations in the wells near the former source (MW10) and downgradient of the potential source (MW9 and MW7). No other COCs have been identified in the most recent groundwater data (January 2001). 2. Modeling has predicted that lateral migration of contamination is unlikely. This prediction has been proven correct because there are sampling points farther downgradient (at the edge of the plume) that indicate no benzene contamination. Benzene has not been detected in the deep surficial groundwater. In addition, vertical migration below the surficial groundwater is unlikely because there is a clay layer (Hawthorn layer) located approximately 45 feet bgs.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

DEMONSTRATION OF EFFICACY (CONTINUED)	
	3. Hydrogeologic and geochemical data have been used to simulate the rate of attenuation. Tables E-1 and E-4 of the revised final addendum (SAIC 2001) to the revised final Phase II RFI report for 16 SWMUs (SAIC 2000) lists the data from site-specific characterization used in the analysis. Biological transformation has been simulated assuming conservative, literature-based values for biodegradation half-lives for the COCs in groundwater. 4. Direct measurement of the nutrients, electron donors, or microbial population present has not been made. However, field measurements during groundwater sampling indicate an aerobic subsurface environment.
APPROPRIATENESS	
Whether Contaminants in Soil or Groundwater Can Be Effectively Remediated by Natural Attenuation Processes	The COCs in soil and groundwater can be effectively remediated by natural attenuation processes. Natural attenuation processes, particularly biological degradation, are well documented for constituents associated with petroleum/waste oil spill sites. The COCs may naturally degrade through microbial activity and ultimately produce nontoxic end products (e.g., carbon dioxide and water). At SWMU 27F, a small area of benzo(*a*)pyrene contamination in surface soil remains. Only benzene has been identified in groundwater as an HHCOC. Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively. The assumptions used by the model are highly conservative, and the representative soil concentrations, as well as the time required to attenuate, are likely to be overestimated. Consequently, the time required for attenuation to achieve the remedial goals is likely to be less than the 26 months and 6 years estimated for soil and groundwater, respectively.
Whether the Plume Is Stable or Whether Conditions Will Change Over Time	Monitoring of shallow surficial wells since 1999 has shown decreasing benzene concentrations in the wells near the former source (MW10) and downgradient of the potential source (MW9 and MW7). No other COCs have been identified in the most recent groundwater data (January 2001). Benzene has not been detected in the deep surficial groundwater wells during any of the monitoring events.
Whether Receptors Will Be Adversely Impacted	Benzo(*a*)pyrene was indicated as a potential slight risk to an on-site Installation worker and a future on-site resident The risk to the on-site Installation worker from benzo(*a*)pyrene is 1.62E-05, which is slightly above the target risk value of 1E-06. The site is not planned for a future residential site. Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999. There is no current human health or ecological risk associated with exposure to benzene and other potential COCs in groundwater at the site because there are no current receptors. Potential future exposure is unlikely because the shallow groundwater is not a viable source of drinking water at FSMR. Attainment of the remedial levels will effectively eliminate any potential future risk. Groundwater may intercept surface water located approximately 450 feet to the southwest; however, modeling has indicated that benzene in groundwater will be naturally attenuated before reaching the surface water; therefore, receptors will not be adversely impacted by implementation of MNA.
Whether There Is a Current or Projected Demand for the Affected Resources	Shallow groundwater is not a viable source of drinking water. The underlying Principal Artesian (Floridan) Aquifer is the primary source of drinking water in the vicinity of SWMU 27F. Within the short timeframe of this remediation (6 years), there will be no demand for the affected groundwater resource.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

APPROPRIATENESS (CONTINUED)	
Whether Contamination Will Exert Long-Term Detrimental Impact on Water Supplies/ Resources	The shallow aquifer is not a viable source of drinking water. Benzene contamination will be remediated at all points within the aquifer to below the remedial levels within 6 years. There will, therefore, be no long-term detrimental impact to water resources within the vicinity of SWMU 27F.
Whether the Estimated Timeframe of Remediation Is Reasonable	Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively. This timeframe is reasonable compared to the 2.5 years to 3 years predicted for active remediation systems.
Whether the Sources of Contamination Can Be Adequately Controlled	Floating product was identified in one well, MW12. Approximately 0.05 foot of a thick, black, viscous material was indicated in MW12 during the measurement of water level in May 2001. MW12 was installed to the top of the clay layer that occurs at approximately 8 feet bgs. The material was removed with an absorbent sock. The material does not readily recharge in MW12 and is not considered a significant source of NAPLs. The source of the benzo(*a*)pyrene in surface soil was confined to a single location near the OWS and the heavily used vehicle maintenance pad. The contaminated soil is believed to be the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to the closure of the OWS. The surface soil contamination is not considered to be an active source of contamination. Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999.
Whether Transformation Products Present a Greater Risk	Methane is a biodegradation product of benzene and is evidence that biodegradation is occurring. Methane is an odorless, colorless gas that is physiologically inert and poses no health risk. Methane is a simple asphyxiate; at high concentrations it can supplant oxygen in the air, creating an oxygen-deficient environment. It is also flammable and has a lower explosive limit in air of 5 percent. Methane monitoring will be performed during the MNA period. Other transformation products formed through subsequent biodegradation of methane include carbon dioxide and water, which pose no health risk.
Whether Active Remediation Measures Will Impact the MNA	Approximately 0.05 foot of free product was discovered in MW12 in May 2001 and removed using an absorbent sock. The free product does not readily accumulate in MW12. Measurement of significant additional free product at the site during the MNA period and is not considered to be a significant source of NAPLs that will impact the time estimated by modeling.
Whether Reliable Institutional Controls Are Available for Monitoring and Enforcement	The U.S. Government will retain ownership of the 3d Engineer Brigade, Northwest of Building 1340, (SWMU 27F) to ensure that monitoring and enforcement of the MNA O&M Plan are completed. Other institutional controls at SWMU 27F include groundwater use restrictions and excavation permits. These controls are reliable for the short-term duration (6 years) of MNA.
REASONABLENESS OF REMEDIATION TIMEFRAME	
Comparison to Other Alternatives	The results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively. This timeframe is reasonable compared to the 2.5 years to 3 years predicted for active remediation systems (i.e., specialized bacteria addition and enhanced bioremediation).
Balancing of Tradeoffs: Classification, Value of Resource	According to the *Pollution Susceptibility Map of Georgia* (GDNR 1992), SWMU 27F is located in an average or higher groundwater pollution susceptibility area. Shallow groundwater is not a viable source of drinking water.
Timeframe in Which Aquifer Will Be Needed	Shallow groundwater is not a viable source of drinking water. The underlying Principal Artesian (Floridan) Aquifer is the primary source of drinking water in the vicinity of SWMU 27F. Within the short timeframe of this remediation (6 years from January 2001), there will be no demand for the affected groundwater resource.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

REASONABLENESS OF REMEDIATION TIMEFRAME (CONTINUED)	
Plume Stability Over Time	Monitoring of shallow surficial wells since 1999 has shown decreasing benzene concentrations in the wells near the former source (MW10) and downgradient of the potential source (MW9 and MW7). No other COCs have been identified in the most recent groundwater data (January 2001). Benzene has not been detected in the deep surficial groundwater wells during any of the monitoring events.
Detrimental Impacts	The shallow aquifer is not a viable source of drinking water. Benzene contamination will be remediated at all points within the aquifer to below the respective remedial levels within 6 years from January 2001. There will, therefore, be no long-term detrimental impact to water resources within the vicinity of SWMU 27F.
Uncertainties in Mass or Time Estimates	Chemical, hydrogeologic, and geochemical data are of adequate quality and usability. Data collection and laboratory analysis have been in accordance with approved U.S. Army Corps of Engineers procedures for assessing data quality, including data validation. The lateral and vertical extent of contamination has been defined adequately to provide accurate estimates of the mass of benzo(*a*)pyrene contamination in surface soil and benzene contamination in groundwater. Time estimates have been made based on SESOIL and AT123D modeling using site-specific chemical, hydrogeologic, and geochemical data and a conservative, literature-based value for the biodegradation rates of benzo(*a*)pyrene and benzene. Uncertainties inherent in these estimates are, therefore, acceptable. The O&M Plan has identified contingent measures to address uncertainties.
Reliability of Monitoring and Institutional Controls	The U.S. Government will retain ownership of SWMU 27F to ensure that monitoring and enforcement of the MNA O&M Plan are completed. Other institutional controls at SWMU 27F include groundwater use restrictions and excavation permits. Because the timeframe for MNA remediation is relatively short (6 years from January 2001), monitoring and institutional controls can be reliably implemented and will be continued until remedial levels have been achieved.
Public Acceptance of Timeframe	The public will be provided with an opportunity for review and comment on the CAP in accordance with the Fort Stewart Hazardous Waste Facility Permit. The public will also be provided with an opportunity for review and comment on any substantive changes in the remediation approach or schedule that may arise during implementation of the corrective action.
Provisions for Availability of Adequate Funding	Funding is assured for the site through O&M Army funds.
REMEDIATION OF SOURCES	
Removal of Contaminated Soil	Contaminated soil will not be removed. The source of the benzo(*a*)pyrene in surface soil is confined to a single location near the closed OWS and the heavily used vehicle maintenance pad. The contaminated soil is believed to be the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to closure of the OWS. The surface soil contamination is not considered an active source of contamination. Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999.
Free-Phase NAPL Removal	Floating product was identified in one well, MW12. Approximately 0.05 foot of a thick, black, viscous material was indicated in MW12 during the measurement of the water level in May 2001. MW12 was installed to the top of the clay layer that occurs at approximately 8 feet bgs. The material was removed with an absorbent sock. The material does not readily recharge in MW12 and is not considered to be a significant source of NAPLs. Monitoring of free product levels in the wells will be performed as part of groundwater monitoring during the MNA period under the O&M Plan, and appropriate removal actions will be taken.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

REMEDIATION OF SOURCES (CONTINUED)	
Treatment	MNA will be used to treat soil and groundwater contamination at SWMU 27F. Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively.
Principal-Threat Waste Treatment	Not applicable. There is no principal-threat waste.
Containment	Not applicable. The identified soil and groundwater contamination is not migrating. The benzo(*a*)pyrene in surface soil was confined to a single location near the OWS and the heavily used vehicle maintenance pad. The contaminated soil is believed to be the result of spillage from the containers (i.e., oil filters, oil cans/containers) that were turned upside down on the OWS grate to remove residual product prior to its closure. The surface soil contamination is not considered to be an active source of contamination. Modeling has indicated that the benzo(*a*)pyrene will be naturally attenuated in 26 months from October 1999. Monitoring of shallow surficial wells since 1999 has shown decreasing benzene concentrations in the wells near the former source (MW10) and downgradient of the potential source (MW9 and MW7). No other COCs have been identified in the most recent groundwater data (January 2001). Benzene has not been detected in the deep surficial groundwater wells during any of the monitoring events.
PERFORMANCE MONITORING AND EVALUATION	
Location	In accordance with Table C-2 of the O&M Plan, 13 shallow surficial groundwater wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] and two soil sampling locations will be monitored. Locations of the soil samples and monitoring wells are shown in Figure C-1 of the O&M Plan.
Frequency	In accordance with Table C-5 of the O&M Plan, the monitoring frequency will begin in January 2002, followed by biannual sampling (every 2 years) for the next 6 years (1 year added as contingency). Modeling has estimated that the remedial level for benzo(*a*)pyrene in soil will be achieved in 26 months from October 1999; therefore, the soil sampling from CY 2002 or the first biannual sampling (CY 2004) will represent the final/confirmatory soil sampling if remedial levels have been achieved. Flexibility for adjusting the monitoring duration is provided through an analysis of trends and effectiveness of the corrective action as presented in progress reports associated with each sampling event. The last complete round of groundwater samples collected January 2001 will be considered to be the baseline groundwater sampling for the MNA period. Confirmatory groundwater sampling will be conducted 1 year after the conclusion of the 7-year MNA period (1 year added as contingency).
Type of Samples	In accordance with Table C-2 of the O&M Plan, soil and groundwater samples will be collected during the performance monitoring starting in CY 2002. Soil sampling will be discontinued upon achieving remedial levels, which is expected to occur during the first soil sampling conducted in CY 2002. However, if soil remedial levels have not been achieved, then additional soil sampling will be conducted during the first biannual sampling (CY 2004). Performance monitoring in groundwater will provide sufficient demonstration of natural attenuation for protection of the surficial aquifer.
Measurements	In accordance with Table C-2 and Section C.5.2 of the O&M Plan, analytical parameters for groundwater will include volatile organic compounds, SVOCs, and natural attenuation parameters [methane, carbon dioxide, nitrate/nitrite, sulfate/sulfide, total iron, and ferrous iron (field analysis)]. Field parameters for groundwater will be measured at the time of sampling and will include dissolved oxygen, temperature, oxidation-reduction potential, conductivity, and pH. Water and free product levels will be measured in all wells. Only SVOCs will be analyzed in soil.

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

PERFORMANCE MONITORING AND EVALUATION (CONTINUED)	
Design: Demonstrate That Natural Attenuation Is Occurring as Expected	Monitoring of the 13 shallow surficial monitoring wells provides suitable measurement of contaminant trends in wells within the plume, upgradient, and laterally to the side of the plume. A decline in benzene concentrations will demonstrate that degradation is occurring as expected. Two soil samples will provide suitable confirmation that remedial levels have been achieved.
Detect Changes (Hydrogeologic, Geochemical, and Microbial)	The presence of elevated methane gas concentrations in wells within the plume (MW7, MW9, and MW14) will demonstrate that biodegradation is occurring. Other geochemical parameters listed under "measurements" above will identify changes in the geochemical conditions at SWMU 27F.
Identify Transformation Products	The presence of elevated methane gas concentrations in wells within the plume (MW7, MW9, and MW14) will demonstrate that biodegradation is occurring, resulting in methane as a transformation product. These constituents will be monitored through the natural attenuation period and confirmatory sampling.
Verify That the Plume Is not Expanding	Monitoring of wells MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18 provides suitable measurement of contaminant trends upgradient and laterally to the side of the plume to verify that the plume is not expanding.
Verify That There Is No Unacceptable Impact to Downgradient Receptors	There are no potential downgradient receptors. Monitoring of wells MW5, MW6, MW14, MW16, MW17, and MW18 located at the perimeter of the plume will provide suitable measurement of groundwater quality just prior to its going off-site.
Detect New Releases	Monitoring of the MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18 located upgradient, downgradient, and along the perimeter of the SWMU 27F site provides suitable detection of any potential new releases from the OWS and vehicle maintenance pad and potential off-site releases (upgradient).
Demonstrate Effectiveness of Institutional Controls to Protect Receptors	Shallow groundwater is not used as a drinking water supply. Monitoring of wells MW5, MW6, MW14, MW16, MW17, and MW18 located at the perimeter of the plume provides suitable measurement of groundwater quality just prior to its going off-site.
Verify Attainment of Remediation Objectives	Monitoring of the 13 wells [MW1 (upgradient), MW3, MW4, MW5, MW6, MW7, MW9, MW10, MW14, MW15, MW16, MW17, and MW18] provides suitable measurement of contaminant concentrations in wells within the plume, upgradient, and laterally to the side of the plume to verify that remediation objectives (remedial levels) have been attained throughout the shallow aquifer. Two soil samples will provide suitable confirmation that remedial levels have been achieved.
Duration	Results of modeling predict that benzo(*a*)pyrene concentrations in surface soil and benzene concentrations in groundwater will decline to below their remedial levels in approximately 26 months from October 1999 and 6 years from January 2001, respectively. Therefore, the MNA period for treatment of benzene in groundwater will determine the duration of treatment. In accordance with Table C-5 of the O&M Plan, groundwater monitoring will be conducted throughout the MNA period [estimated to be 7 years from January 2001 (1 year added as contingency)] or until remedial levels (remediation objectives) have been met. Flexibility for adjusting the duration is provided through an analysis of trends and effectiveness of the corrective action as presented in semiannual progress reports. Extending (or reducing) the duration of monitoring is a contingent remedy to be evaluated as part of the progress reports associated with each sampling event.
Remedy Evaluation	Results of monitoring well sampling and analysis, in particular an analysis of trends in the rate of decline in contaminant concentrations, will be evaluated after each sampling event throughout the MNA period. If trends do not match predicted modeled behavior, then contingencies will be considered, including the following:

Table D-1. Implementation Checklist for Monitored Natural Attenuation of COCs[a]
3d Engineer Brigade, Northwest of Building 1340, Fort Stewart Georgia (continued)

CONTINGENCY REMEDIES	
	• modifying the conceptual site model and/or hydrogeologic model, • revising the SESOIL and/or AT123D model to correlate to new data, • extending (or reducing) the duration of MNA, and • reevaluating and potentially implementing active remediation. Specific alternatives to be evaluated at that time include addition of specialized bacteria addition or enhanced biodegradation through injection of oxygen and/or nutrients.
Triggers: Concentrations Groundwater Show Increase	If benzene concentrations in any given well increase at least 50 percent for two consecutive sampling events, then a contingency remedy evaluation will be implemented. The contingency remedy evaluation will be presented to GEPD in the CAP progress report.
Near-Source Wells Show Increase (New Release)	If benzene concentrations in the monitoring wells increase to a level exceeding twice their maximums predicted by modeling, then a contingency remedy evaluation will be implemented. The contingency remedy evaluation will be presented to GEPD in the CAP progress report.
Contaminants Are Found Outside the Original Plume Boundary	If benzene concentrations in any individual well increase to a level greater than previously detected, then a contingency remedy evaluation will be implemented. The contingency remedy evaluation will be presented to GEPD in the CAP progress report.
Concentrations not Decreasing Sufficiently to Meet Remediation Objectives	If benzene concentrations exceed the predicted concentration by more than 25 percent for two consecutive sampling events, then a contingency remedy evaluation will be implemented. The contingency remedy evaluation will be presented to GEPD in the CAP progress report.
Land and/or Groundwater Use Has Changed	If land use or groundwater use at SWMU 27F changes, then a contingency remedy evaluation will be implemented. The contingency remedy evaluation will be presented to GEPD in the CAP progress report.

[a]This checklist follows U.S. Environmental Protection Agency guidance as described in Office of Solid Waste and Emergency Response Directive 9200.4-17P (EPA 1999).

Notes:

AT123D = Analytical Transient 1-, 2-, 3-Dimensional.
bgs = Below ground surface.
BHHRA = Baseline human health risk assessment.
CAP = Corrective Action Plan.
CMCOC = Contaminant migration constituent of concern.
COC = Constituent of concern.
CY = Calendar year.
FSMR = Fort Stewart Military Reservation.
HHCOC = Human health constituent of concern.
MCL = Maximum contaminant level.
MNA = Monitored natural attenuation.
NAPL = Nonaqueous-phase liquid.
O&M = Operations and maintenance.
OWS =Oil/water separator.
RCRA = Resource Conservation and Recovery Act.
RFI = RCRA Facility Investigation.
SESOIL = Seasonal Soil Compartment.
SVOC = Semivolatile organic compound.
SWMU = Solid waste management unit.

References:

EPA (U.S. Environmental Protection Agency) 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites,* Directive 9200.4-17P, April.

GDNR (Georgia Department of Natural Resources) 1992. *Pollution Susceptibility Map of Georgia.*

SAIC (Science Applications International Corporation) 2000. *Phase II RCRA Facility Investigation Report for 16 Solid Waste Management Units at Fort Stewart, Georgia* (Revised Final), April.

SAIC 2001. *Addendum for SWMU 27F: 3d Engineer Brigade, Northwest of Building 1340 to the Revised Final Phase II RCRA Facility Investigation Report for 16 Solid Waste Management Units at Fort Stewart, Georgia* (Revised Final), June.