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. TASK 1...	60.0d
A1000	0.0d
A1010	60.0d
SWMU 27F. TASK 2...	90.0d
A1020	30.0d
A1030	0.0d
A1040	30.0d
A1050	30.0d
A1060	0.0d
SWMU 27F. TASK 3...	1860.0d
A1070	15.0d
A1080	5.0d
A1090	5.0d
A1100	5.0d
A1110	5.0d
SWMU 27F. TASK 4...	1695.0d
A1120	225.0d
A1130	60.0d
A1140	0.0d
A1150	30.0d
A1160	30.0d
A1165	0.0d
A1170	45.0d
A1180	30.0d
A1190	0.0d
A1200	30.0d
A1210	225.0d
A1220	60.0d
A1230	0.0d
A1240	30.0d
A1250	30.0d
A1255	0.0d
A1260	45.0d
A1270	30.0d
A1280	0.0d
A1290	30.0d
A1300	225.0d
A1310	60.0d
A1320	0.0d
A1330	30.0d
A1340	30.0d
A1345	0.0d
A1350	45.0d
A1360	30.0d
A1370	0.0d
A1380	30.0d
SWMU 27F. TASK 5...	315.0d
A1390	60.0d
A1400	0.0d
A1410	30.0d
A1420	30.0d
A1430	0.0d
A1440	45.0d
A1450	30.0d
A1460	0.0d
A1470	30.0d
A1480	0.0d
A1490	0.0d

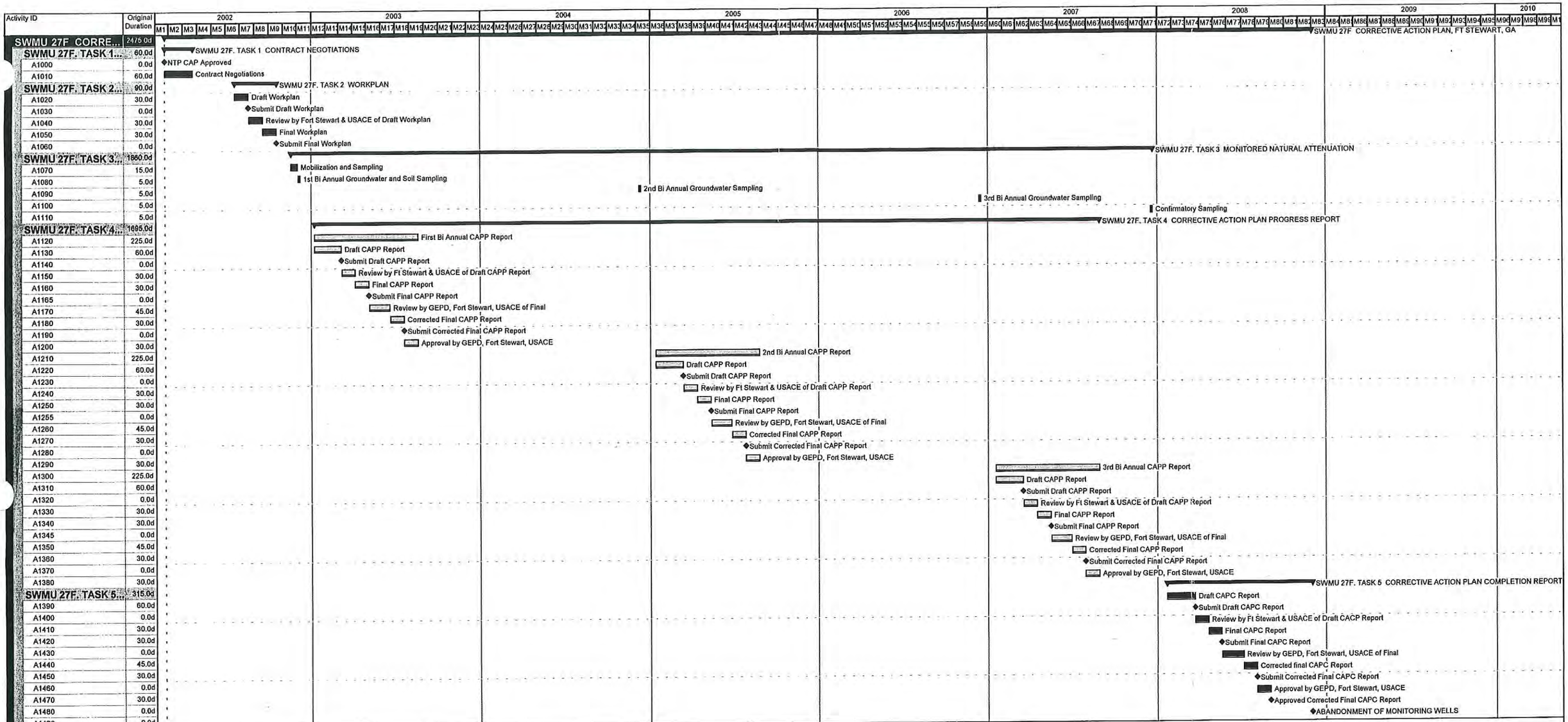

Figure 5-1. Corrective Action Schedule, SWMU 27F, Northwest of Building 1340

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6.0 REFERENCES

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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

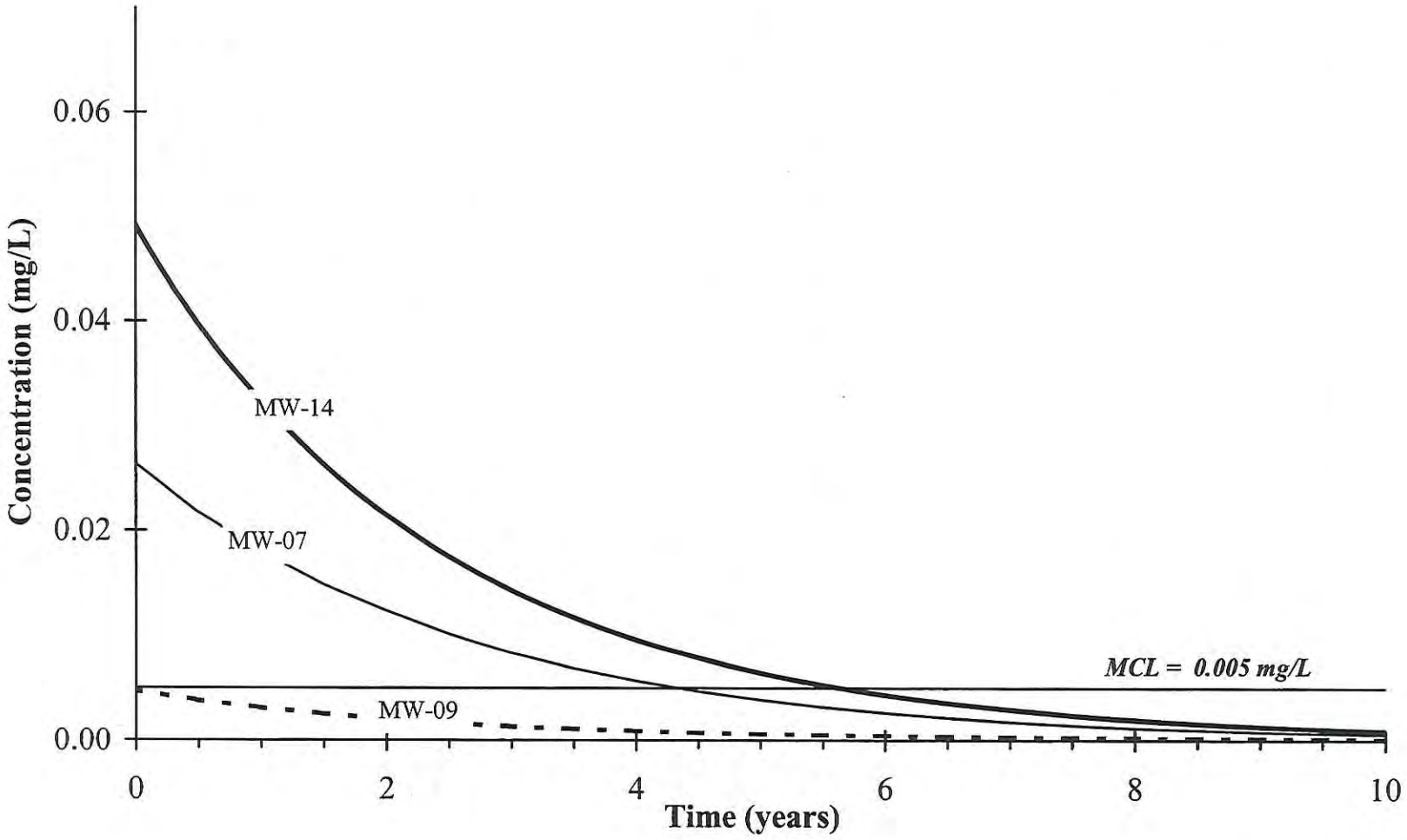


Table A-1. Dilution and Attenuation Factors, SWMU 27F

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

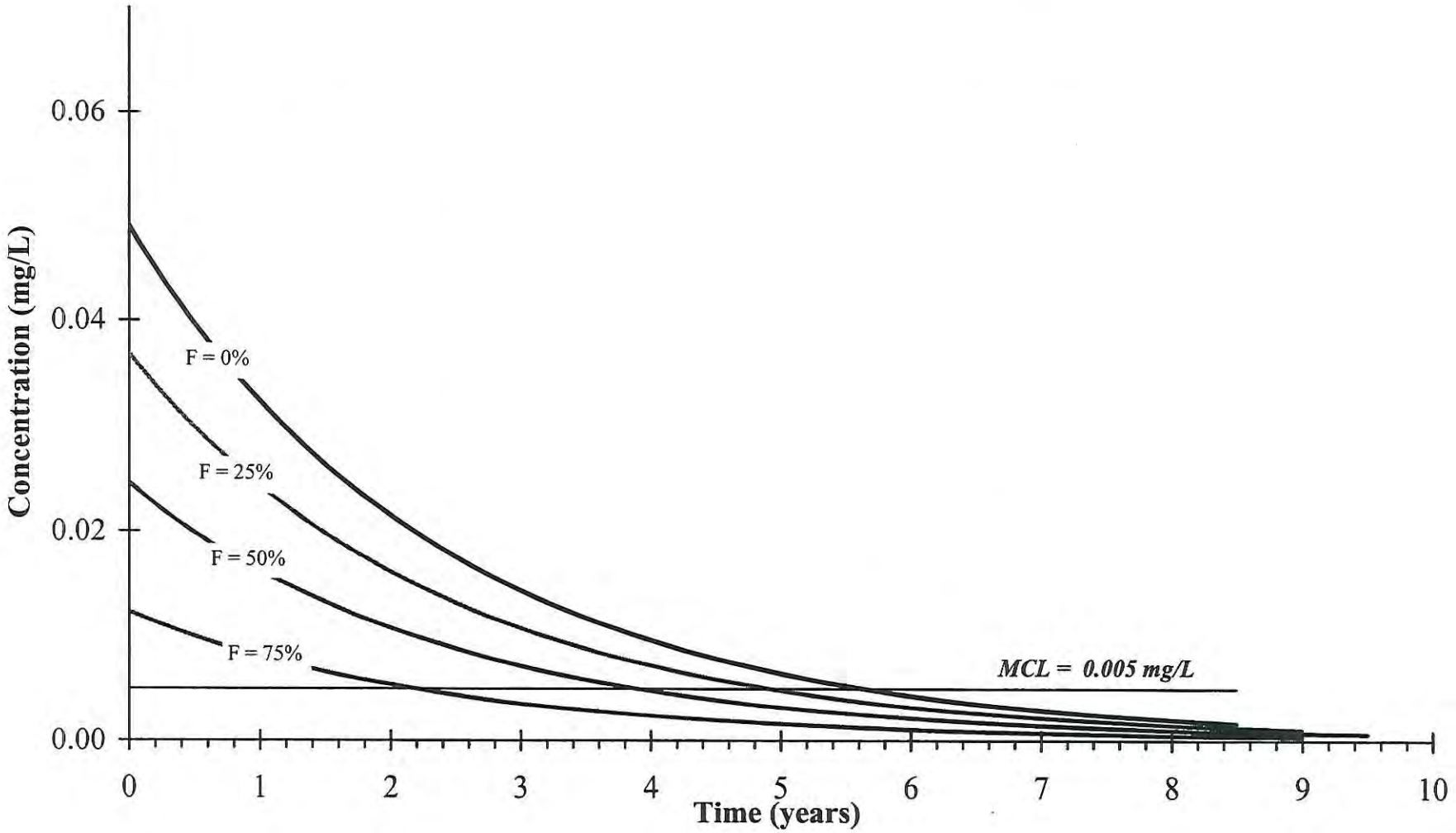
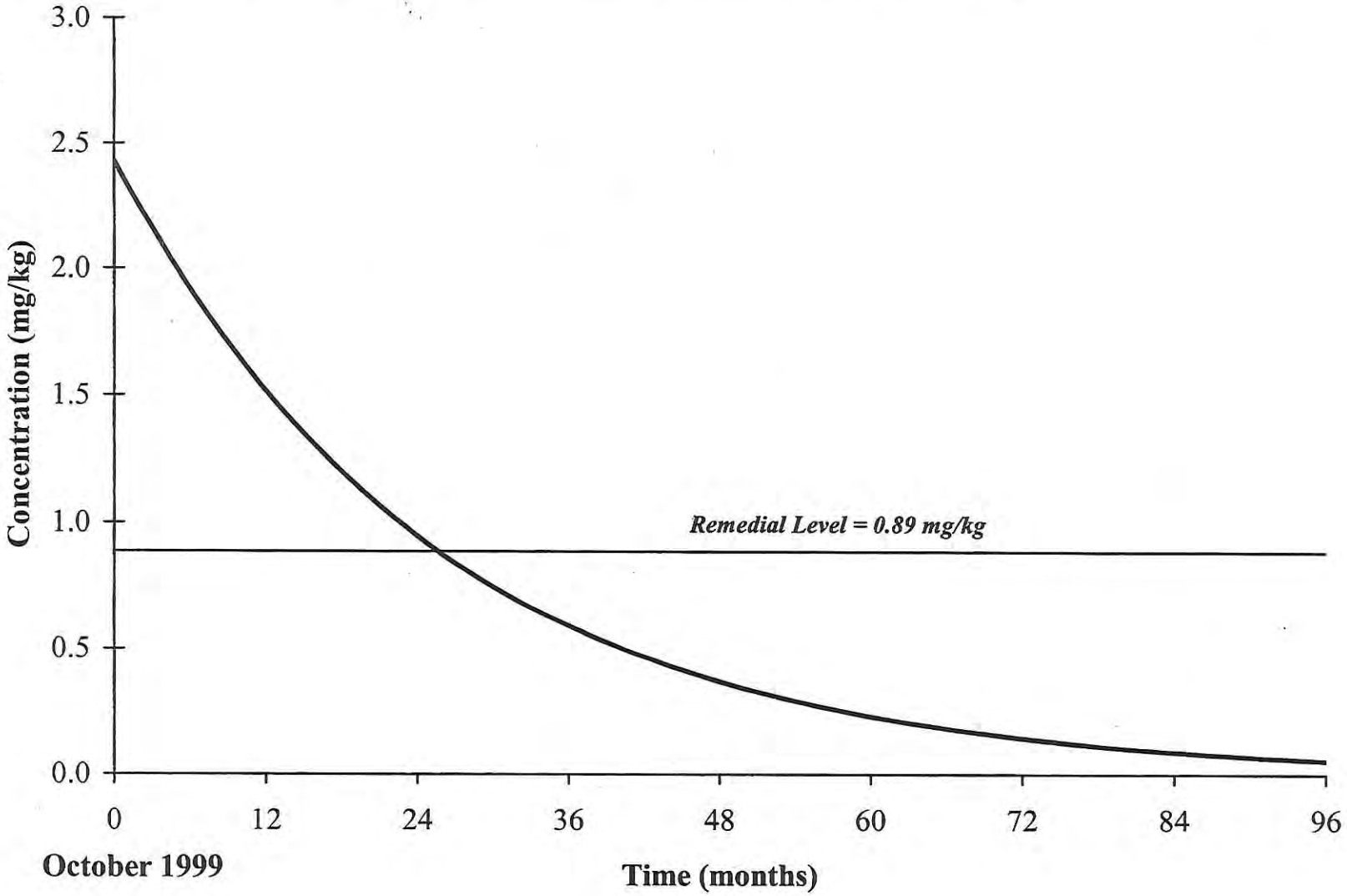


Figure A-3. SESOIL-Predicted Maximum Soil Concentration of Benzo(a)pyrene Based on Initial Contaminant Loading from SWMU 27F



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.

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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.

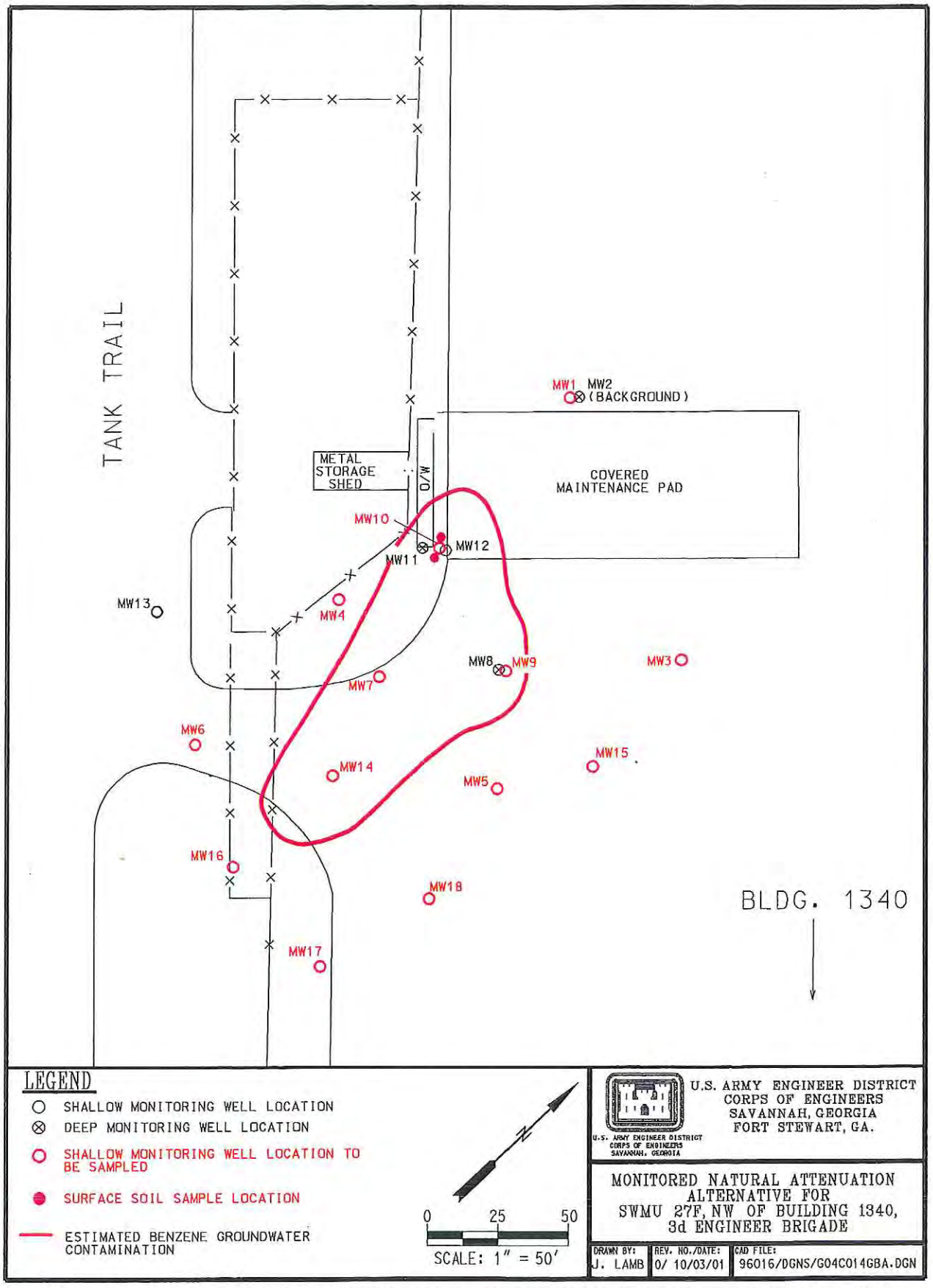

Figure C-1. Monitored Natural Attenuation Alternative for SWMU 27F, Northwest of Building 1340

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

Problems/Triggers	Considerations	Potential Solutions
Benzene concentrations in groundwater from MW7, MW9, or MW14 increase at least 10 percent for two consecutive sampling events.	Transient may be migrating through aquifer; an undiscovered source of contaminant may be present; additional release may have occurred.	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.
Benzene concentrations in wells other than MW7, MW9, and MW14 increase to a level exceeding 5 µg/L.	Groundwater flow direction may have changed; additional release may have occurred; analytical error may have occurred.	
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.	Rate of attenuation may be slower (faster) than predicted; additional release may have occurred.	
Other COCs are detected in groundwater.	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.	

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.