6132

FORT DEVENS
FEASIBILITY STUDY
AOCS 44 AND 52

FINAL
FEASIBILITY STUDY REPORT
DATA ITEM A009

CONTRACT DAAA15-91-D-0008

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

JANUARY 1994

FINAL
FEASIBILITY STUDY REPORT
FOR UNSATURATED SOILS AT THE MAINTENANCE YARDS
(AREAS OF CONTAMINATION 44 AND 52)
FORT DEVENS

Prepared for:

U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland
Contract DAAA15-91-D-0008

Prepared by:

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JANUARY 1994

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ABB-ES	ABB Environmental Services, Inc.
AOC	Area of Contamination
ARAR	Applicable or Relevant and Appropriate Requirements
AREE	Area Requiring Environmental Evaluation
ATEC	ATEC Environmental Consultants
B2E[illegible]	bis(2-ethylhexyl)phthalate
B([illegible]	benzo(a)pyrene
bgs	below ground surface
BRAC	Base Realignment and Closure Act
BTEX	benzene, toluene, ethylbenzene, and xylene
CDM	Camp, Dresser & McKee
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMR	Commonwealth of Massachusetts Regulation
cPAH	carcinogenic polynuclear aromatic hydrocarbons
cy	cubic yard
EPC	Exposure Point Concentrations
ESMP	Excavated Soil Management Plan
FS	Feasibility Study
GC/FID	gas chromatograph/flame ionization detector
HASP	health and safety plan
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
IR	infrared spectroscopy
IRIS	Integration Risk Information System
ISB	in-situ bioremediation
m	meter
m^3	cubic meter
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level

MCP	Massachusetts Contingency Plan
mg/cm	milligram per centimeter
mg/kg	milligram per kilogram
MNG	Massachusetts Army National Guard
NAAQS	National Ambient Air Quality Standard
NCP	National Contingency Plan
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
PAH	polynuclear aromatic hydrocarbons
PAL	Project Analyte List
PCB	polychlorinated biphenyl
PCL	protective contaminant level
PHC	petroleum hydrocarbon compound
ppm	parts per million
ROD	Record of Decision
RTS	Regional Training Site
SA	Study Area
SARA	Superfund Amendments and Reauthorization Act of 1986
SI	Site Investigation
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TBC	to be considered
TCLP/EP	Toxicity Characteristic Leachate Procedure/Extraction Procedure
TDA	Table of Distribution and Allowances
TEF	Toxic Equivalency Factor
TPHC	total petroleum hydrocarbon compound
TSS	total suspended solids
$\mu g/g$	micrograms per gram
$\mu g/l$	micrograms per liter
USACE	United States Army Corps of Engineers

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

USAEC	United States Army Environmental Center
USAEHA	United States Army Environmental Hygiene Agency
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

PREFACE

In 1991, the U.S. Department of the Army and the U.S. Environmental Protection Agency (USEPA) signed a Federal Facility Agreement under Section 120 of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), for environmental investigations and remedial actions at Fort Devens. The agreement requires that a Feasibility Study (FS) be undertaken at each Area of Contamination (AOC) to develop and analyze potential remedial alternatives leading to a Record of Decision (ROD).

In 1991, Fort Devens was identified for closure, by July 1997, under Public Law 101-510, the Defense Base Realignment and Closure Act of 1990 (BRAC). This has resulted in accelerated schedules for the environmental investigations at Fort Devens.

In 1991, under Contract DAAA15-91-D-0008, the U.S. Army Environmental Center (USAEC) tasked ABB Environmental Services, Inc. (ABB-ES) to conduct site investigations at eleven study areas (SAs) in SA Groups 3, 5, and 6 as described in the Fort Devens Master Environmental Plan (Biang et al., 1992). A Final Site Investigation (SI) Report summarizing ABB-ES's findings, conclusions, and recommendations for the site investigation conducted at SA Groups 3, 5, and 6 was prepared in April 1993 (ABB-ES, 1993).

Due to the presence of contamination in soils at the Cannibalization Yard (SA 44) and the Table of Distribution and Allowances (TDA) Maintenance Yard (SA 52), these two sites were designated as AOCs and are being looked at as one operable unit. The USAEC has directed ABB-ES to conduct a FS for the unsaturated soils in AOCs 44 and 52. Should investigation indicate that groundwater has been affected by AOCs 44 and 52 soils, remediation of groundwater will be addressed under a separate operable unit.

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EXECUTIVE SUMMARY

AOCs 44 and 52 are located northeast of Building 3713, on Barnum Road, on the Main Post. The total area of these two areas is approximately 8.8 acres. The areas are totally fenced in and are actively used for vehicle storage.

AOC 44 is known as the Cannibalization Yard. It is a separately fenced, unpaved area where vehicles are stored before being dismantled for usable parts. AOC 52 was originally comprised of only the TDA Maintenance Yard. Because the adjacent Regional Training Site (RTS) Yard and K-Yard have also had a long and continuing history of vehicle storage, these two yards have been included with AOCs 44 and 52 (all yards combined as one site) at the direction of the Army for the purpose of this study. The TDA Maintenance Yard, Regional Training Site Yard and K-Yard are separately fenced, unpaved, vehicle storage and maintenance yards where vehicles with maintenance needs are stored while awaiting repairs.

Gasoline, solvent, motor oil, and other automotive fluids (e.g., battery electrolyte, brake fluid, hydraulic fluid, antifreeze, etc.) were likely released during vehicle dismantling operations in the Cannibalization Yard. Removal of contaminated surface soil for off-site disposal was a common practice in this yard, which probably accounts for the lack of observed surface soil staining. Individual releases are not likely to have been of any significant volume, but numerous releases during the period in which the yard has been used account for the soil contamination problem. Historically, 55-gallon drums of waste oil were also stored in the Cannibalization Yard.

Approximately 20 gallons of "mogas" (motor vehicle gasoline) and hydraulic fluid were reportedly released in the center of the Cannibalization Yard (AOC 44) on April 25 through 26, 1985, during the vehicle cannibalization process. Visibly contaminated soil was immediately excavated by installation personnel and drummed for off-site disposal (Army, 1985).

A 1,000-gallon underground storage tank, formerly used to store waste oil, was located in the Cannibalization Yard until its removal in May 1992. Visibly contaminated soil was stockpiled, and laboratory analysis of soil samples from the bottom and one side of the tank excavation showed total petroleum hydrocarbon compound concentrations of 17,600 ppm and 9,780 ppm, respectively (ATEC Environmental Consultants [ATEC], 1992). After over-excavation of the tank site in July 1992, residual soil total petroleum hydrocarbon compound levels ranged up to 2,700 ppm (ATEC, 1992) at the limits of excavation.

Based on the results of Site Investigation activities, ABB-ES concluded that petroleum-related organic compounds are prevalent in soils throughout the two areas, concentrating in surface (0 to 2 feet below ground surface) samples. This finding is consistent with the release mechanisms discussed above. Concentrations of these analytes decrease with depth suggesting that limited downward migration has occurred. The absence of chlorinated solvents in all of the soils analyzed suggests that releases of these compounds have not occurred in the study areas. Inorganic analyte concentrations were observed in a distribution similar to organic compounds, suggesting coincidental releases and perhaps sources. Crank case oil is a potential source of these organic and inorganic analytes. Cutting and welding activities may be an additional source of the inorganic analytes associated with metal alloys.

Sampling and analysis conducted to date indicate that AOCs 44 and 52 soils have not affected groundwater quality. Consequently, migration of contaminants from AOCs 44 & 52 via groundwater flow to surface water and sediment is not likely.

As part of this Feasibility Study, general response objectives were formulated for the soils based on contaminants of concern defined during the Site Investigation, quantitative risk evaluation, and analysis of site-specific applicable or relevant and appropriate requirements. The following general response objectives were identified for the soil medium at AOCs 44 and 52:

- Minimize direct contact/ingestion and inhalation with AOCs 44 and 52 surface soils which are estimated to exceed the USEPA Superfund target range of 1E-4 to 1E-6 excess cancer risk for carcinogens.

- Reduce off-site run-off of contaminants that might result in concentrations in excess of ambient surface water quality standards and in background concentrations in sediments.

- Reduce or contain the source of contamination to minimize potential migration of contaminants of concern which might result in groundwater concentrations in excess of the Maximum Contaminant Levels.

Specific remedial action objectives were developed and response actions for soils in AOCs 44 and 52 were then developed and include the following: No Action, Limited Action, Containment, In-situ Treatment, Collection/Removal, Treatment, and Discharge/Disposal.

Technologies that address the general response actions and remedial action objectives were identified. Within each general response action there are several remedial technologies. An example includes the in-situ treatment (response action) of the vadose zone soils by aerobic treatment, soil flushing, soil venting, and several other technologies. Technologies were identified based on a review of literature, vendor information, performance data, and experience in developing other feasibility studies under the CERCLA. Over 20 technologies were determined to be potentially applicable to meet the remedial response objectives.

Technologies considered implementable were screened based on the waste characteristics (effectiveness) and applicability to the site (implementability). This screening produced an inventory of suitable technologies that could be assembled into complete remedial action alternatives capable of mitigating existing contamination in AOCs 44 and 52 soils.

Within each technology retained for further evaluation, there are several process options. Examples of this include the capping of AOCs 44 and 52 soils (technology) by using bituminous pavement or concrete (process options). These technologies and process options were evaluated in more detail and the most appropriate option(s) retained for each technology. In accordance with USEPA guidance, these process options were screened based on their effectiveness, implementability, and relative cost. This intermediate screening step was performed to select a representative process option for the retained technologies, and streamline the Feasibility Study process by reducing the number of alternatives developed and evaluated. Process options were evaluated for treatment technologies and for capping materials.

Prior to the evaluation of the process options, design parameters for the soils remedial response actions were identified. These parameters include the volume of soil which is contaminated in the different areas of the AOCs.

Technologies and process options retained in previous FS steps were combined to develop remedial alternatives appropriate to each of the AOCs. Eleven remedial alternatives were developed. The remedial alternatives were then screened based on criteria described in Section 121 of Superfund Amendments and Reauthorization Act of 1986 (SARA), and on FS remedial objectives. A detailed comparative analysis of the seven remedial alternatives which survived the screening step was conducted to present the relevant information that allows decision-makers to select a remedy for the AOCs. The analyses included descriptions of the components of each alternative and evaluations of the alternatives with respect to seven of the nine evaluation criteria outlined in the National Contingency Plan. The results of the comparative analysis of alternatives is presented in Table ES-1. State and community acceptance criteria are not addressed in this FS.

TABLE ES-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative.9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
OVERALL PROTECTION							
HUMAN HEALTH PROTECTION							
- Direct Contact/Soil Ingestion	No Risk Reduction	Risk Reduction Through Institutional Control and Fencing to Restrict Access. Hot Spot Area Contaminants Would Be Immobilized.	Barrier Layer (Cap) and Immobilization of Contaminants in Hot Spot Areas Reduces Risk	Immobilization of Contaminants Across Site and In Hot Spot Areas Reduces Risk	Remediation Through Bioventing Reduces Risk Over Time and Cap Reduces Risk during Implementation	Remediation Through Landfarming Reduces Risk Over Time	Excavation and Off-site Treatment Removes Soil Contamination from Site. Treatment by Composting Reduces Risk over Time. Asphalt Batching Immobilizes the Contaminants.
ENVIRONMENTAL PROTECTION	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk.
COMPLIANCE WITH ARARS							
CHEMICAL-SPECIFIC ARARS (Risk-based cleanup levels)	Does Not Reduce Concentrations to Risk-based Levels.	Does Not Reduce Concentrations to Risk-based Levels.	Does Not Reduce Concentrations to Risk-based Levels.	Does Not Reduce Concentrations to Risk-based Levels.	Would Meet Risk-based Target Levels.	Would Meet Risk-Based Target Levels.	Would Meet Risk-based Target Levels.
LOCATION-SPECIFIC ARARS	Does Not Reduce Potential Off-site Run-off of Contaminants to Wetlands.	Does Not Reduce Potential Off-site Run-off of Contaminants to Wetlands.	Reduces Potential Off-site Run-off of Contaminants to Wetlands and Will Manage Increased Surface Water Flow to Wetlands from Paved Surface.	Reduces Potential Off-site Run-off of Contaminants to Wetlands and Will Manage Increased Surface Water Flow to Wetlands from Paved Surface.	Reduces Potential Off-site Run-off of Contaminants to Wetlands and Will Manage Increased Surface Water Flow to Wetlands from Paved Surface.	Reduces Potential Off-site Run-off of Contaminants to Wetlands.	Reduces Potential Off-site Run-off of Contaminants to Wetlands. Facility Siting Would Comply with State Siting Regulations Regarding Impacts to Groundwater.
ACTION-SPECIFIC ARARS	Groundwater Monitoring Performed in Compliance with ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Waste Pile, and Recyclable Materials ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Waste Pile, Closure Actions and Recyclable Materials ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Waste Pile, Closure Actions and Recyclable Materials ARARs.	Would Comply with Air Quality and Groundwater Monitoring ARARs.	Would Comply with Air Quality, Groundwater Monitoring, and Land Treatment Units ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Land Treatment Units, Waste Piles, Closure Activities and Recyclable Material ARARs.

(Continued)

TABLE ES-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
LONG-TERM EFFECTIVENESS AND PERMANENCE							
MAGNITUDE OF RESIDUAL RISK							
- Direct Contact/Soil Ingestion	4E-3 to 7E-4 excess cancer risk.	Would Reduce Risk by Limiting Exposure.	Would Reduce Risk by Limiting Exposure.	Would Reduce Risk by Limiting Exposure.	Would Reduce Risk by Limiting Exposure and Reducing Contaminant Concentrations to Meet USEPA's Target Risk Range.	Would Reduce Risk by Reducing Contaminant Concentrations to Meet USEPA's Target Risk Range.	Would Reduce Risk by Removing Contaminated Soils Exceeding USEPA's Target Risk Range from the Site.
ADEQUACY AND RELIABILITY OF CONTROLS	No Controls Implemented	Institutional Controls Reliable if Enforced. Maintain Fence to Control Site Access.	Institutional Controls Reliable if Enforced. Maintain Cap to Control Exposure, Risk and Migration.	Asphalt Batching Proven to Immobilize Contaminants	Adequacy Determined by Treatability Test and Literature Studies.	Adequacy Determined by Treatability Test and Case Studies.	Adequacy of Composting Determined by Treatability Test and Case Studies. Asphalt Batching Proven to Immobilize Contaminants.
REDUCTION IN TOXICITY, MOBILITY, OR VOLUME							
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	None	Reduces Mobility of Contaminants in Hot Spot Area Soils.	Reduces Mobility of Contaminants in Hot Spot Soils and Soils Beneath Cap.	Reduces Mobility of Contaminants in Hot Spot Soils and Surface Soils across the Site.	Reduces the Toxicity, Mobility, and Volume of Organic Contaminants in Hot Spot Soils and Surface Soils across the Site.	Reduces the Toxicity, Mobility, and Volume of Organic Contaminants in Hot Spot Soils and Surface Soils across the Site.	Off-site Treatment Reduces Toxicity, Mobility, and Volume of Soil Contaminants at Site by Removal.
IRREVERSIBLE TREATMENT	Not Applicable	Studies Have Shown That Contaminants Will Not Leach from Soils That Have Been Treated by Asphalt Batching.	Studies Have Shown That Contaminants Will Not Leach from Soils That Have Been Treated by Asphalt Batching.	Studies Have Shown That Contaminants Will Not Leach from Soils That Have Been Treated by Asphalt Batching.	Biodegradation Permanently Reduces Organic Contaminant Concentrations.	Biodegradation Permanently Reduces Organic Contaminant Concentrations.	Biodegradation Permanently Reduces Organic Contaminant Concentrations. Asphalt Batched Soils Will Not Leach Contaminants Based on Studies.

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TABLE ES-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
TYPE AND QUANTITY OF RESIDUALS REMAINING AFTER TREATMENT	Not Applicable	Asphalt Batched Material from Hot Spots Only.	Asphalt Batched Material from Hot Spots Only.	Asphalt Batched Material from Entire Site	None	None	Treated Soil and Asphalt Batched Material from Soil Not Readily Biodegradable.
STATUTORY PREFERENCE FOR TREATMENT	Not Met	Hot Spot Areas Would be Treated.	Hot Spot Areas Would Be Treated.	Entire Site Would Be Treated.	Entire Site Would Be Treated.	Entire Site Would Be Treated.	Entire Site Would Be Treated.
SHORT-TERM EFFECTIVENESS							
COMMUNITY PROTECTION	Risk to Community Minimized Through Monitoring	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Tilling and Excavation.	Would Need to Control Dust during Excavation and Treatment.
WORKER PROTECTION	No Significant Risk to Workers Conducting Monitoring.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.
ENVIRONMENTAL IMPACTS		None	Modifications to stormwater collection system necessary.	Modifications to stormwater collection system necessary.	Modifications to stormwater collection system necessary.	None	None.
TIME UNTIL ACTION IS COMPLETE	Risk-based cleanup levels would not be met.	3 weeks for remediation of hot spots.	3 months for remediation of hot spots and capping entire site.	4 months for remediation of entire site.	Up to 10 years for remediation of entire site.	Up to 7 years for remediation of entire site.	Total of three months for on-site activities (excavation of soil and backfilling site). Up to 4 years for biodegradation of contaminants for total site.

(Continued)

TABLE ES-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
IMPLEMENTABILITY							
ABILITY TO CONSTRUCT AND OPERATE	None required. Existing Wells Could Be Used For Monitoring.	Easy; Standard Construction Techniques. No Long-term Operation Required.	Easy; Standard Construction Technique. No Long-term Operation Required, but Cap Maintenance Required.	Easy; Standard Construction Technique. No Long-term Operation Required.	Cap And Well Construction Are Common Techniques. Basic Operation and Maintenance.	Standard Construction; Basic Operation and Maintenance	Standard Construction Technique; Basic Operation And Maintenance.
EASE OF DOING MORE ACTION IF NEEDED	Would Not Interfere With Future Actions.	Batched Pavement May Need To Be Removed If Future Actions Are Necessary.	Possibly Difficult Due to Cap over Site.	Possibly Difficult Due to Asphalt Batched Material over Site.	Possibly Difficult Due to Cap over Site.	Would Not Interfere with Future Actions.	Would Not Interfere with Future Actions.
ABILITY TO MONITOR EFFECTIVENESS	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater, Soil Sampling, and Process Monitoring.	Effectiveness Would Be Monitored by Monitoring Groundwater and Soil.	Effectiveness Would Be Monitored by Process Monitoring.
ABILITY TO OBTAIN APPROVALS AND COORDINATE WITH OTHER AGENCIES	Coordination Required Among Property Owners, State and Local Agencies. Difficulties Anticipated Regarding Sale of Property.	Coordination Required Among Property Owners, State and Local Agencies. Difficulties Anticipated Regarding Sale of Property and Institutional Controls.	Coordination Required Among Property Owners, State and Local Agencies. Difficulties Anticipated Regarding Sale of Property and Institutional Controls.	Although No Institutional Controls are Needed, Placing a Pavement Cap over the Site Limits Future Land Use and is not Likely to be Favored by Land Developers.	Zone II Issues Likely to Limit Acceptance of this Alternative by Agencies.	Zone II Issues Likely to Limit Acceptance of this Alternative by Agencies.	Siting of the Facility Will Require Coordination with Property Owners, State and Local Agencies.
AVAILABILITY OF SERVICES AND CAPACITIES	Sampling and Analytical Services Are Widely Available.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Disposal of Screened Material Required.	Treatment Facility with Necessary Capacity Is Not Likely To Be Available Off-site. Facility Will Need To Be Constructed Specifically for Fort Devens Soils.

(Continued)

TABLE ES-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, *Capping* Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
AVAILABILITY OF EQUIPMENT, SPECIALISTS, AND MATERIALS	Available Locally.	Available Locally.	Available Locally.	Available Locally.	Bioremediation Specialists Are Available for Design and Operation of the System.	Bioremediation Specialists Are Available for Design and Operation of the System.	Asphalt Batching Vendors Available Locally; *Bioremediation Specialists* Are Available for Design and Operation of the Facility.
AVAILABILITY OF TECHNOLOGIES	Groundwater Monitoring Is Common Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common *Construction* Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology. Bioventing Has Been Used for Remediating Fuel-related Contamination in Soils at Other Locations.	Groundwater Monitoring Is Common Technology. Landfarming is a Simple Technology Used for Bioremediating Fuel Contamination in Soils.	Groundwater Monitoring and Paving are Common Technologies. Composting is a Common Technology for Remediating Biosolids from Municipal Waste Water Treatment and Remediating Fuel *Contaminated* Soils.
DISRUPTION TO YARD OPERATIONS	None	Temporary Disruption of Yard during Hot Spot Remediation.	Temporary Disruption of Yard during Hot Spot Remediation and Capping.	Disruption of Yard during 4-month Remediation Period.	Disruption of Yard during 3-week *Construction* Period. Yard Could Be Used during Remediation.	20% of Yard not Usable for *Yard Operations Once* Remediation Begins.	20% of Yard not Usable for Yard Operations Once Remediation Begins.
COST							
Capital Cost	$0	$204,000	$1,017,000	$1,667,000	$1,053,000	$621,000	$2,739,000
1st Year O&M	$35,000	$37,000	$33,000	$19,000	$77,000	$94,000	$204,000
Present Worth Cost	$133,000	$356,000	$1,221,000	$1,739,000	$1,548,000	$1,553,000	$3,398,000

Note: AOC = Area of Contamination
ARARs = Applicable or Relevant and Appropriate Requirements
O&M = *Operation and Maintenance*
USEPA = U.S. Environmental Protection Agency

1.0 INTRODUCTION

ABB-ES, under contract with the USAEC has prepared this FS based on data collected as part of the SA Groups 3, 5 and 6 SI (ABB-ES, 1993) which confirmed the presence of contamination in the unsaturated soils of AOCs 44 and 52 at Fort Devens, Massachusetts. The primary contaminants of concern in AOCs 44 and 52 are associated with motor oil, diesel fuel, gasoline and hydraulic fluids released from leaking vehicles and vehicle dismantling operations. The two areas are located in SA Group 3 as defined in the Federal Facility Agreement between the Army and USEPA.

1.1 PURPOSE AND REPORT ORGANIZATION

The purpose of this FS is to identify remedial alternatives that are potentially feasible for mitigating conditions which exist in the unsaturated soils of AOCs 44 and 52 (Maintenance Yards). The FS further evaluates screened alternatives and provides the information necessary to select a remedy. To achieve this purpose, remedial alternatives were developed, screened and evaluated following the guidelines provided under CERCLA (USEPA, 1988).

This process entails identifying remedial action objectives, general response actions and remedial technologies; followed by screening the identified remedial technologies and process options, and evaluating retained process options; and then developing remedial alternatives, screening the alternatives and finally performing a detailed analysis of the retained alternatives.

This FS consists of seven sections. Section 1.0 provides a brief description and history of the site, a summary of ABB-ES SI data and other findings, a quantitative risk evaluation of the soil at AOCs 44 and 52, and a discussion of Applicable or Relevant and Appropriate Requirements (ARARs) and ARAR use in the detailed analysis of alternatives.

Section 2.0 identifies the remedial action objectives and general response actions and provides an estimate of waste volumes.

Section 3.0 identifies the potentially applicable technologies and process options based on the general response actions required for AOCs 44 and 52. These technologies and process options are screened considering site-specific waste characteristics and applicability to the site.

Section 4.0 provides an intermediate evaluation step for instances where more than one process option has been retained from Section 3.0 for a remedial technology. Evaluation is based on effectiveness, implementability and cost of the process option.

Section 5.0 assembles a number of possible remedial alternatives from the retained technologies and process options from Section 4.0. These alternatives are screened based on effectiveness, implementability and cost.

Section 6.0 provides a detailed analysis of the alternatives retained in Section 5.0. During the detailed analysis, the alternatives are evaluated against seven of nine CERCLA evaluation criteria (USEPA, 1988). The seven criteria are:

1. overall protection of human health and environment;
2. compliance with ARARs;
3. long-term effectiveness and performance;
4. reductions in toxicity, mobility, and volume through treatment;
5. short-term effectiveness;
6. implementability; and
7. cost.

The eighth and ninth CERCLA evaluation criteria, state acceptance and community acceptance are modifying criteria and will be addressed following the public information meeting, public hearing, and public comment period.

Section 7.0 presents a comparison of the retained remedial alternatives, highlighting the relative advantages and disadvantages of the alternatives with respect to the seven evaluation criteria.

1.2 INSTALLATION AND SITE DESCRIPTION

Fort Devens was placed on the National Priorities List under CERCLA as amended by SARA in December 1989. In addition, under Public Law 101-510, (BRAC), Fort Devens was selected for cessation of operations and closure. In accordance with these acts, numerous studies, including a Master Environmental Plan, and Enhanced Preliminary Assessment, and SIs have been conducted which address potential areas of contamination referred to as SAs at Fort Devens. A current total of 59 SAs have been identified and placed in 13 priority groups defined in the Federal Facility Agreement between the Army and USEPA.

Beginning in 1991, SIs were conducted in SA Groups 3, 5, and 6. The Cannibalization Yard (SA 44) and TDA Maintenance Yard (SA 52) were two SAs in SA Group 3 which were investigated and designated as AOCs due to the presence of contamination in the soils. The following site descriptions for AOCs 44 and 52 are drawn largely from the SI Report for SA Group 3 (ABB-ES, 1993).

AOCs 44 and 52 are located northeast of Building 3713, on Barnum Road, on the Main Post (Figure 1-1). The total area of these two SAs is approximately 8.8 acres. The areas are totally fenced in and are actively used for vehicle storage. The topography is flat and open; precipitation is likely to infiltrate into the soil, so minimal surface runoff is expected.

AOC 44 is known as the Cannibalization Yard (Figure 1-1). It is a separately fenced, unpaved area where vehicles are stored before being dismantled for usable parts. Historically, 55 gallon drums of waste oil were also stored in the yard. AOC 52 was originally comprised of only the TDA Maintenance Yard. Because the adjacent RTS Yard and K-Yard (Figure 1-1) have also had a long and continuing history of vehicle storage, these two yards have been included with AOCs 44 and 52 (all yards combined as one site) at the direction of the Army for the purpose of this study. All four yards are collectively referred to in this FS Report as the Maintenance Yards. The TDA Maintenance Yard, RTS Yard and K-Yard are separately fenced, unpaved vehicle storage and maintenance yards where vehicles with maintenance needs are stored while awaiting repairs. Vehicles with oil leaks are now kept in a Spill Containment Basin area which was constructed in 1991 within the TDA Maintenance Yard (Figure 1-1). The Army has indicated that vehicle storage has been historically, and continues to be restricted to the areas within the security fences which define AOCs 44 and 52.

Army policy (Regulation 190-51) requires that all vehicles awaiting repairs be located within the secured fence area. (Army, 1994). Under BRAC, Fort Devens is required to close by July 1997. Although it is anticipated that main operations at the base will cease by the fall of 1995, the Maintenance Yards are expected to remain operational until the summer of 1996.

Gasoline, motor oil and other automotive fluids were likely released during vehicle dismantling operations in the Cannibalization Yard. Removal of contaminated surface soil for off-site disposal was a common practice throughout this yard which probably accounts for the lack of observed surface soil staining. Individual releases are not likely to have been of any significant volume, but numerous releases during the period in which the yard has been used account for the soil contamination problem.

Approximately 20 gallons of "mogas" (motor vehicle gasoline) and hydraulic fluid were reportedly released near the center of the Cannibalization Yard on April 25 and 26, 1985 during the cannibalization process. Visibly contaminated soil was immediately excavated and containerized by Army personnel (Army, 1985). Soil samples taken from boring 44B-92-06X during ABB-ES' SA Groups 3, 5 and 6 SI reveal total petroleum hydrocarbon compound (TPHC) concentrations ranging from 8520 micrograms per gram ($\mu g/g$) to 1560 $\mu g/g$ from ground surface to 12 feet below grade respectively and are believed to be associated with the spill area. At the time of the incident, the spill area measured approximately 20 by 20 feet.

A 1,000-gallon underground storage tank (UST), formerly used to store waste oil, was located in the Cannibalization Yard until its removal in May 1992. Visibly contaminated soil was stockpiled, and laboratory analysis of soil samples from the bottom and one side of the tank excavation showed TPHC concentrations of 17,600 parts per million (ppm) and 9,780 ppm respectively (ATEC, 1992). Laboratory analysis was also conducted on a waste oil sludge sample obtained from inside the tank for hazardous waste manifest characterization purposes. Results revealed the following levels of semivolatile organic compounds (SVOCs) and Toxicity Characteristic Leaching Procedure (TCLP) metals: 110 ppm naphthalene, 128 ppm bis(2-ethylhexyl)phthalate (B2EHP), 240 ppm 2-methylnaphthalene, 0.04 ppm cadmium, 0.4 ppm lead, 0.05 ppm nickel and 3.07 ppm zinc. Analytical results did not reveal the presence of volatile organic compounds (VOCs) and polychlorinated biphenyls (PCBs). Reportedly, the tank was observed to be in good condition with no holes or severe corrosion.

However, inspection revealed that the fill pipe was improperly connected to the bung of the tank, allowing the pipe contents to leak at the connection (ATEC, 1992).

Later in July 1992, contaminated soils surrounding the removed tank were excavated. Reportedly, the over excavation measured approximately 15 feet by 22 feet by 12 feet deep (ATEC, 1992a). Laboratory tests on samples collected by the contractor from two sidewalls and stockpile following the over excavation revealed residual TPHC concentrations ranging from 1,110 to 2,740 ppm.

Exploratory test pits were excavated for construction of a concrete spill-containment basin in the southeast corner of the TDA Maintenance Yard (Figure 1-1), in July 1991. These test pits revealed zones of contaminated soil below the surface (Mullen, 1991; ABB-ES, 1992b; Lincoln Environmental, 1992). TCLP analyses detected 3 to 7 micrograms per liter ($\mu g/l$) of benzene in leachate from the soil samples. TPHC was found at 420 to 700 ppm concentrations in surface soil samples and at 80 ppm in one sample from a 4-foot depth. TPHC was not detected in the 8-foot-deep soil samples.

Groundwater in the surficial aquifer at the facility has been assigned to Class I under Commonwealth of Massachusetts regulations (314 CMR 6.03). Class I consists of groundwaters that are "found in the saturated zone of unconsolidated deposits or consolidated rock and bedrock and are designated as a source of potable water supply" (MADEP, 1988).

The town of Ayer currently owns and operates two water supply wells within 150 feet of the south side of Grove Pond and approximately 0.5 mile from AOCs 44 and 52. The wells are currently used as a backup to the town's other supply wells on Spectacle Pond. Complaints of excessive iron and manganese concentrations in the Grove Pond wells led to the construction of the two primary source wells on Spectacle Pond in 1974 and in 1987. Additionally, tetrachloroethene was detected (1.2 $\mu g/l$) in a sample collected from the Grove Pond #2 well in 1991 (USAEHA, 1991). As part of a plan for meeting future water needs, the town of Ayer has considered returning its two potable supply wells on Grove Pond to regular service. In addition, the town reportedly is investigating the installation of an additional water supply well near the existing Grove Pond wells (CDM, 1993). Fort Devens also has a drinking water supply well field located approximately 1,200 feet west of the Ayer water supply wells along Grove Pond. Very low concentrations of trichloroethene have been detected at the Fort Devens Grove Pond Well Field (0.55 to 0.8μg/l) during sampling from 1988 to 1991 (USAEHA, 1991).

The Town of Ayer has engaged Camp Dresser & McKee (CDM) to define a Zone II area of influence around its wells. CDM's report (CDM, 1993) defines the Zone II area as the conceptual zone of contribution to the wells under a specific set of conditions which simulates the most severe pumping and recharge conditions that can be realistically anticipated. The report shows the Zone II area as including AOCs 44 and 52. CDM states that the Zone II area was conservatively extended to discharge areas or low permeability boundaries, which are areas of glacial till or bedrock and represent the limits of aquifer materials. The report shows the Zone II extending from approximately 0.5 mile north of Grove Pond to a distance of 0.5 mile west of the railroad tracks. The approximate location of the Zone II is shown on Figure 1-2. The report further lists AOCs 44 and 52 as being a potential source of contamination for the Ayer Grove Pond wells.

AOCs 44 and 52 are located approximately 1,600 to 1,700 feet from the Fort Devens Grove Pond wellfield, which is within the default Zone II (½ mile radius) of this Army wellfield.

Engineering Technologies Associates, Inc., under contract to USAEC, prepared a report (ETA, 1992) which developed a regional groundwater flow model to assist in determination of cumulative impacts to groundwater quality from multiple sites at Fort Devens. Groundwater flow was simulated with a computer using a three dimensional finite difference model (MODFLOW). Simulations for existing conditions and for conditions of high pumpage rate from the Fort Devens Grove Pond wellfield and Ayer wells indicate that groundwater flow under the Maintenance Yards is towards Grove Pond and the wells. This groundwater flow direction is also inferred from groundwater level data reported in the ABB-ES SI Report (ABB-ES, 1993).

AOCs 44 and 52 are located approximately 1,200 feet west of Cold Spring Brook which is a tributary of the Nashua River. The water of the Nashua River has been assigned to Class B (314 CMR 4.03). Class B surface water is "designated for the uses of protection and propagation of fish, other aquatic life and wildlife, and for primary and secondary contact recreation" (MADEP, 1990).

1.3 SUMMARY OF SI FINDINGS

ABB-ES has compiled an SI Report (ABB-ES, 1993) detailing the results of the field investigative work which has been conducted at AOCs 44 and 52. Major elements from this report which relate to the conditions at AOCs 44 and 52 are summarized below.

- Installation of seven monitoring wells, one of which is located in the TDA Maintenance Yard, (Figure 1-3) and groundwater sampling from these wells. Well locations were selected to provide circumferential coverage of the Group 3 SAs and to provide for evaluation of the Maintenance Yards impact on groundwater. Additionally, groundwater levels and aquifer conductivities were assessed using data obtained from these new wells in conjunction with seven monitoring wells on the adjacent Massachusetts Army National Guard (MNG) facility.

- Advancement of 16 soil borings to observe and sample soils throughout AOCs 44 and 52 (Figure 1-3). One of these borings, G3M-92-04X, was converted to a monitoring well. Soil samples were collected at the 0-to 2-foot, 5- to 7-foot and 10- to 12-foot depths. (Except G3M-92-04X where samples were collected at 0- to 2-foot, 12- to 14-foot, and 26- to 28-foot depths.)

Additionally, surface water and sediment samples were collected from Cold Spring Brook to assess potential contaminant migration from the Group 3 SAs. No organic compounds were detected in surface water and few inorganic analytes were detected. Sediment samples exhibited some organic compound contamination. The results of sediment sampling support the conclusion that contaminant migration via storm and surface water runoff is a possible source of sediment contamination in Cold Spring Brook. However, the organic compounds detected in a downstream sediment sample are not specifically derived from AOCs 44 and 52 (samples were not analyzed for inorganics). Figure 1-1 and 1-4 show the stormwater drainage system layout for AOCs 44 and 52. Cold Spring Brook sediments are outside the scope of this FS. The Army is addressing sediment issues under Area Requiring Environmental Evaluation (AREE) 70 Storm Water Discharge System.

1.3.1 Geologic Conditions

The surficial geologic deposits of the Group 3 area of the Main Post are products of glacial meltwater deposition in lake and ice-contact environments during the final retreat of Pleistocene glaciers. These meltwater (outwash) deposits are associated with various successive stages of glacial Lake Nashua. The Group 3 AOCs are located on a kame terrace associated with the last of 12 successive fluvial-outwash sequences in the region (Jahns, 1953). The deposits consist of stratified sands and gravelly sands possibly overlying till. Soil data from borings in AOCs 44 and 52 reveal generally clean sand with variable gravel and silt content.

Grain size distribution tests were conducted at six borings. Five of the six were taken from depths 5 to 24 feet below grade. These soils were described generally as poorly graded sand with Unified Soil Classification System (USCS) classification of SP. Sand content ranged between 74 and 93 percent while fines (percent passing the #200 sieve) ranged between 2 and 4 percent. The sixth grain size distribution was taken 0 to 2 feet below grade and was described as a silty sand and given a USCS classification of SM. Sand content was 75 percent with fines content of 19 percent This would indicate that the surface soils might contain more fines than deeper soils.

During the Army's construction of the spill containment basin, soils were described as consisting of two distinct layers: a contaminated dirty dark brown and black sand and silt layer varying between 8 and 12 inches with a "clean", reddish yellow coarse sand layer below (Lincoln, 1992). During removal of the 1,000 gallon waste oil tank, soils descriptions were less distinctive with regard to layers (ATEC, 1992). However, the report describes the top 6 inches as a fine sand, gravel and cobble fill. Sand color is described as medium and dark brown from surface to a depth of 2 feet and light brown from 2 feet to the bottom of the 8 foot excavation. These soil descriptions from independent reports would suggest that there may be a top siltier (and visibly contaminated) layer of fill between 1 to 3 feet thick covering the native soil below. These soil descriptions may be representative of overall Maintenance Yards soils.

1.3.2 Nature And Extent of Contamination

The SI for AOCs 44 and 52 focused on sampling soil and groundwater for analysis of a variety of organic and inorganic analytes and for TPHC. Sampling and analytical results from the SI Report associated with the borings at AOCs 44 and 52 (ABB-ES, 1993) are summarized and briefly interpreted in the following paragraphs.

Tables 1-1 and 1-2 present the laboratory results for organic compounds from each of the 16 soil borings. Tables 1-3 and 1-4 present the results for inorganic analytes.

Figures 1-5, 1-6, and 1-7 show the distribution of total VOCs, SVOCs and TPHC in soils collected at the three depth intervals within the SAs. Figures 1-8, 1-9 and 1-10 also show the distribution of total carcinogenic polynuclear aromatic hydrocarbons (cPAHs), total polynuclear aromatic hydrocarbons (PAHs) and total SVOCs at the same three depth intervals.

Figures 1-11, 1-12, and 1-13 show the distribution of inorganic analytes at the three depth intervals exceeding calculated background concentrations for typical Fort Devens soils.

Motor oil is a potential source of the organic and inorganic analytes detected. Cutting and welding activities may be an additional source of the inorganic analytes associated with metal alloys. The following general observations with regard to organic contamination are drawn from the SI soil data:

- Aromatic VOCs were detected in three out of a total of 48 soil samples. One of the three samples was from boring 44B-92-06X, which is believed to be associated with the 1985 mogas spill.

- There appears to be no obvious lateral or vertical distribution pattern of VOCs in soil.

- SVOCs, predominantly PAHs, were detected in many of the samples throughout the AOCs.

- SVOC concentrations are typically higher in surficial samples and are generally absent or of lower concentration with depth. TPHC appears to mimic the distribution of SVOCs. This is consistent with the presumed release mechanisms discussed previously.

- No lateral distribution pattern for SVOCs or TPHC is evident.
- Absence of chlorinated solvents in all of the soils analyzed indicates that these compounds were not released in the SAs.

The following general observations with regard to inorganic contamination are drawn from the SI soil data:

- Generally, the same vertical trend in concentrations found for the SVOCs and TPHC appears to exist with the inorganic analytes (i.e., higher concentrations of inorganic analytes are found near the ground surface). Soils near the surface exhibit inorganic analyte concentrations generally two to three times higher than soils at 5 foot and 10 foot depths.
- Chromium, copper, nickel, zinc, sodium and beryllium are analytes that show a pattern of consistent exceedances above background concentrations. Chromium, copper, nickel and zinc, which appear in almost all surficial soil samples, could be the result of vehicle maintenance activity. Sodium is likely attributable to road salting. Beryllium occurs on a more random basis (in instances at higher concentration at greater depth) and is believed to be naturally occurring.
- Surficial soils that appear to contain the most inorganic analytes were found at sampling locations 44B-92-06X, 44B-92-01X, 52B-92-01X and 52B-92-06X.

Groundwater at well location G3M-92-04X, located in the TDA Maintenance Yard, is approximately 28.5 feet below ground surface (bgs). Based on groundwater sampling conducted in July 1992, October 1992 and January 1993 in the Group 3 area, there is no evidence suggesting that contaminants found in AOCs 44 and 52 soils are affecting groundwater quality.

1.4 SUPPLEMENTAL SITE INVESTIGATIONS AND DATA GATHERING

During the preparation and regulatory review of this FS, specific data gaps were identified which required supplemental field investigation and data gathering. These data gaps included the need to:

- investigate the groundwater directly downgradient of the hot spot areas defined as the removed underground waste oil storage tank and mogas spill in the Cannibalization Yard;

- better define the vertical and horizontal extent of contamination around the mogas spill area and the contamination that remains around the excavated waste oil storage tank area;

- quantify the effectiveness of the biological treatment process options of bioventing, landfarming and composting in reducing the concentration of cPAH contaminants in AOCs 44 and 52 soils; and

- investigate the influence of bituminous pavement on soil analysis for cPAH contaminants.

1.4.1 Groundwater

The need to investigate groundwater directly downgradient of the former waste oil tank and mogas spill was discussed during a draft FS review meeting held at Fort Devens on May 5, 1993. During the meeting it was suggested that the existing wells located in and around the AOCs 44 and 52 area may not be positioned to readily detect the full impact of the tank and spill contamination sources on the groundwater.

To assess groundwater conditions near these two potential contamination sources, two additional groundwater monitoring wells, G3M-93-10X and -11X, were installed downgradient of the removed underground waste oil storage tank and mogas spill in the Cannibalization Yard, respectively (Figure 1-14). Table 1-5 presents the results for two rounds of sampling from these monitoring wells for organic and inorganic analytes. Analysis was performed for VOCs, SVOCs, TPHC, inorganics and total suspended solids (TSS). Figure 1-15 shows the distribution of organic and inorganic analytes detected in these two wells.

Results from Round 1 show no detectable concentrations of TPHC or VOCs present. The only organic contaminant detected was B2EHP at 22 μg/l in G3M-93-10X. Historically, B2EHP has been found to be a lab contaminant (ABB-ES, 1993). Inorganic contaminants generally exceeded background concentrations, but are likely due to suspended particulates and are not representative of groundwater quality at that location. TSS for G3M-93-10X and -11x were 206 and 1,110 ppm respectively.

In Round 2, trace concentrations of toluene (2.6 μg/ l and 1.25 μg/l in G3M-93-10X and -11X respectively) and tetrachloroethene (2.6 μg/l in G3M-93-10X) were detected in the groundwater. Concentrations for both these analytes are below state and federal Maximum Contaminant Levels (MCLs) for drinking water. The exact source of these compounds is unknown but they are not believed to be derived from AOCs 44 and 52 soils. No tetrachloroethene was detected in soil samples from borings upgradient or in the vicinity of G3M-93-10X, or in any other soil samples collected at AOCs 44 and 52. Sludge samples from the excavated UST upgradient of G3M-93-10X were free of VOC contaminants. Trace concentrations of toluene (0.05 μg/g and lower) were detected in only 3 of 67 soil samples collected in the Maintenance Yards during the SI and Supplemental Site Investigations. No toluene was detected in soil samples collected below 5 feet in depth. As in Round 1, inorganic contaminants in Round 2 unfiltered samples generally exceeded background concentrations but are due to suspended particulates and are not representative of groundwater quality at that location. Only sodium exceeded background concentration in filtered samples (13,800 and 16,800 μg/l for G3M-93-10X and -11X respectively) and is likely due to use of road salt. Detected concentrations of sodium are below state and federal guidelines for drinking water. Based on the sampling results from these two wells and the sampling conducted in the SI for the Group 3 area, there is no evidence suggesting that the contaminants associated with the hot spot areas or those found in other areas of AOCs 44 and 52 soils have adversely affected groundwater quality.

1.4.2 Soils (Mogas Spill and Waste Oil Storage Tank Area)

Defining the vertical and horizontal extent of contamination around the former tank and spill areas was required to better assess the remedial alternatives to be evaluated in the FS. Although soil removal actions have taken place around the excavated tank, the extent (specifically depth) of contamination remaining was not readily defined due to the lack of conclusive analytical data at the time of the soil over-excavation. The horizontal and vertical extent of contamination from the mogas spill was unknown except perhaps in the vicinity of existing boring 44B-92-06X. This boring may have been located only at the periphery of the spill or not in the spill area at all. An Army Pollution Incident Report was discovered which located the mogas spill closer to the center of the Cannibalization Yard.

The supplemental field investigation entailed drilling a total of four borings, 44B-93-07X, -08X, -09X and -10X, in the Cannibalization Yard in the vicinity of the excavated underground tank area and mogas spill area (Figure 1-14) and then sampling soil from these borings to better define the extent of contamination. Soil analyses were conducted for inorganics (only lead in 44B-93-09X and -10X) SVOCs, TPHC, and PCBs. Table 1-6 presents the laboratory results for organic and inorganic compounds for each of the four borings. Figures 1-16 through 1-19 show the distribution of SVOCs, TPHC, PCBs and inorganics at four depth intervals (5, 10, 15 and 25 feet bgs).

TPHC was detected in only two of 16 samples; 121 μg/g in boring 44B-93-08X at 10 feet bgs and 38.1 μg/g in boring 44B-93-09X at 5 feet bgs. Boring 44B-93-08X is located near the southeast end of the excavated UST. The TPHC detected at the 10 foot level generally corresponds with the location of the tank bottom and is likely due to residual contamination from the excavated UST. Boring 44B-93-09X is located in the Cannibalization Yard approximately 25 feet north of the area where the mogas spill was suspected of occurring. The duplicate of this sample revealed a concentration below the detection level (29.6 μg/g). It is not conclusive if this detected concentration is a result of the mogas spill. The only SVOC compounds detected were B2EHP at 1.4 μg/g in 44B-93-09X at the 25 foot depth and trace concentrations of fluoranthene, phenanthrene and pyrene (0.25, 0.09, and 0.12 μg/g respectively) in 44B-93-09X at the 5 foot depth. The duplicate of the 5 foot depth sample revealed concentrations below detection level for these PAHs.

Inorganics which exceed background concentrations include arsenic, beryllium, copper, nickel and sodium. Of these analytes, only arsenic is a typical constituent of used automotive oil (Franklin, 1984). Nickel was also detected in a waste oil sludge sample taken from the UST (ATEC, 1992). These five inorganic analytes are present in the mogas spill and waste oil storage tank area soils at concentrations which are the same order of magnitude above background as detected on an AOCs 44 and 52 site-wide basis.

1.4.3 Bioremediation Feasibility Testing

Feasibility testing was conducted to assist in evaluating the effectiveness of the bioremediation technology for reducing the concentration of cPAHs and TPHC in AOCs 44 and 52 soils. Data obtained from the testing was used to evaluate the remedial action alternatives in the FS which involve bioventing, landfarming and composting (described in more detail in later sections).

The supplemental field investigation entailed obtaining a total of four shelby tube soil samples from two of the four borings (44B-93-07X and 44B-93-09X) in an effort to obtain undisturbed soil samples for air permeability testing. Additionally, a surficial soil sample (0 to 2 feet) was to be taken from an area in the Maintenance Yards where the soil was either visibly stained with oil or from an area previously recorded as having high PAH concentrations (44B-92-01X, 44B-92-05X, or 52B-92-03X). The areas previously recorded as having high PAH concentrations were found to have broken pavement either at or below the ground surface; consequently, soil was obtained from a visibly oil-stained spot located in the north corner of the Cannibalization Yard, taking precautions to avoid collecting any pieces of bituminous paving in the sample. The surficial sample was used for a variety of tests including bacterial analysis, chemical analysis, and nutrient adsorption. Details of the specific testing performed are provided in Biological Treatability Study Report (ABB-ES, 1993b)

The biodegradation testing was conducted under laboratory simulated bioventing and land treatment conditions to determine the rate and extent of contaminant removal that occurs as a result of biodegradation. For this study landfarming was chosen as the simulated land treatment method. However, biodegradation rates for other land treatment methods such as composting should be comparable. The results of these tests are detailed in the Biological Treatability Study Report (ABB-ES, 1993b) and summarized below.

The laboratory study indicated that approximately 50% of the waste oil TPHC contamination in the soil sample was readily biodegradable within the first month of treatment. However, the remaining TPHC compounds were more difficult to biodegrade and would require a treatment time significantly longer than the laboratory test period. The testing also showed that cPAHs in waste oil contaminated soil did not biodegrade under laboratory conditions within the 2-month study period. However, based on the evidence of petroleum degradation in this laboratory study, it is expected that reduction of cPAHs will occur, but will require a longer treatment time than the laboratory test period. Landfarming and composting are believed to be viable treatment alternatives for soil containing TPHC and cPAHs based on the results of the treatability study and the bioremediation treatment time data contained in Appendix C. Additionally, the treatability study indicated that bioventing is not as aggressive in reducing TPHC concentrations as landfarming. Reduction in TPHC was only 20 to 30% compared with approximately 50% using landfarming simulation. Cleanup time for bioventing is expected to be at least twice as long as for the composting and landfarming alternative technologies.

1.4.4 Bituminous Pavement Analysis

The apparent randomness in detecting PAH compounds in AOCs 44 and 52 soils during the SI raised questions about the potential source of these contaminants. Based on visual observations, broken-up bituminous paving is present in various areas of AOCs 44 and 52 surface soils. However, there appear to be no historical records indicating when and in what areas the pavement was applied. Aerial photographs taken over the past 50 years also do not show any evidence of paving. Bituminous paving contains PAH compounds and it is believed that the presence of paving in AOCs 44 and 52 soils may impact the soil analytical results.

To investigate the potential influence of bituminous pavement on soil analysis for cPAH contaminants, a sample of non-oil stained bituminous pavement was obtained from the north corner of the TDA Maintenance Yard and analyzed for chromatographable organic compounds, including target cPAHs contaminants of concern to establish a general fingerprint of contaminants potentially associated with paving. The same analysis was performed on the oil-stained surficial soil sample (0 to 2 feet) taken from the Cannibalization Yard. Chemical analyses was performed for aromatic and alkane compounds using a gas chromatograph/flame ionization detector (GC/FID) fingerprint (modified EPA Method 8100). A split soil and pavement sample was submitted to another laboratory where chemical analysis was performed for Project Analyte List (PAL) SVOCs using mass spectrometry as was used for the SI analytical work. Contaminant concentrations present in the paving were compared with those present in the soil sample and with the contaminants detected in the surficial soils during the SI.

Final mass spectrometry analytical results for the bituminous pavement and stained soil are presented in Table 1-7 and compared with similar analysis performed on SI soil samples previously recorded as having high cPAH concentrations (44B-92-01X, 44B-92-05X, and 52B-92-03X). The total PAH (and related compounds) concentration in the stained soil and bituminous pavement was found to be 4.35 ppm and 11,380 ppm, respectively. Concentrations for each of the analytes are also computed as a percentage of the total PAH concentration and presented in Table 1-7 for the pavement, stained soil and the three boring samples. These percentages are plotted graphically comparing pavement versus stained soil (Figure 1-20), pavement versus soil from locations 44B-92-05X, 44B-92-01X and 52B-92-03X (Figures 1-21, 1-22 and 1-23) and stained soil versus soil from locations 44B-92-05X, 44B-92-01X and 52B-92-03X (Figures 1-24, 1-25 and 1-26). Based on this data, it is evident that the analyte distribution for the pavement is very similar to that found in each of the SI soil samples. There is much less of a correlation between the oil stained soil and SI soil sample analyte distribution. This would tend to support the assessment that the elevated PAH concentrations found in at least three of the SI soil samples could be due to the presence of broken pavement in the soil.

It should also be noted that elevated concentrations of cPAHs are not expected in soils contaminated with only used motor oil. The mean concentrations of benzo(a)pyrene (B[a]P) and benz(a)anthracene measured in 1,071 samples of used motor oils were found to be 24.5 and 71.3 ppm, respectively (Franklin, 1984). In a soil sample with TPHC concentration of 1,210 ppm (as detected in 44B-92-05X), this would equate to B(a)P and benzo(a)anthracene concentrations of 0.03 ppm and 0.09 ppm, respectively, and not 30 ppm and 40 ppm, respectively, as detected in the 44B-92-05X surface soil sample.

The finding of high concentrations of target cPAHs in asphalt fragments may have significance to the selection and design of a remedy. For example, if a practical screening process could result in a large volume of soil meeting the response objectives and a small volume of asphalt fragments that could be disposed of inexpensively, screening would be an essential part of a cost-effective remedy.

ABB-ES has considered the likelihood of a physical screening process producing the above result. To evaluate the effectiveness of screening quantitatively, it would be necessary to analyze different soil fractions (particle size ranges) for PAH and TPHC. To assure that the ultimate remedial action is cost-effective, it is recommended that pre-design sampling include activities to fill this data gap. Thus, the design of any remedy (assuming that one is selected that includes ex-situ treatment) will have an improved basis for the components that involve material handling.

1.5 SUMMARY OF QUANTITATIVE RISK EVALUATION

1.5.1 Crankcase Releases - AOCs 44 and 52

In the Final SI Report (ABB-ES, 1993), human health risk estimates were generated for soil contamination associated with crankcase releases at AOCs 44 and 52. Health risk estimates were developed for two exposure scenarios: one involving a construction worker and the other involving a long-term worker employed at AOCs 44/52 for a working lifetime.

The summary that follows contains risk estimates for cPAHs developed using two standard approaches. The first is the USEPA Region IV's toxic equivalency factor (TEF) approach. TEFs were used to convert each cPAH's concentration to an equivalent concentration of B(a)P. At the request of USEPA Region I and MADEP, risk estimates were also made (for the same exposure scenarios) using USEPA Region I's approach that assumes all cPAHs are as potent as the B(a)P approach. Appendix A contains both sets of risk estimates - one set based on the TEF approach and one set based on the B(a)P approach. Table A-14 contains the USEPA Region IV TEFs.

Risk Evaluation Assumptions. AOCs 44 and 52 historically and currently have been used as vehicle maintenance areas. The future use of these areas is expected to remain commercial/industrial in nature as discussed with Land Bank representatives at the June 28, 1993 Draft FS Report Review Meeting. Under current and future use, it is possible that a worker could be exposed to chemicals detected in soil if excavation were to occur. This might occur for utility repair or new building construction. It is also possible that an employee of Building 3713 could contact contaminants in surface soil during an activity such as grounds maintenance.

For the construction worker exposure scenario, it was assumed in this Risk Evaluation that a construction worker would be exposed to chemicals in the surface and subsurface soil (to a depth of 10 feet) in AOCs 44 and 52 for a period of three months (5 workdays for 12 weeks). It was further assumed that the worker would be exposed through direct contact with the chemicals on his arms and hands (at a soil adherence factor of 1 milligram per centimeter^2 [mg/cm^2]) and through the incidental ingestion of soil particles.

For the long-term worker exposure scenario, it was assumed that an employee of Building 3713 could be exposed to chemicals in the surface soil (to a depth of 2 feet) in the Maintenance Yards for a working lifetime of 25 years (250 days/year). As for the construction worker scenario, it was assumed that the worker would be exposed through direct contact on his arms and hands (at a soil adherence factor of 1 mg/cm^2) and incidental ingestion.

To estimate the exposure point concentrations to which a construction worker might be exposed, ABB-ES used both AOC-wide average concentrations as well as AOC maximums. For the construction worker scenario, AOC arithmetic averages were calculated using all soil sampling locations at three depths; samples included 44B-92-01X through 44B-92-05X and 52B-92-01X through 52B-92-09X (at 0-10 foot depths) and G3M-92-04X (at 0 and 12 foot depths). For the long-term worker scenario, averages were calculated using the same soil samples but at depths of 0 to 2 feet only. For both exposure scenarios, the maximum concentration was that which was found anywhere (within the respective limits on soils depth) on the Maintenance Yards.

Appendix A contains the spreadsheet used to estimate risks under both the construction worker and long-term worker exposure scenarios. All exposure parameter values and their references are provided in their spreadsheets.

Particulate Exposures Via Inhalation During Construction Activities. Also, at the request of USEPA Region I and MADEP, the construction worker receptor was evaluated for potential exposures to surface and subsurface soil contaminants (to a depth of 10 feet) via the inhalation of particulates raised during construction activities. It was assumed that contaminant concentrations in airborne particulates would be equivalent to the (arithmetic average) concentrations of contaminants in surface and subsurface soil. A range of potential Exposure Point Concentrations (EPCs) in air was then calculated. First, it was assumed that the respirable particulate concentration (PM10) in the air was equal to the National Ambient Air Quality Standard (NAAQS) of 50 μg per cubic meter (μg/m^3) annual arithmetic mean concentration (see Table A-10 in Appendix A). Second, a reasonable air upper-bound EPC was calculated by assuming that the PM10 concentration was equal to 150 μg/m^3, the NAAQS maximum concentration for a 24-hour period not to be exceeded more than once per year (see Table A-12 in Appendix A).

Using the calculated air contaminant EPCs that construction workers were assumed exposed to for the entire exposure duration, and an inhalation rate of 2.5 m^3 per hour (or 20 m^3 per day divided by an 8-hour workday), risks were evaluated for the particulate inhalation pathway. Toxicity constants (i.e., inhalation cancer slope factors, and inhalation reference concentrations) were obtained from the USEPA Integration Risk Information System (IRIS) or USEPA's Health Effects Assessment Summary Tables (HEAST). Inhalation toxicity constants were used if available. Chemicals lacking inhalation slope factors or reference concentrations were evaluated using oral slope factors or oral reference doses as surrogate values. As with the other exposure routes (direct contact and incidental ingestion), a construction worker was assumed to inhale particles five days per week for a three month-long construction project.

Tables A-11 and A-13 in Appendix A contain the risk estimate spreadsheets for this exposure scenario. The carcinogenic risks range from 3E-8 to 8E-8 at the ambient particulate limits of 50 and 150 μg/m^3, respectively. The hazard indices ranged from 0.04 to 0.1. These risks are well within USEPA Superfund target risk limits.

The site worker receptor was not evaluated for the particulate inhalation pathway. Normal site worker activities are unlikely to raise dust in amounts or for periods of time which would result in significant exposures. The MADEP Risk Assessment Shortform Residential Scenario (MADEP, 1992), while stating that construction/excavation exposure may be of importance and should be quantified, does not evaluate residential particulate inhalation exposure. The Shortform demonstrates that the particulate inhalation pathway is not likely to contribute more than one percent of total (ingestion, dermal contact, and inhalation of particulates) soil exposure for a residential receptor (MADEP, 1992). Therefore, risks from the particulate inhalation pathway under exposure scenarios that do not include dust-producing activities can be expected to be insignificant compared to risks from other soil exposure pathways, and have not been quantified.

Findings. Risk estimates made under a construction worker exposure scenario for crankcase releases at the Maintenance Yards fell within the USEPA Superfund target risk range of 1E-4 to 1E-6 excess cancer risk for carcinogens and a target HI of 1. The cancer risk estimates, assuming exposure to AOC average and maximum concentrations (in soil to a depth of 10 feet), ranged from 2E-6 to 1E-5 (TEF approach) and 4E-6 to 5E-5 (B[a]P approach)

Risk estimates made under a long-term worker exposure scenario exceeded the USEPA Superfund target risk range of 1E-4 to 1E-6 excess cancer risk for carcinogens. The cancer risk estimates, assuming exposure to AOC average and maximum concentrations (in soil to a depth of 2 feet), ranged from 9E-4 to 2E-4 (TEF approach) and 4E-3 to 7E-4 (B[a]P approach).

The chemicals that contribute most significantly to risk are cPAHs, arsenic, and beryllium. (Although the cancer risk associated with long-term exposure to arsenic is 1.3 x 10^{5}, the average concentration of arsenic in surface soil across AOCs 44 and 52 [14 μg/g] is below the base-wide calculated background concentration of 21 μg/g. As discussed in the SI Report, beryllium does not appear to be related to Army activity and is probably naturally occurring.) The hazard indices are below or approximate 1.

1.5.2 Mogas Spill

This section presents risk estimates calculated by ABB-ES, and reported in the Final SI Report (ABB-ES, 1993), for the motor vehicle gas (mogas) spill at SA 44. Health risk estimates were developed for a construction worker exposure scenario for the mogas spill reported to have taken place in the area of sampling location 44B-92-06X. A summary of the risk estimates reported in the SI Report and an evaluation of these estimates for the FS follow.

Risk Evaluation Assumptions. SA 44 historically and currently has been used as a vehicle maintenance area. The future use of this area is expected to remain commercial/industrial in nature. Under current and future use, it is possible that a worker could be exposed to chemicals detected in soil if excavation were to occur. This might occur for utility repair or new building construction. Because of the limited areal extent of this spill (represented by sampling location 44B-92-06X), long-term, repeated exposure is considered to be unlikely. Therefore, worker exposure that would be chronic in duration was not evaluated.

For the risk evaluation, it was assumed that a construction worker would be exposed to chemicals in the surface and subsurface soil in the area of the mogas spill for a period of three months (5 workdays for 12 weeks). This represents a conservative assumption because repeated exposure to soil in this particular area is unlikely. It was further assumed that the worker would be exposed through direct contact with the chemicals and through the incidental ingestion of soil particles.

The maximum concentration detected at any depth at sampling location 44B-92-06X was selected to represent the EPC.

Most of the residual contamination associated with the mogas release was detected and reported as TPHC. This is consistent with the composition of mogas, a high-octane leaded gasoline. Because no dose-response value exists with which to evaluate the toxicity of TPHC, a surrogate dose-response value was used, that of gasoline. (The reader is referred to Section 4.2.7.2 of the SI Report [ABB-ES, 1993] for details of this evaluation).

Findings. Risk estimates made under a construction worker exposure scenario for the mogas spill in AOC 44 fell within the acceptable USEPA Superfund target risk range of 1E-4 to 1E-6 excess cancer risk for carcinogens. The cancer risk estimate, assuming exposure to the maximum concentration found at sampling location 44B-92-06X, was calculated to be 2E-6. The hazard index (HI) was estimated at 1.9. The chemicals that contribute most significantly to the HI are arsenic (HI = 0.8) and TPHC (HI = 0.7).

For the FS, the significance of the HIs generated in the SI Report was further evaluated. Following USEPA risk assessment guidance, when a HI exceeds 1.0, it is appropriate to consider the toxicological endpoints upon which the non-carcinogenic hazards are based and the target organs for toxicological effects. Hazard indices for individual compounds should properly be added together only if the toxicological endpoints or mechanisms of action of the compounds are similar. In the case of arsenic and TPHC, their toxicological effects would be expected to differ. The dose/response value for arsenic is based on effects to the skin (i.e., hyperpigmentation and keratosis) while the dose/response value for TPHC (gasoline) is based on reduction in body weight gain. The toxicity of gasoline is attributed primarily to Central Nervous System effects. Because the toxicological endpoints of concern for arsenic and TPHC are different, it is inappropriate to add their hazard indices together. Therefore, based on this consideration, the noncarcinogenic HI would be less than 1.0.

1.6 SUMMARY OF PRELIMINARY ECOLOGICAL RISK EVALUATION

In the Final SI Report (ABB-ES, 1993), a preliminary ecological risk evaluation was performed. It was concluded that no significant habitat for resident or migratory ecological receptors occur at AOCs 44 and 52, and no rare or endangered species are known to occur in the vicinity of these AOCs. The Maintenance Yards are typically filled with parked heavy equipment vehicles, and are surrounded by barbed-wire fence. The sites are devoid of any woody or herbaceous vegetation. Based on the lack of ecological exposure pathways, no comparison of surface soil analytes to protective contaminant level (PCL) reference values was conducted.

Potential risks for exposure to surface water and sediments in the portion of Cold Spring Brook adjacent to this general area are being evaluated as part of the AREE 70 evaluation.

1.7 ARARs

Compliance with ARARs is one of the CERCLA criteria to be evaluated for each of the alternatives screened for detailed analysis in Section 6. Applicable requirements are those clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or Massachusetts law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the Fort Devens site. All jurisdictional prerequisites must be met for a rule to be determined to be "applicable". Relevant and appropriate requirements are also clean-up standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or Massachusetts law. These standards, however, are not "applicable" to a specific hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at Fort Devens, but address problems or situations sufficiently similar to those encountered at the Fort Devens site. Portions of a requirement may be relevant and appropriate, even if the entire requirement is not. Also, the concept of relevant and appropriate does not apply to off-site activities (i.e., the requirement is either "applicable" or not a requirement).

Selection of ARARs is dependent on the hazardous substances present at a site, site characteristics and location, and the actions selected for a remedy. Thus, ARARs can be location-specific, chemical-specific, and/or action-specific.

Location-specific requirements involve restrictions established for specific substances or activities based on their location. They address circumstances such as wetland impacts from site activities.

Action-specific requirements involve performance, design, or other action-specific requirements and are generally technology- or activity-based. They are used to control or restrict particular types of remedial actions selected as alternatives for cleanup of a site. Action-specific requirements include air pollution control regulations which apply to treatment technologies and excavation activities performed at the site. They also include soils management regulations relating to the handling of contaminated soils and requirements for groundwater monitoring. Chemical-specific requirements generally involve health- or risk-based numerical values or methodologies that determine site-specific acceptable chemical concentrations and/or amounts. Chemical-specific ARARs are used to establish the need for cleanup (i.e., action levels) as well as to define cleanup goals. Where chemical-specific ARARs do not exist or would not be sufficiently protective of human health or environment for the given circumstances (e.g., aggregate risk considerations), non-promulgated advisories or to be considered (TBC) guidance and risk assessment-based data are used to establish action levels and cleanup goals. TBC guidance, although not enforceable, can be used to indicate that adverse environmental or human health effects could occur under certain circumstances if concentrations listed are exceeded. Currently, there are no set maximum allowable residual levels for chemicals in soil or sediments under federal law.

USEPA ARARs guidance provides that CERCLA response actions must comply with other environmental and public health laws and regulations to the extent they are substantive (i.e. pertain directly to actions or conditions in the environment), but do not need to comply with those which are administrative (i.e. mechanisms that facilitate the implementation of the substantive requirements) (USEPA, 1988a). As noted in the ARARs guidance:

> The CERCLA program has its own set of administrative procedures which assure proper implementation of CERCLA. The application of additional or conflicting administrative requirements could result in delay or confusion.

Of the 11 operable units currently being investigated for cleanup under CERCLA, seven (including AOCs 44 and 52) are located on the Main Post area at Fort Devens. The Main Post consists of approximately 2,300 acres, and is bounded on the north by State Route 2A, on the south by State Route 2, on the east by State Routes 110/111, and on the west by West Main Street. The seven operable units on the Main Post involved related military activities and future land use of the Main Post is expected to be similar in nature. For purposes of CERCLA, the Main Post constitutes a "facility" as defined in CERCLA § 101(9).

The central soil treatment facility proposed for Alternative 9 (alternatives are developed and screened in Section 5.0) will be located on the Main Post approximately 0.5 mile from AOCs 44 and 52. Facility site selection is detailed in the Final Siting Report (ABB-ES, 1994a). Since the soil treatment facility site will be located on the CERCLA facility (i.e., the Main Post), it is not necessary to obtain any federal, state or local permits for this treatment facility because treatment activities which take place on a CERCLA facility are considered on-site and are, therefore exempt from obtaining federal, state and local permits. (55 FR 8688-90, March 8, 1990). In addition, the landfarming technology (proposed in Alternative 8) and the asphalt batching technology (proposed in Alternatives 2, 3, and 5) will also take place on the Main Post (these activities will be conducted entirely at AOCs 44 and 52), and therefore no permits will be required for these activities.

The Massachusetts Contingency Plan (MCP), 310 CMR 40.0000 (November 19, 1993) is applicable to AOCs 44 and 52. (See 310 CMR 40.0003). However, most provisions of the MCP are largely administrative in nature and, therefore, do not have to be complied with in connection with the response action selected for

AOCs 44 and 52. Further, the MCP contains a specific provision (310 CMR 40.0111) for deferring application of the MCP at CERCLA sites. 310 CMR 40.0111(1)(a) provides that response actions at CERCLA sites shall be deemed adequately regulated for purposes of compliance with the MCP, provided the MADEP concurs in the CERCLA record of decision. MADEP concurrence in the response action for the Maintenance Yards will be further evaluated at the Proposed Plan stage.

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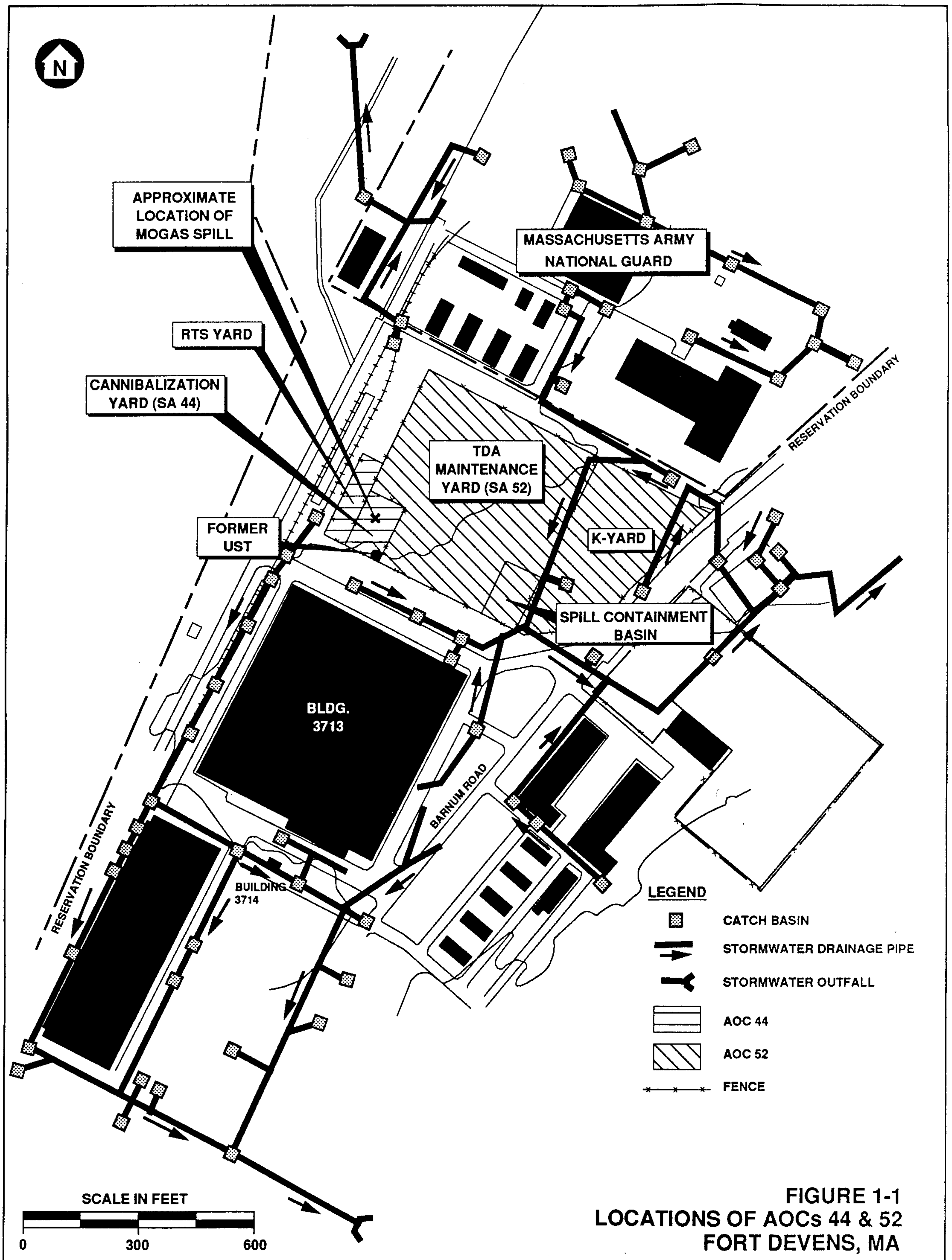

FIGURE 1-1
LOCATIONS OF AOCs 44 & 52
FORT DEVENS, MA

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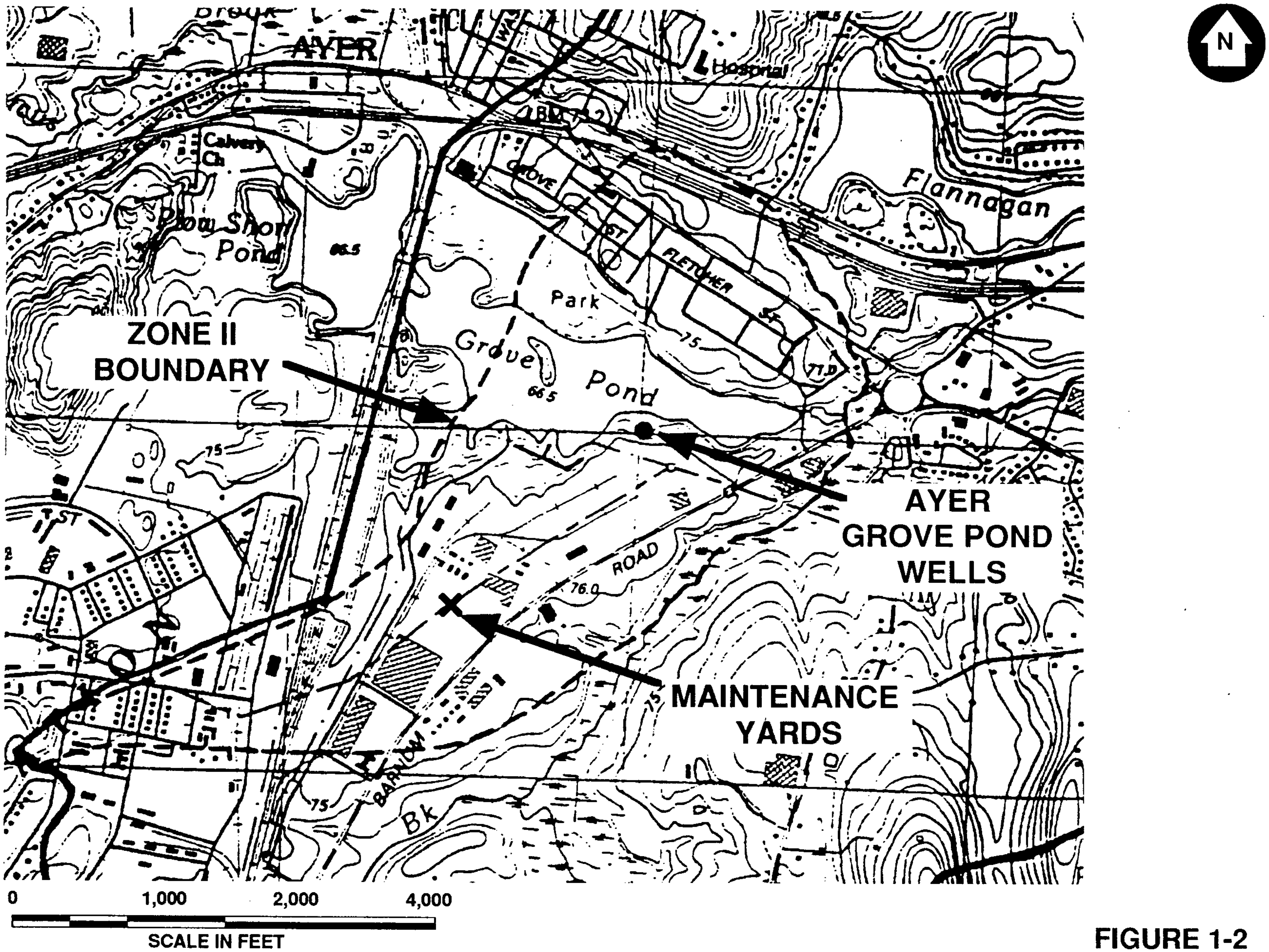

FIGURE 1-2
ZONE II DELINEATION - AYER GROVE POND WELLS
FORT DEVENS, MA

(REF.: CDM, 1992)

ABB Environmental Services, Inc.

6917-07B

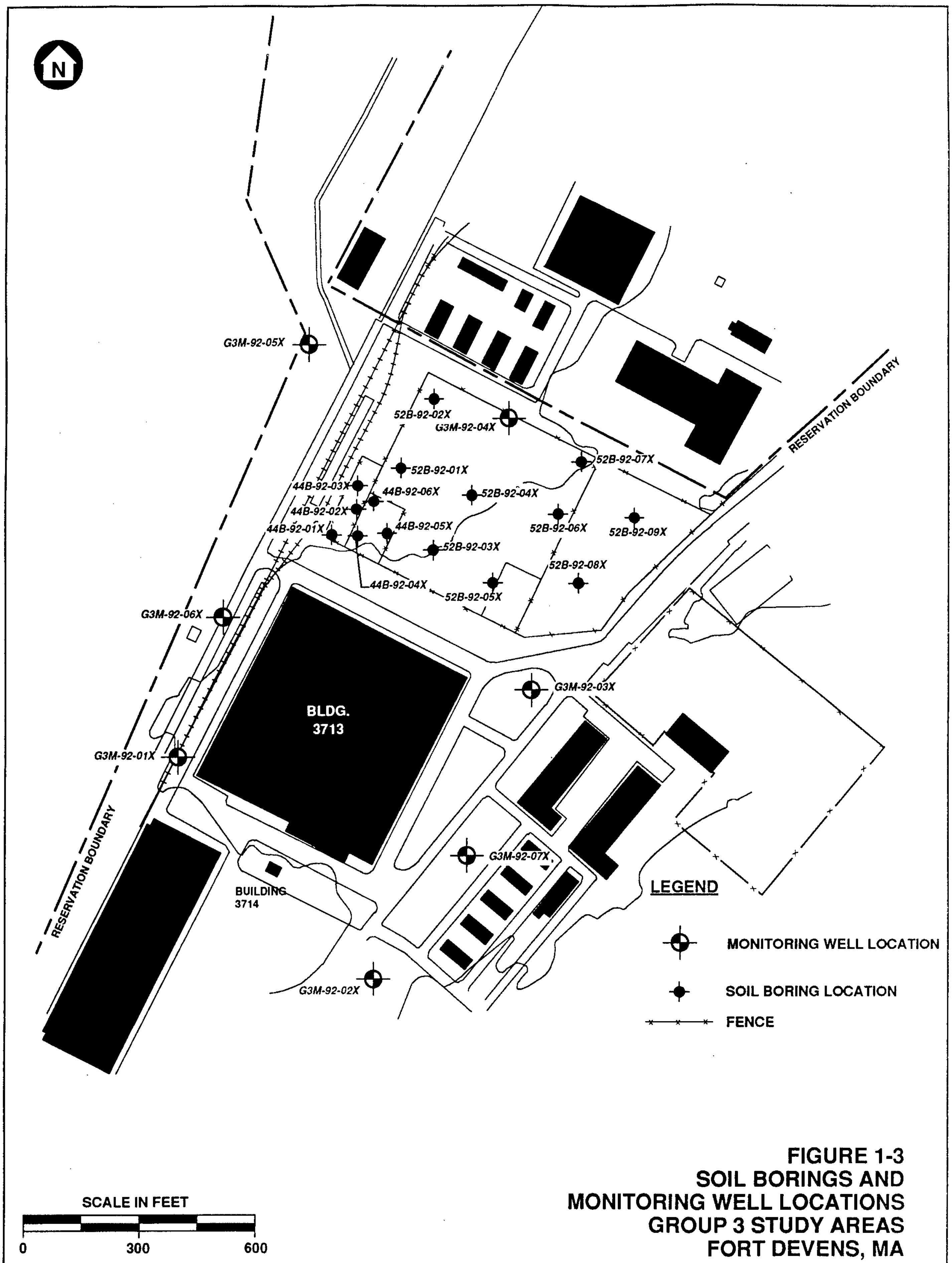

FIGURE 1-3
SOIL BORINGS AND MONITORING WELL LOCATIONS GROUP 3 STUDY AREAS FORT DEVENS, MA

ABB Environmental Services, Inc.

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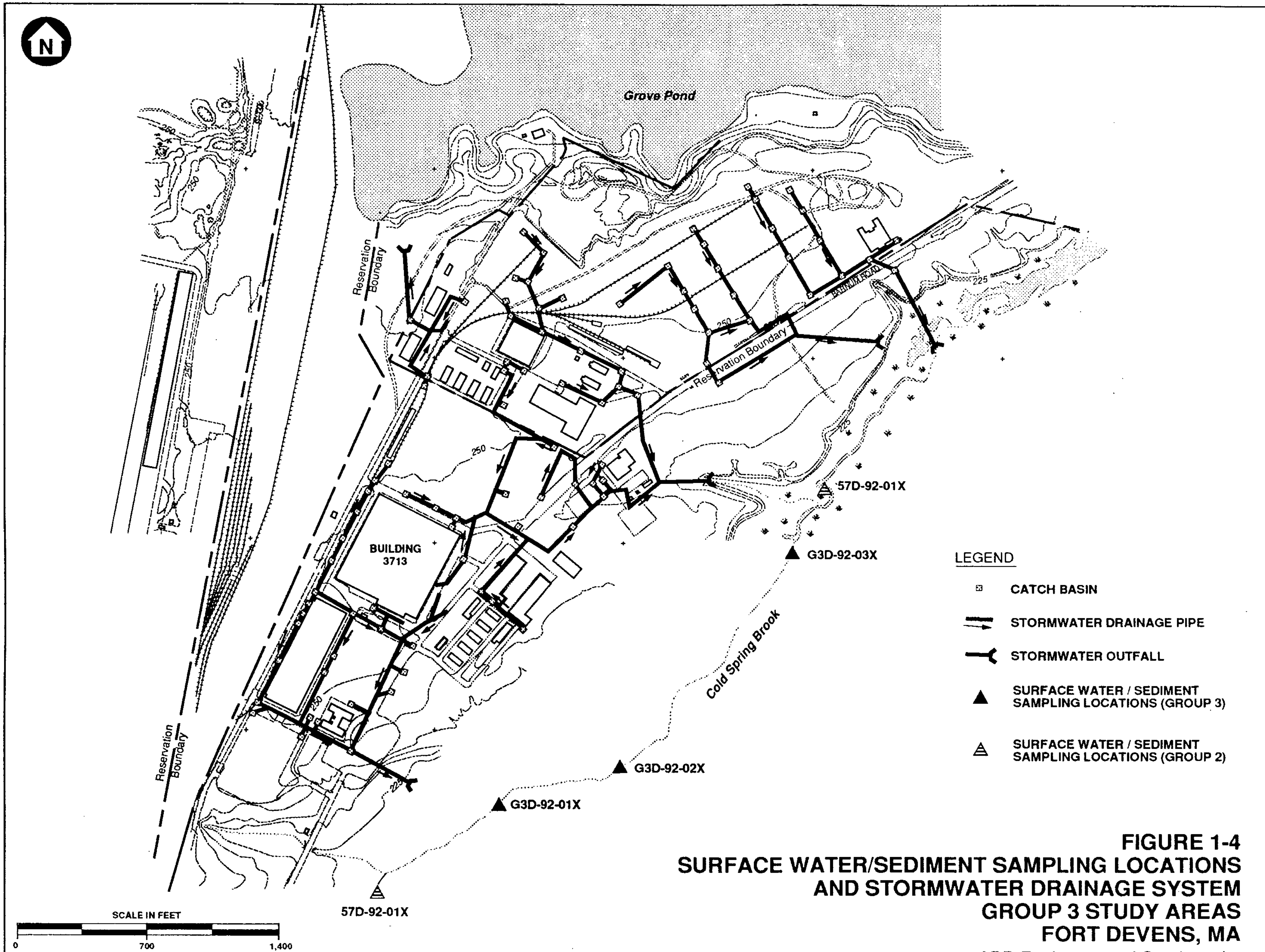

FIGURE 1-4
SURFACE WATER/SEDIMENT SAMPLING LOCATIONS AND STORMWATER DRAINAGE SYSTEM
GROUP 3 STUDY AREAS
FORT DEVENS, MA

ABB Environmental Services, Inc.

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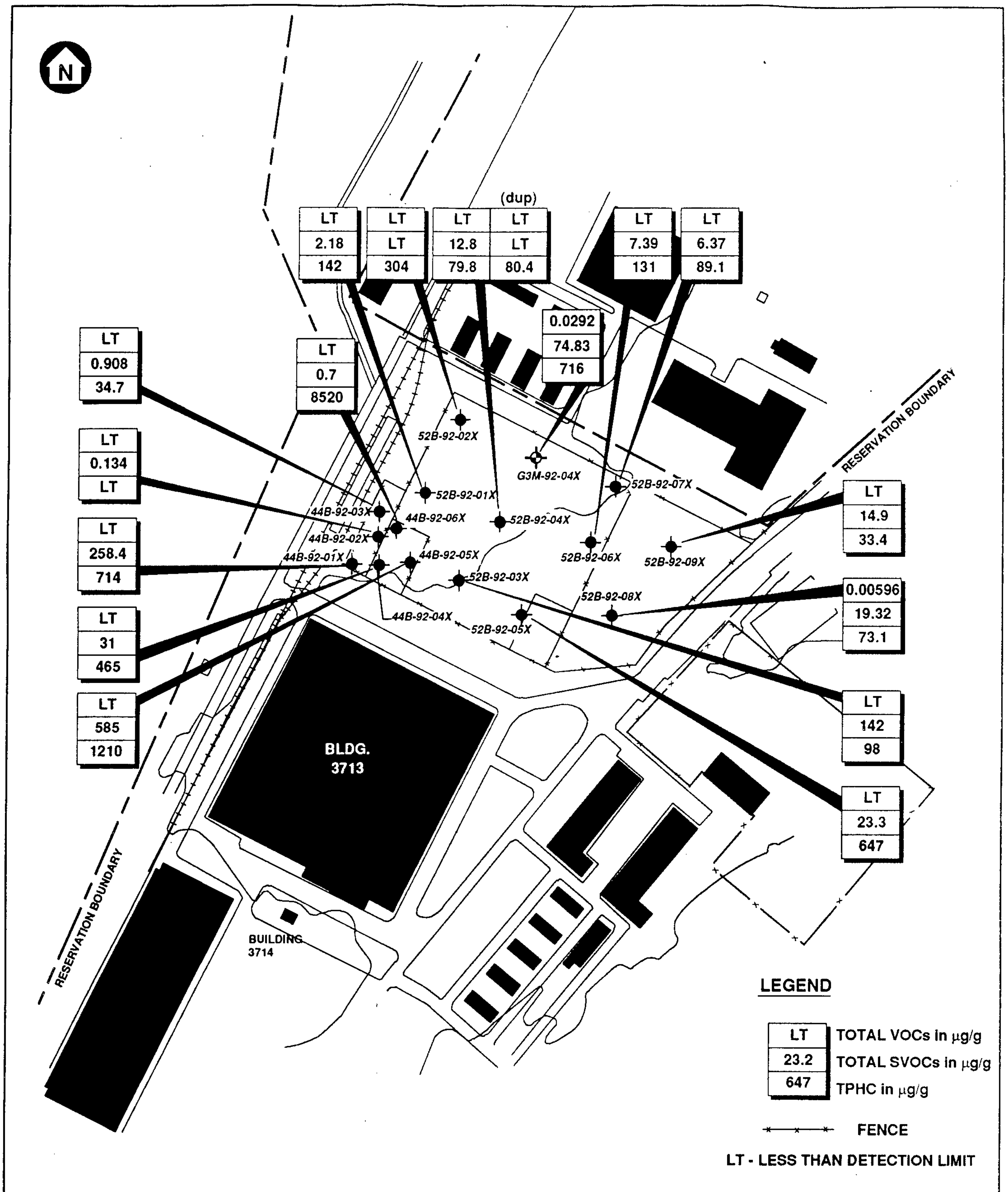

FIGURE 1-5
ORGANIC ANALYTES IN SOIL
DEPTH = 0 to 2 FEET
AOCS 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.

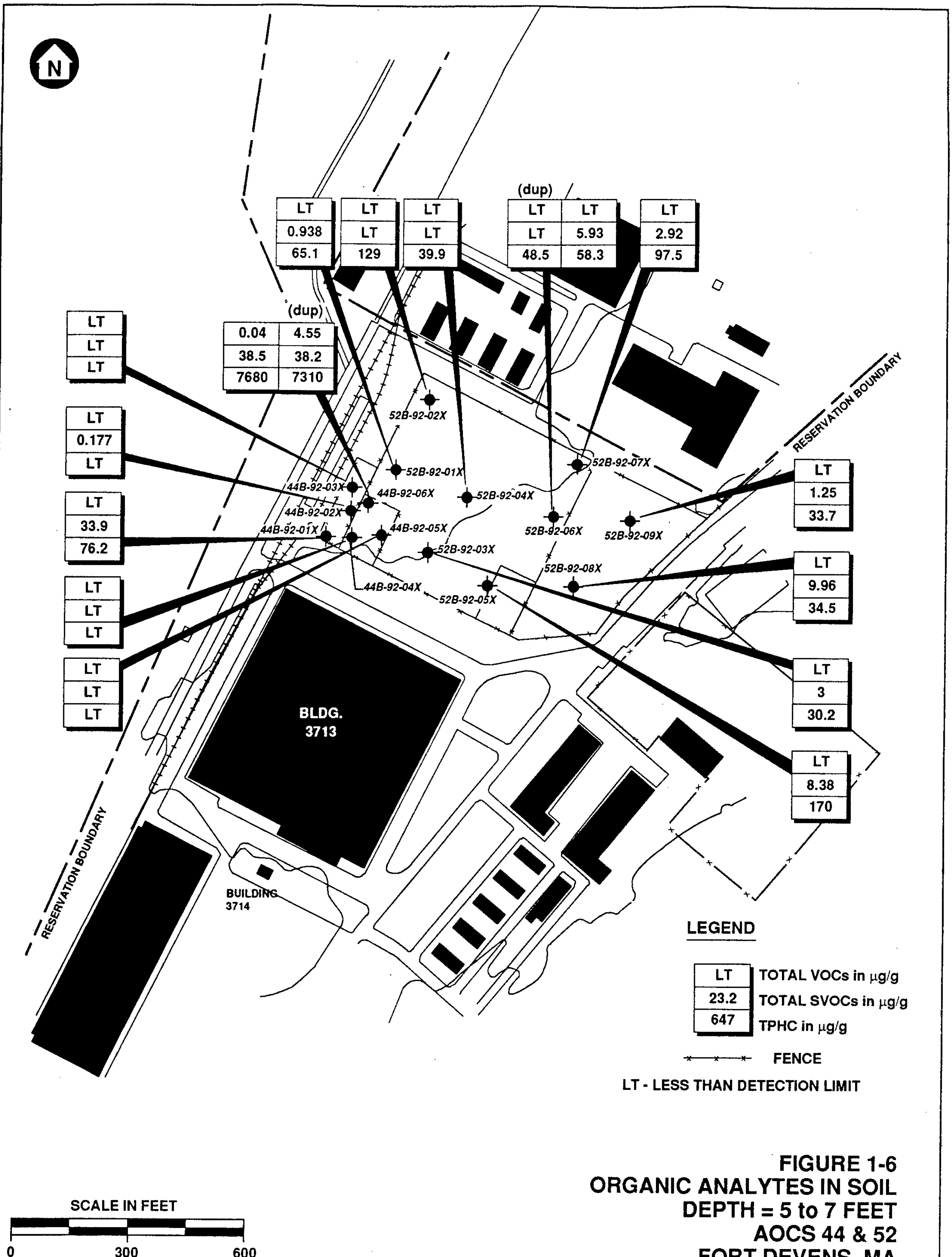

FIGURE 1-6
ORGANIC ANALYTES IN SOIL
DEPTH = 5 to 7 FEET
AOCS 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.

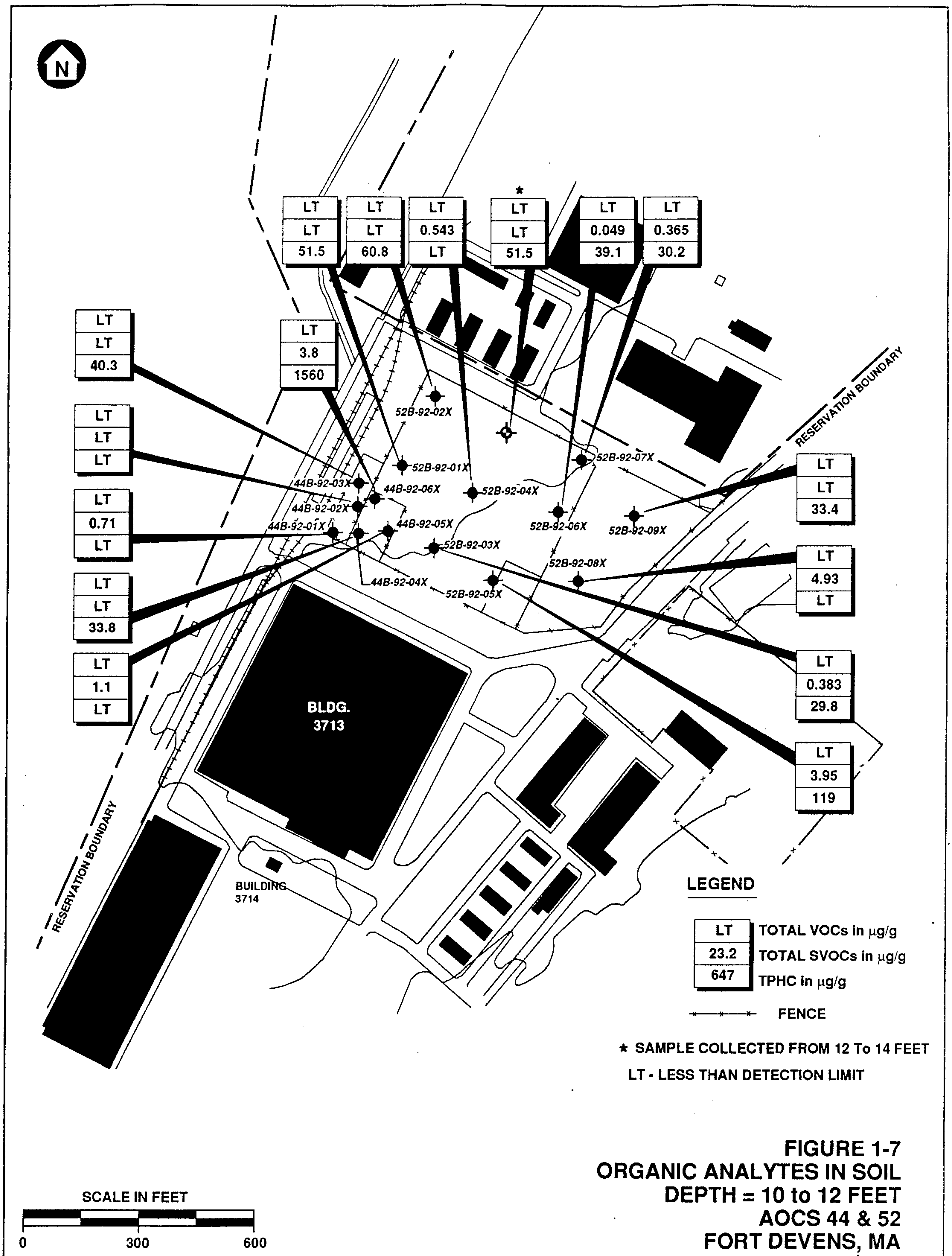

FIGURE 1-7
ORGANIC ANALYTES IN SOIL
DEPTH = 10 to 12 FEET
AOCS 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.

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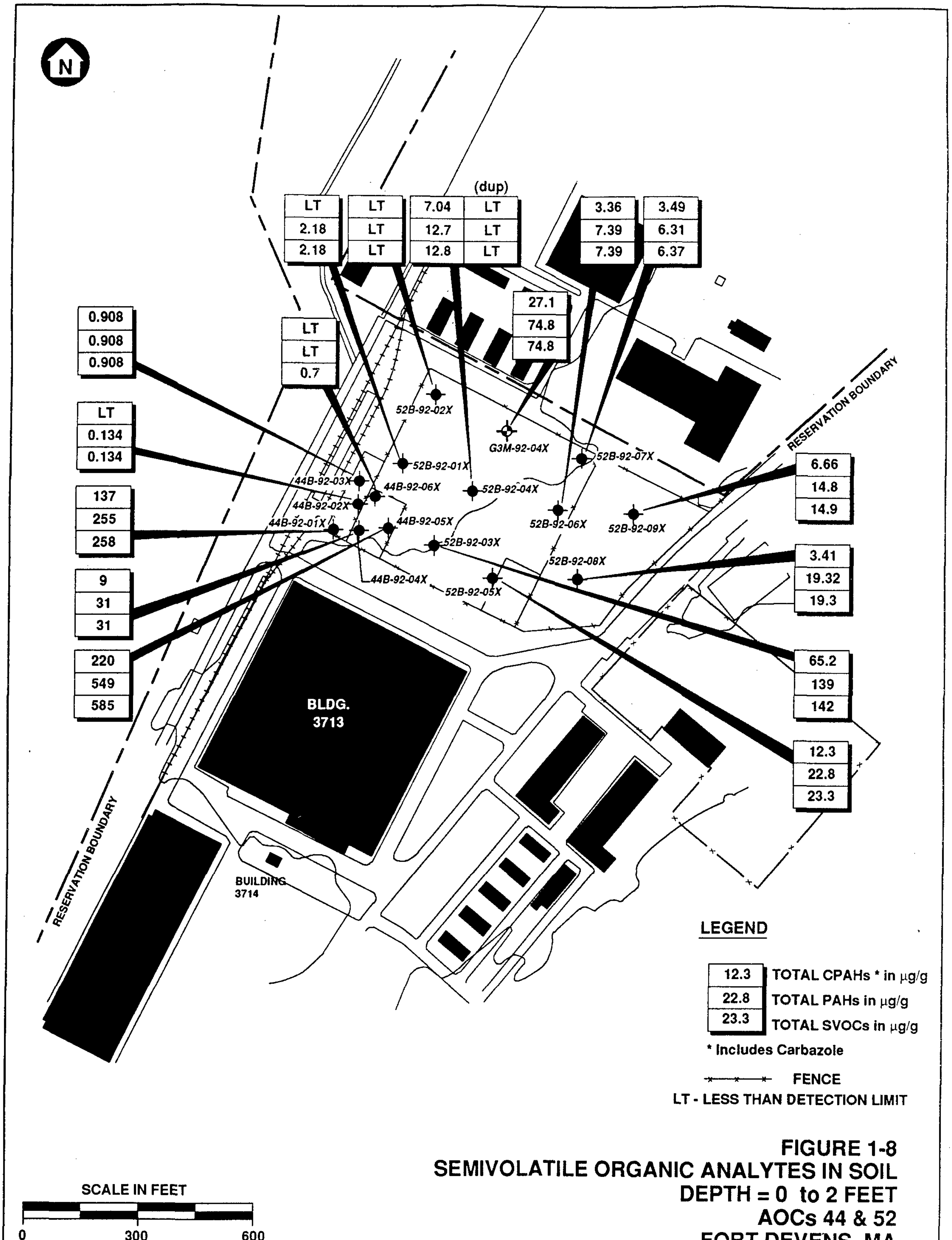

FIGURE 1-8
SEMIVOLATILE ORGANIC ANALYTES IN SOIL
DEPTH = 0 to 2 FEET
AOCs 44 & 52
FORT DEVENS, MA

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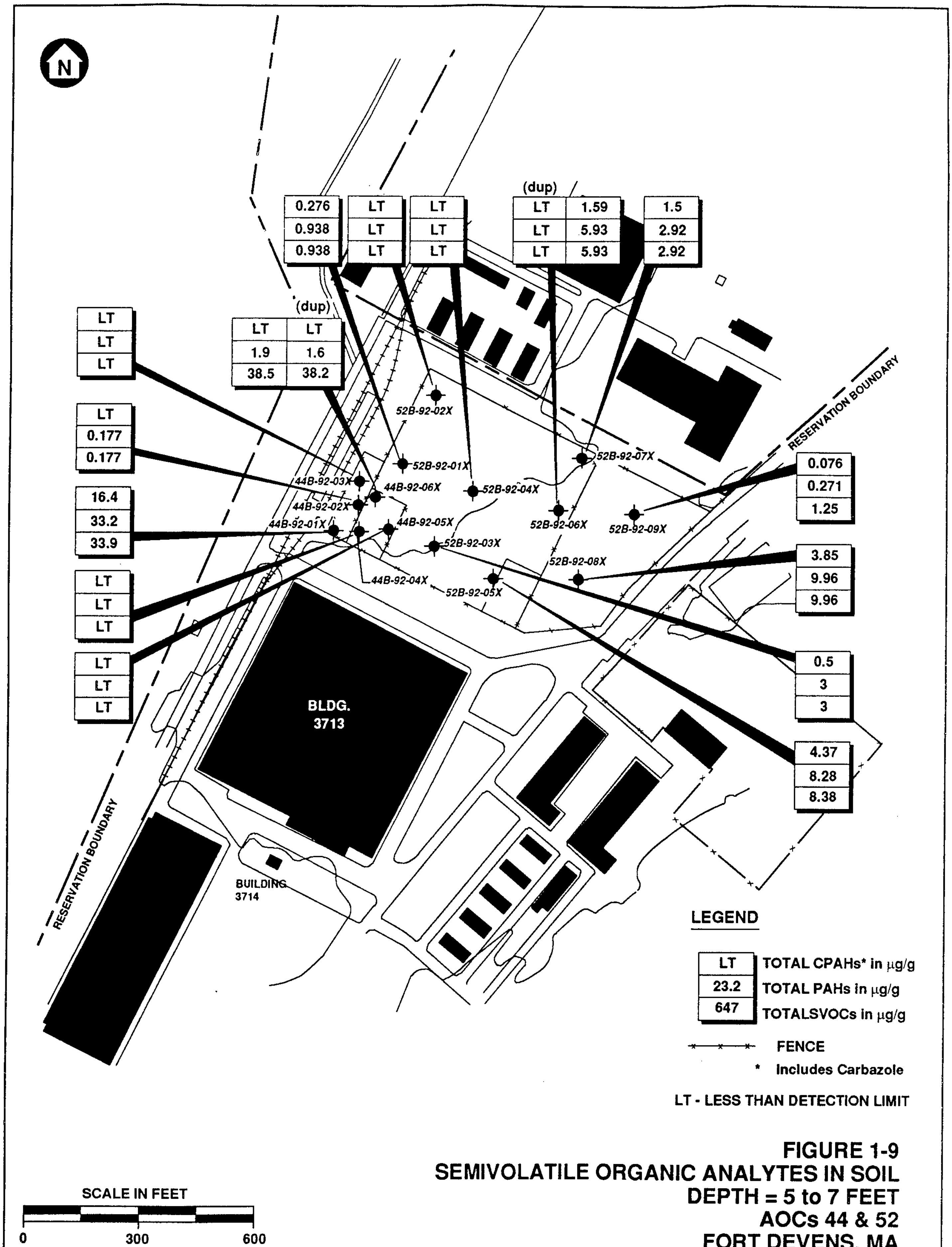

FIGURE 1-9
SEMIVOLATILE ORGANIC ANALYTES IN SOIL
DEPTH = 5 to 7 FEET
AOCs 44 & 52
FORT DEVENS, MA

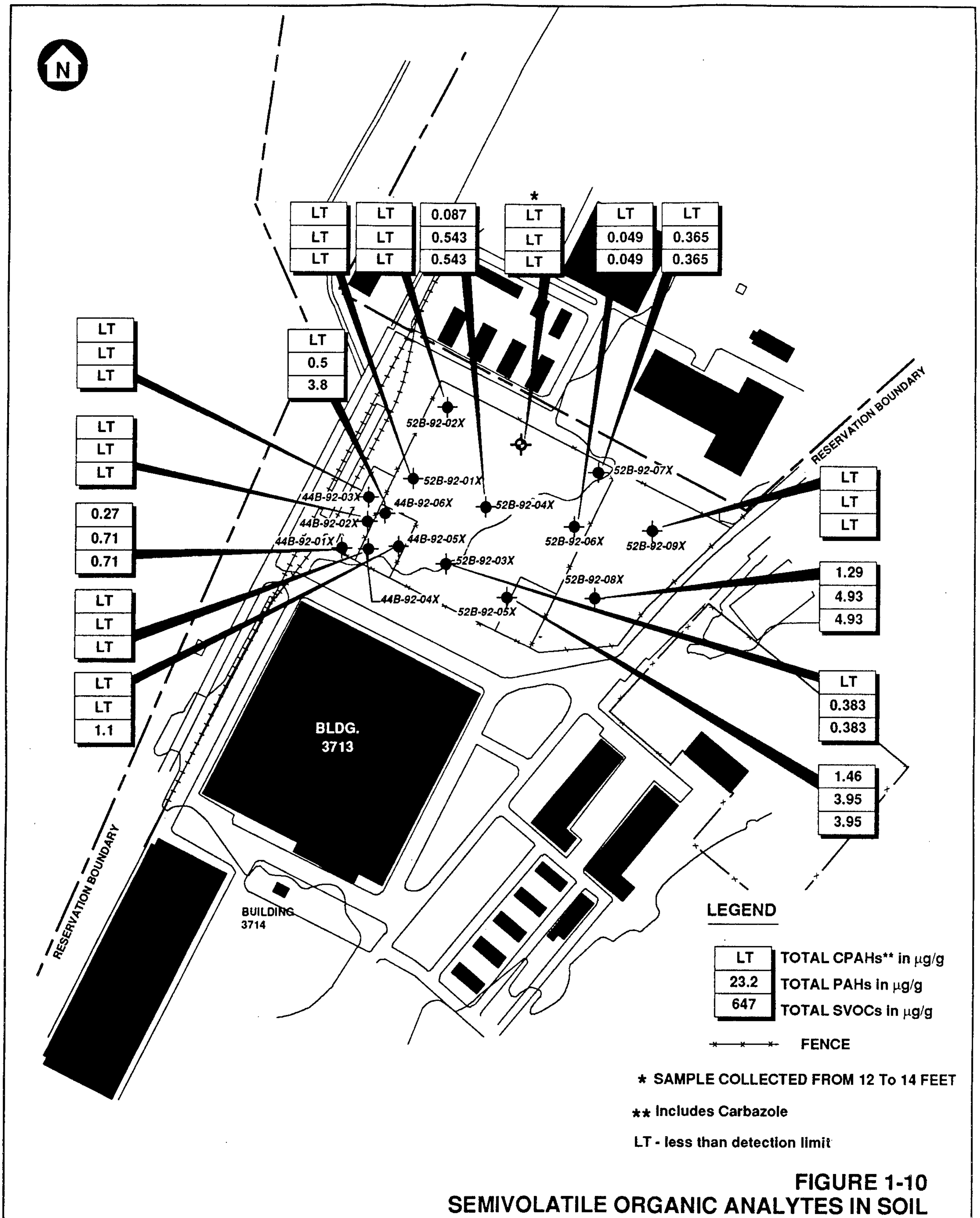

FIGURE 1-10
SEMIVOLATILE ORGANIC ANALYTES IN SOIL
DEPTH = 10 to 12 FEET
AOCs 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.

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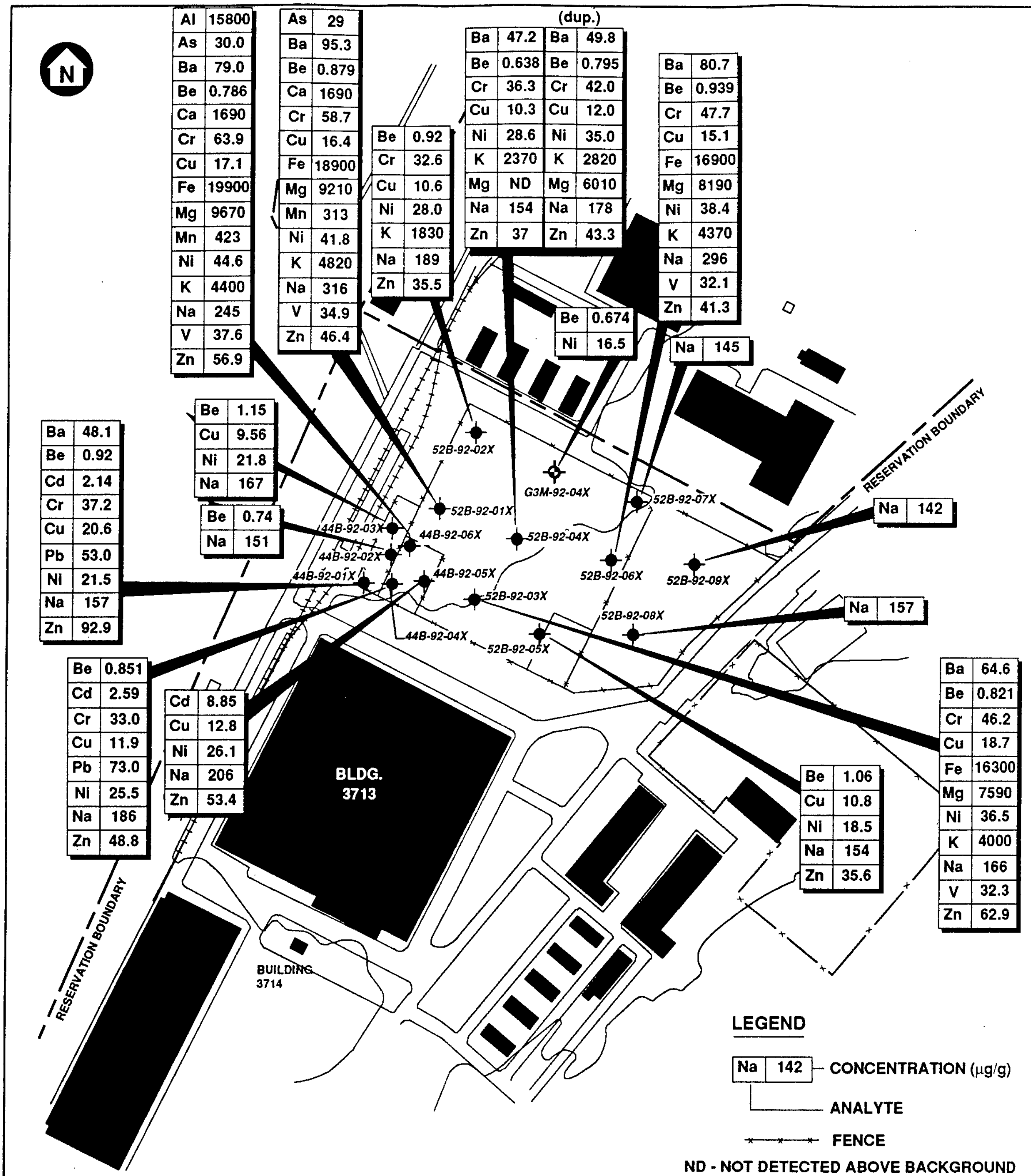
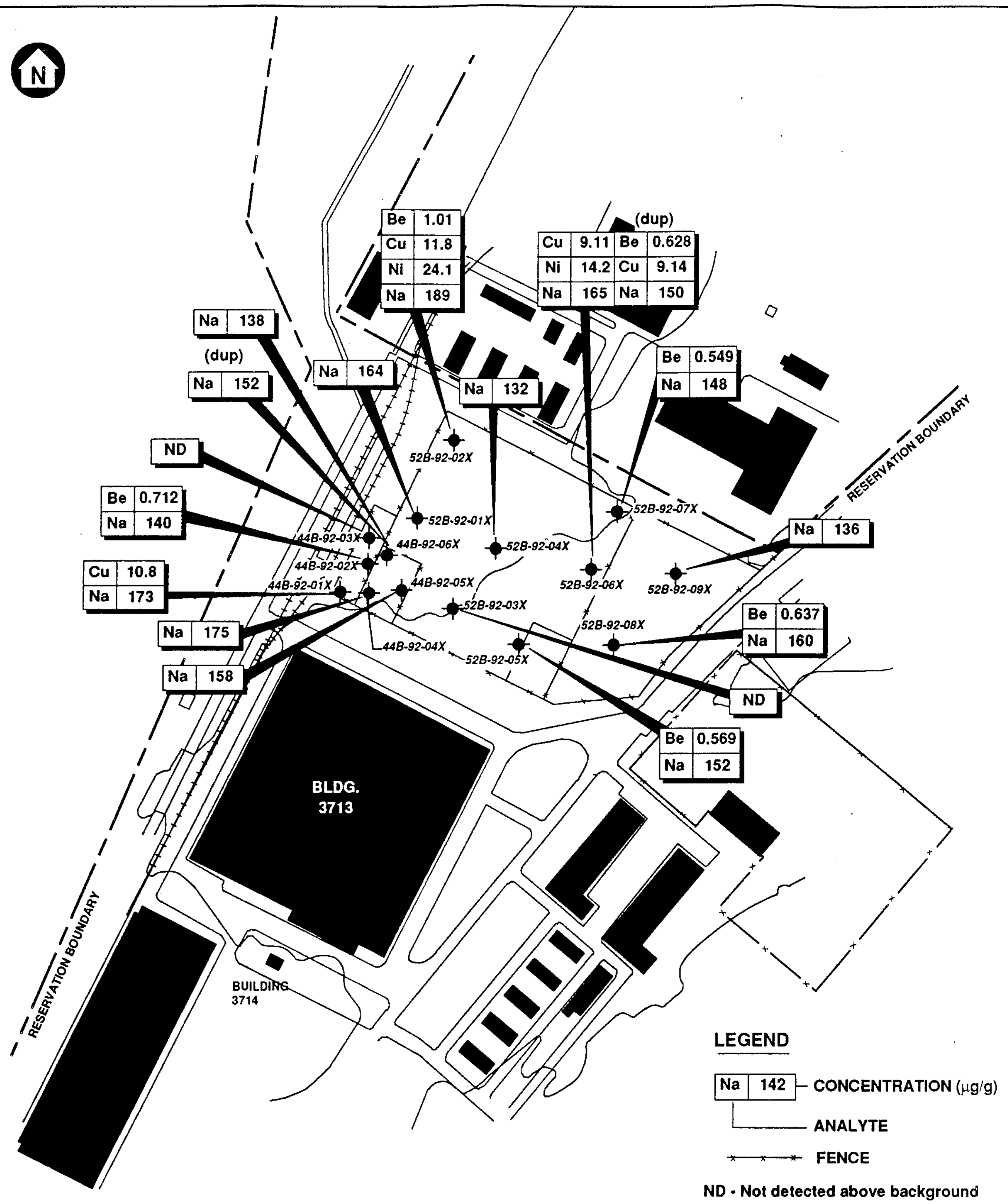


SCALE IN FEET

0 300 600

FIGURE 1-11
INORGANIC ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS
DEPTH = 0 to 2 FEET
AOCs 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.



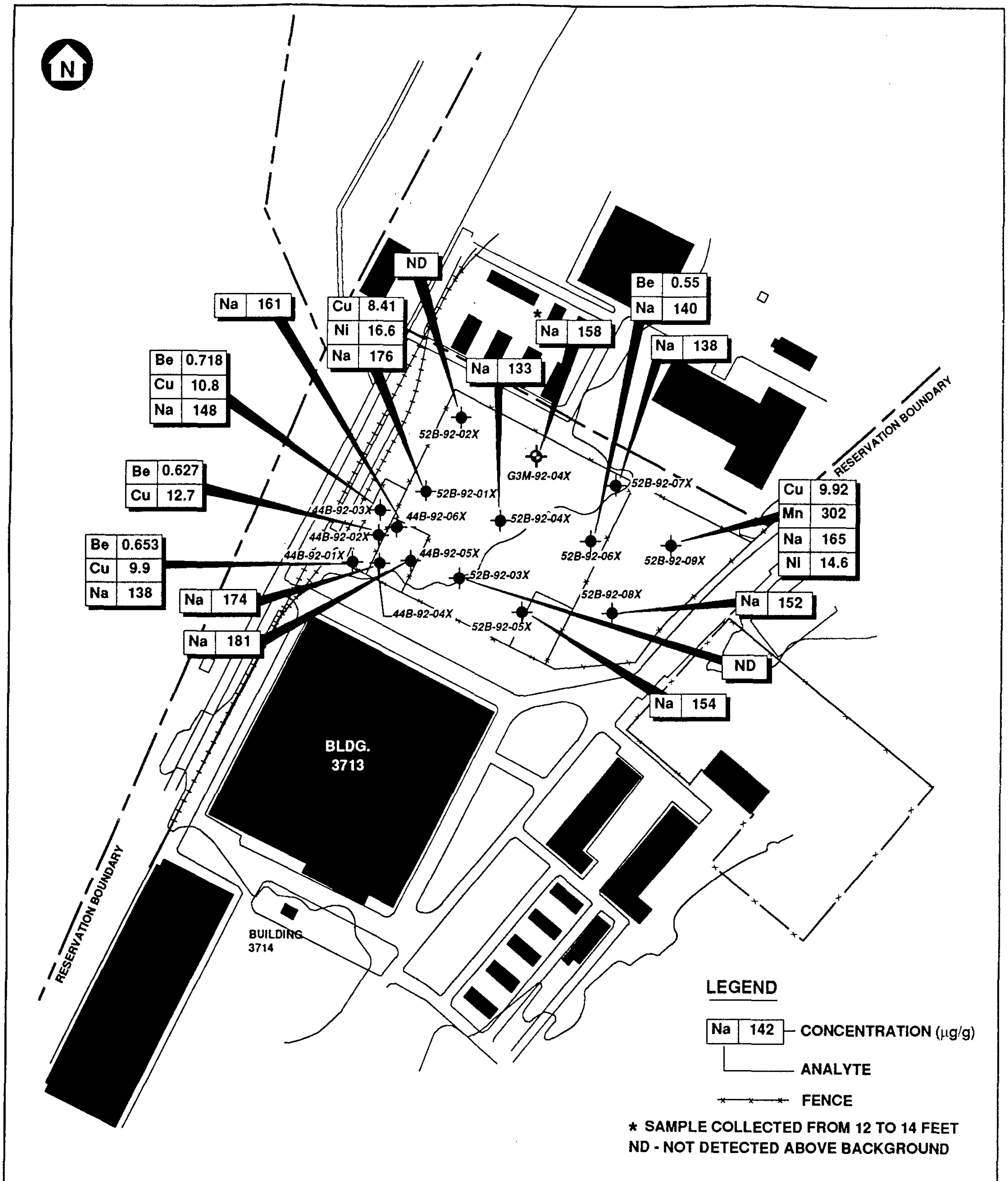
SCALE IN FEET

0 300 600

FIGURE 1-12
INORGANIC ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS
DEPTH = 5 to 7 FEET
AOCs 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.

6917-07(g) 7 C



LEGEND

Na | 142 — CONCENTRATION (µg/g)

ANALYTE

FENCE

* SAMPLE COLLECTED FROM 12 TO 14 FEET

ND - NOT DETECTED ABOVE BACKGROUND

SCALE IN FEET

0 300 600

FIGURE 1-13
INORGANIC ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS
DEPTH = 10 to 12 FEET
AOCs 44 & 52
FORT DEVENS, MA

ABB Environmental Services, Inc.

6917-07(g) 7 D

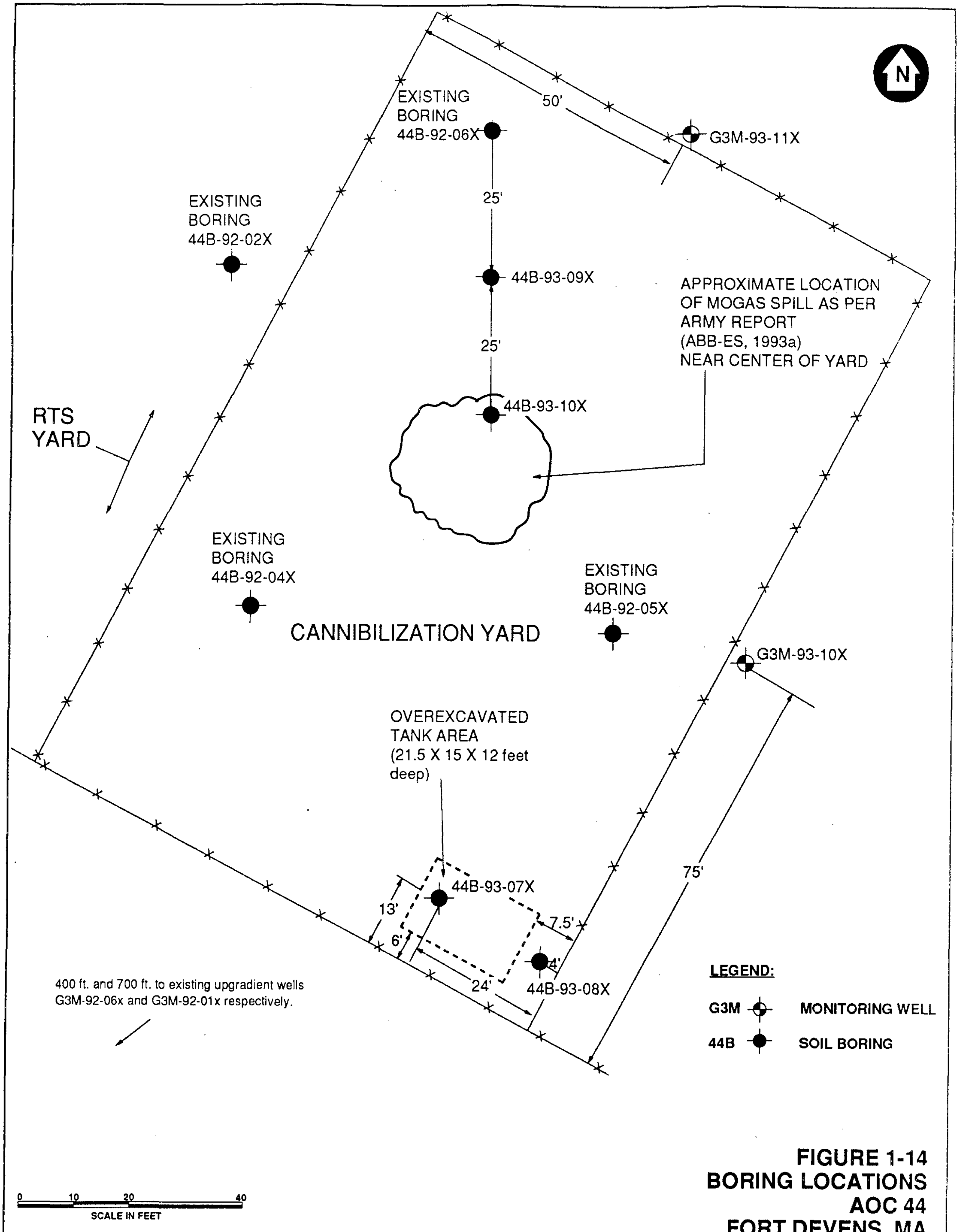


FIGURE 1-14
BORING LOCATIONS
AOC 44
FORT DEVENS, MA

6917-07 Z

ABB Environmental Services, Inc.

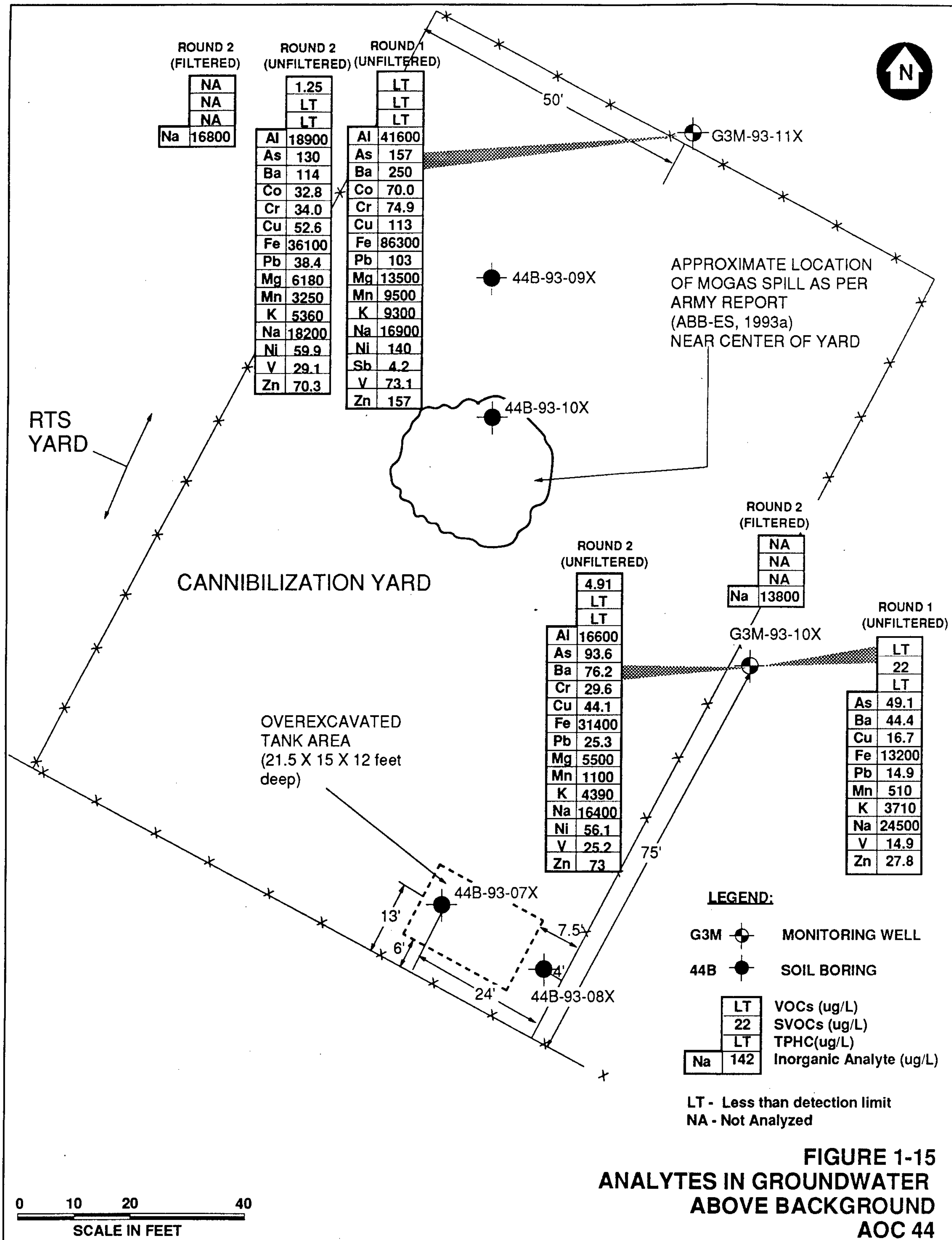


FIGURE 1-15
ANALYTES IN GROUNDWATER ABOVE BACKGROUND
AOC 44
FORT DEVENS, MA

ABB Environmental Services, Inc.

6917-07 Z

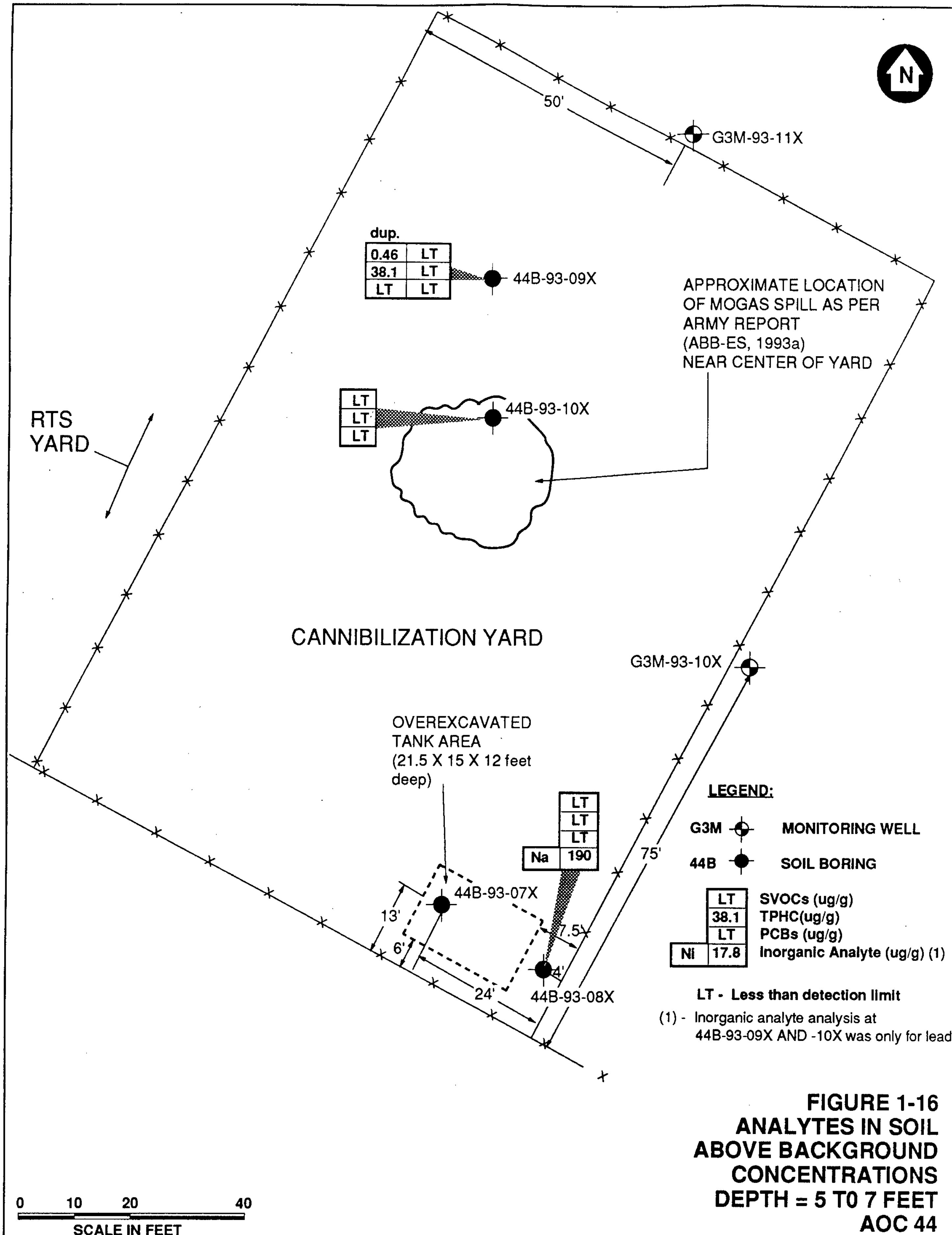


FIGURE 1-16
ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS DEPTH = 5 T0 7 FEET
AOC 44
FORT DEVENS, MA

6917-07 Z

ABB Environmental Services, Inc.

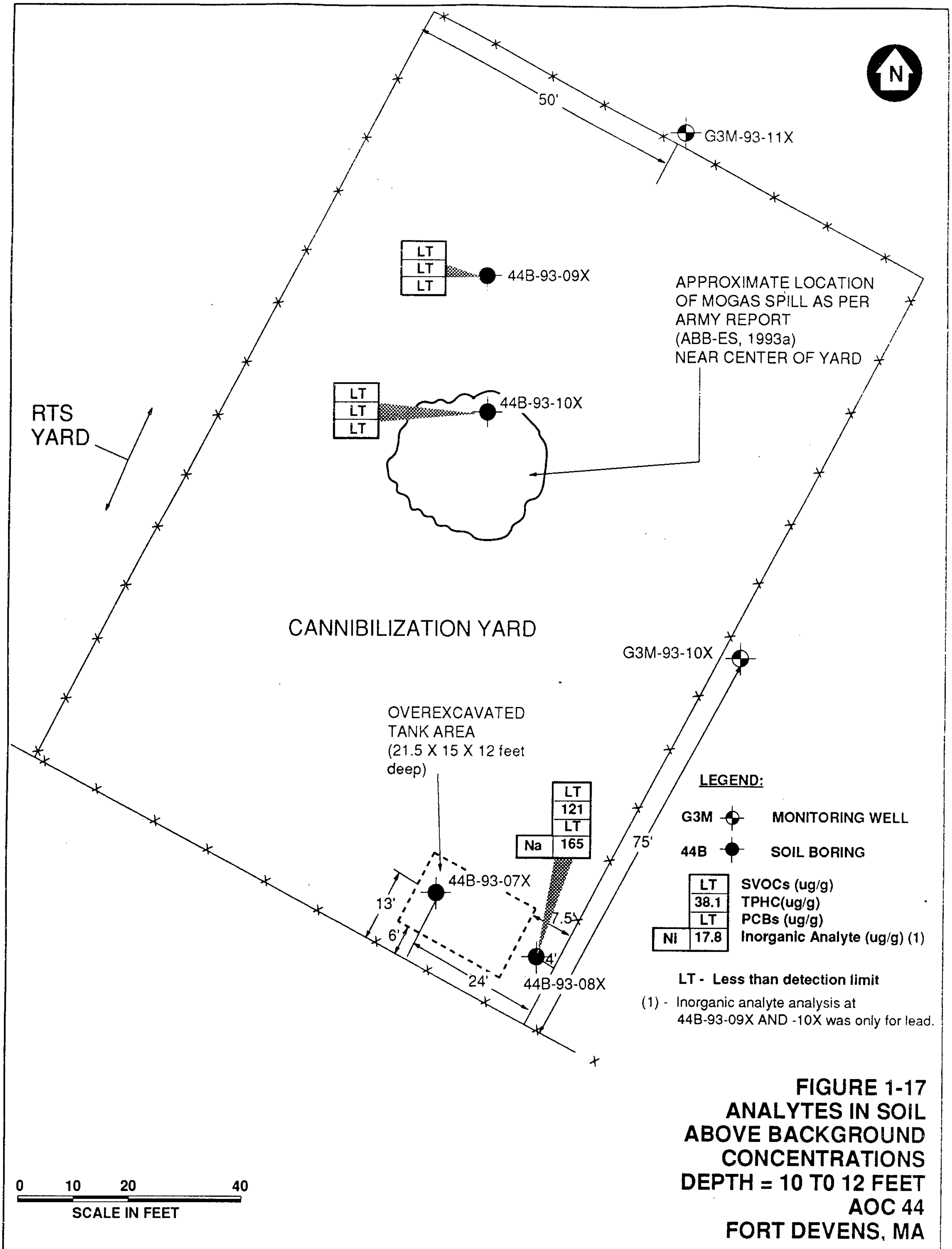


FIGURE 1-17
ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS
DEPTH = 10 T0 12 FEET
AOC 44
FORT DEVENS, MA

6917-07 Z

ABB Environmental Services, Inc.

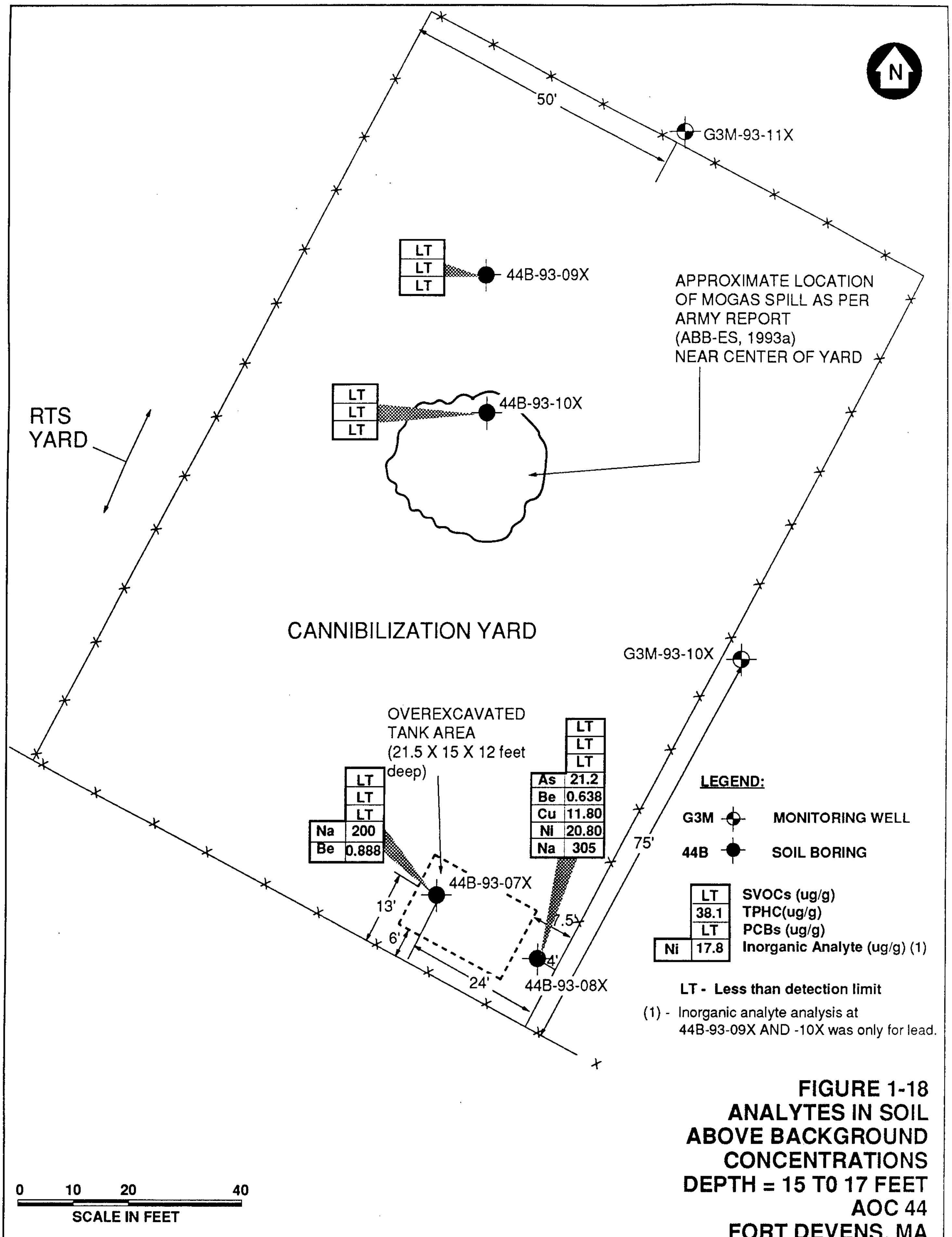


FIGURE 1-18
ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS
DEPTH = 15 T0 17 FEET
AOC 44
FORT DEVENS, MA

ABB Environmental Services, Inc.

6917-07 Z

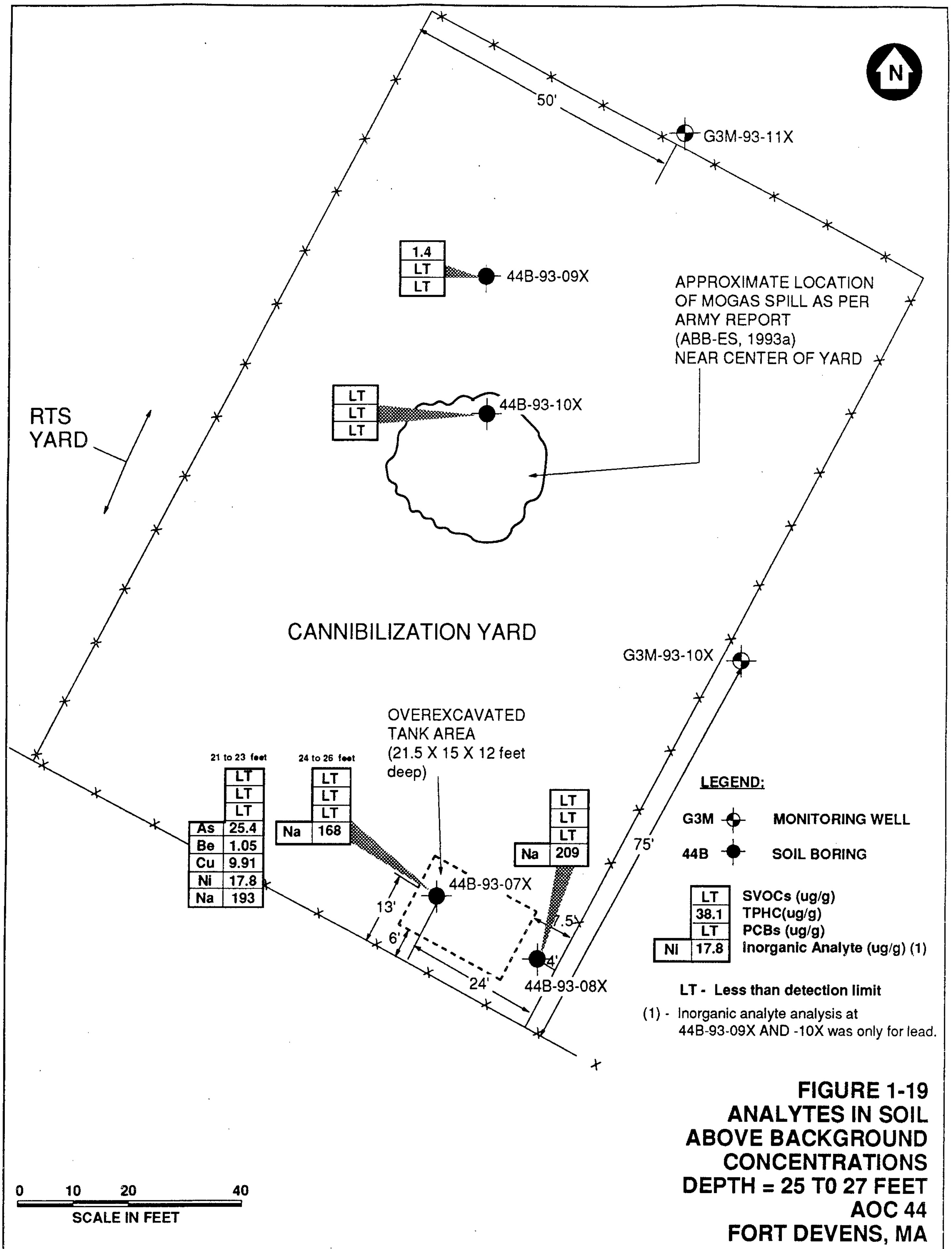


FIGURE 1-19
ANALYTES IN SOIL ABOVE BACKGROUND CONCENTRATIONS
DEPTH = 25 T0 27 FEET
AOC 44
FORT DEVENS, MA

ABB Environmental Services, Inc.

6917-07 Z

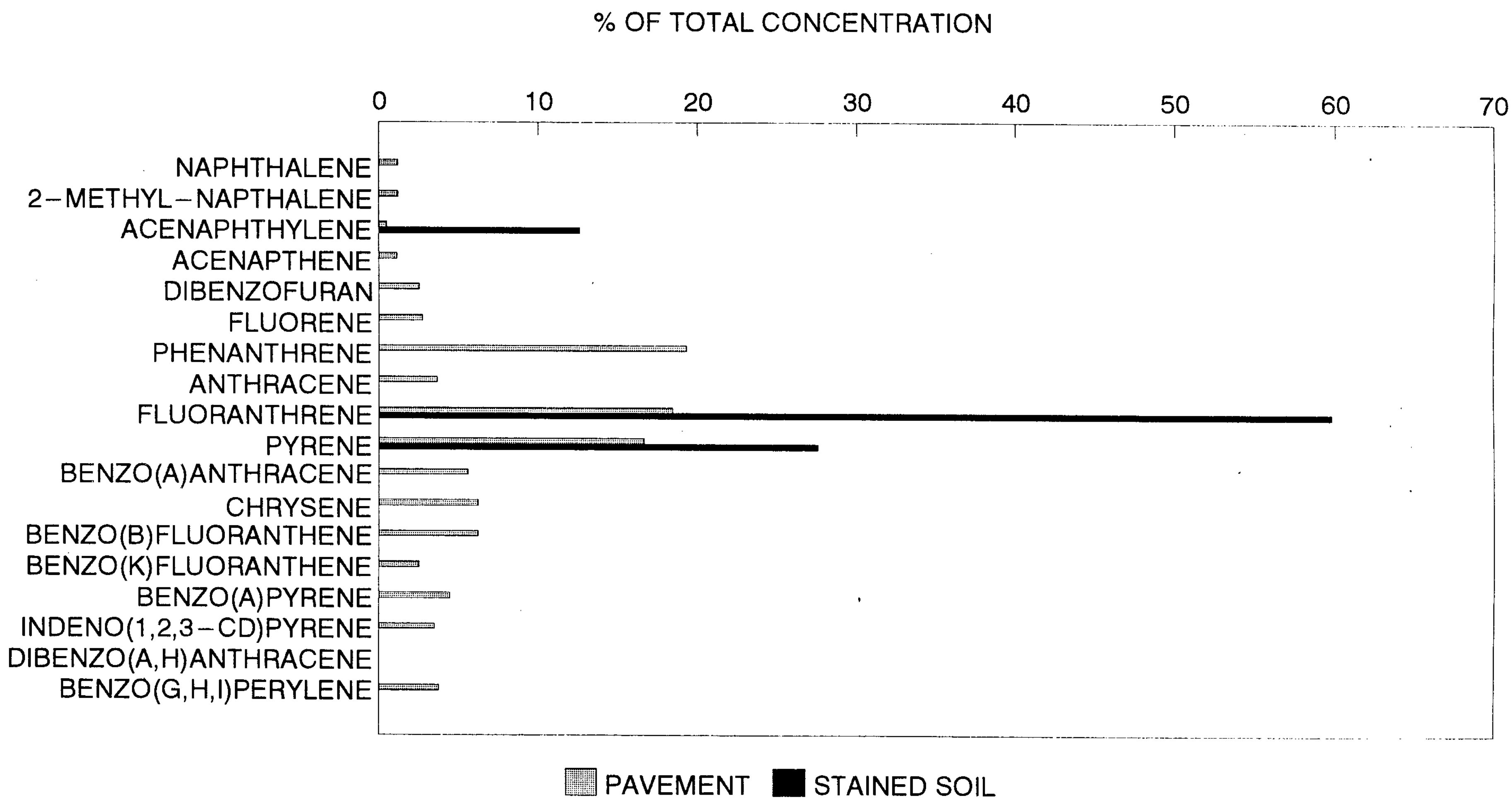


FIGURE 1-20
ANALYTICAL COMPARISON
PAVEMENT vs STAINED SOIL
AOCs 44 & 52
FORT DEVENS, MA

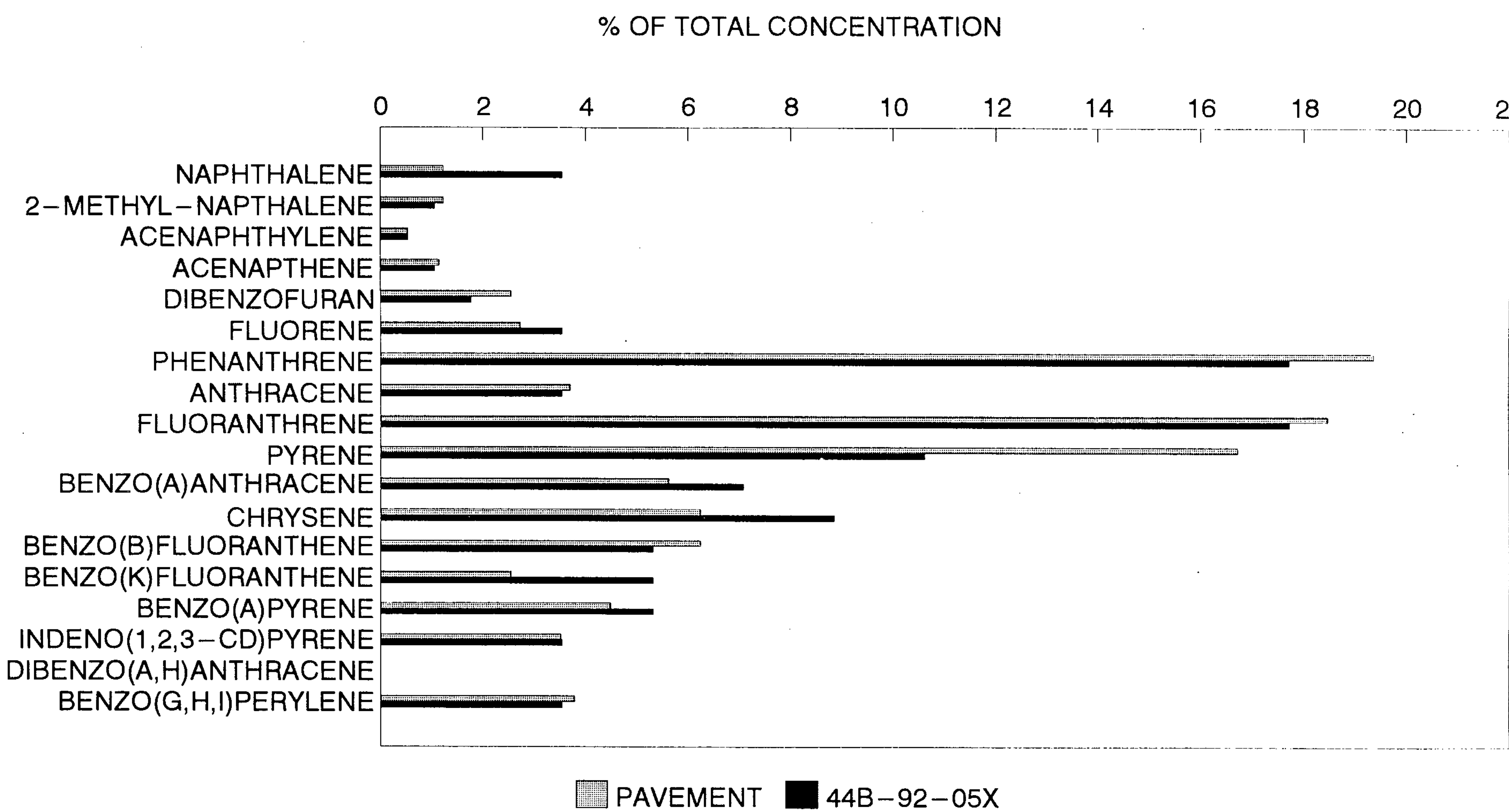


FIGURE 1-21
ANALYTICAL COMPARISON
PAVEMENT vs 44B-92-05X
AOCs 44 & 52
FORT DEVENS, MA

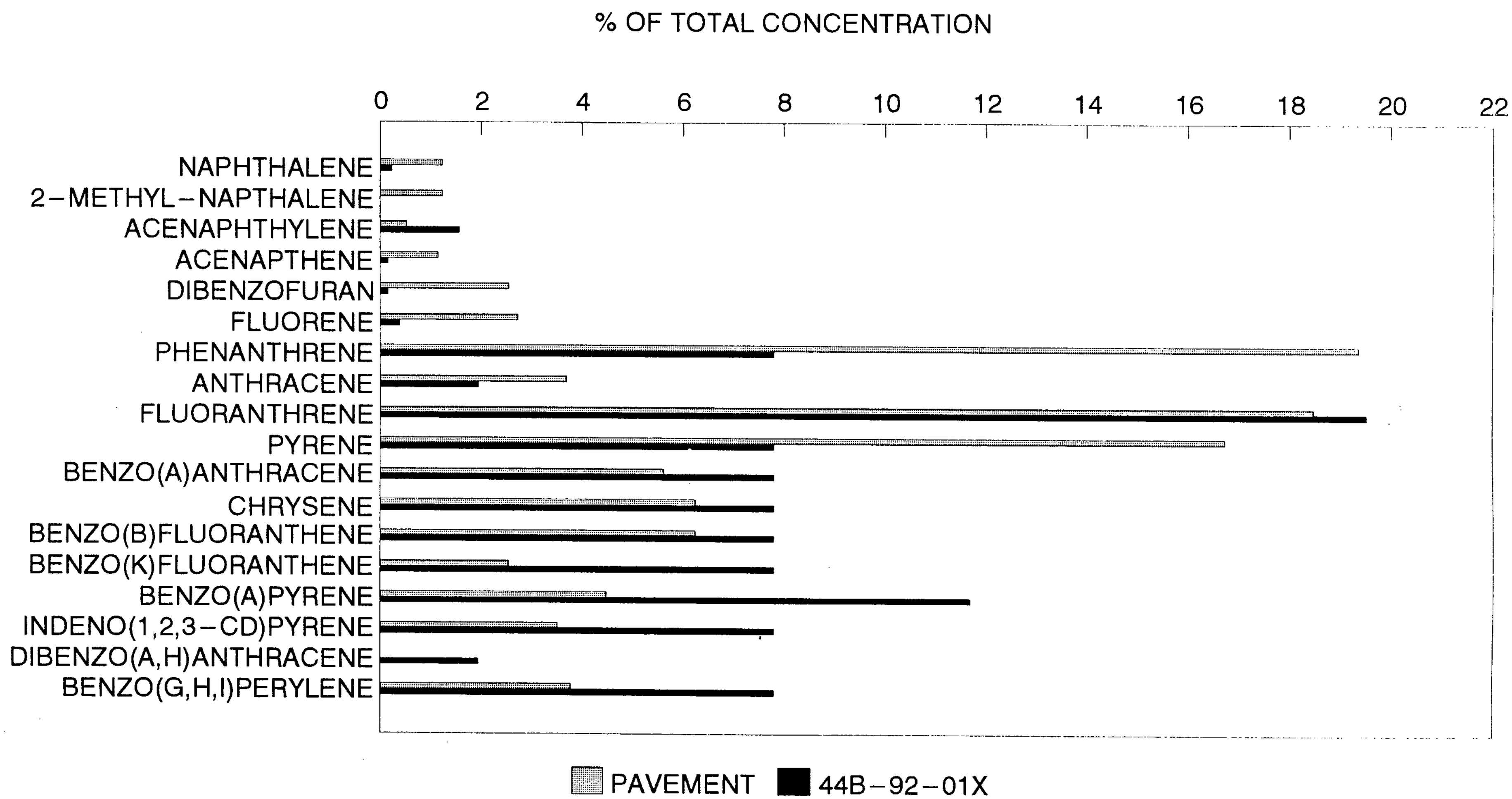


FIGURE 1-22
ANALYTICAL COMPARISON
PAVEMENT vs 44B-92-01X
AOCs 44 & 52
FORT DEVENS, MA

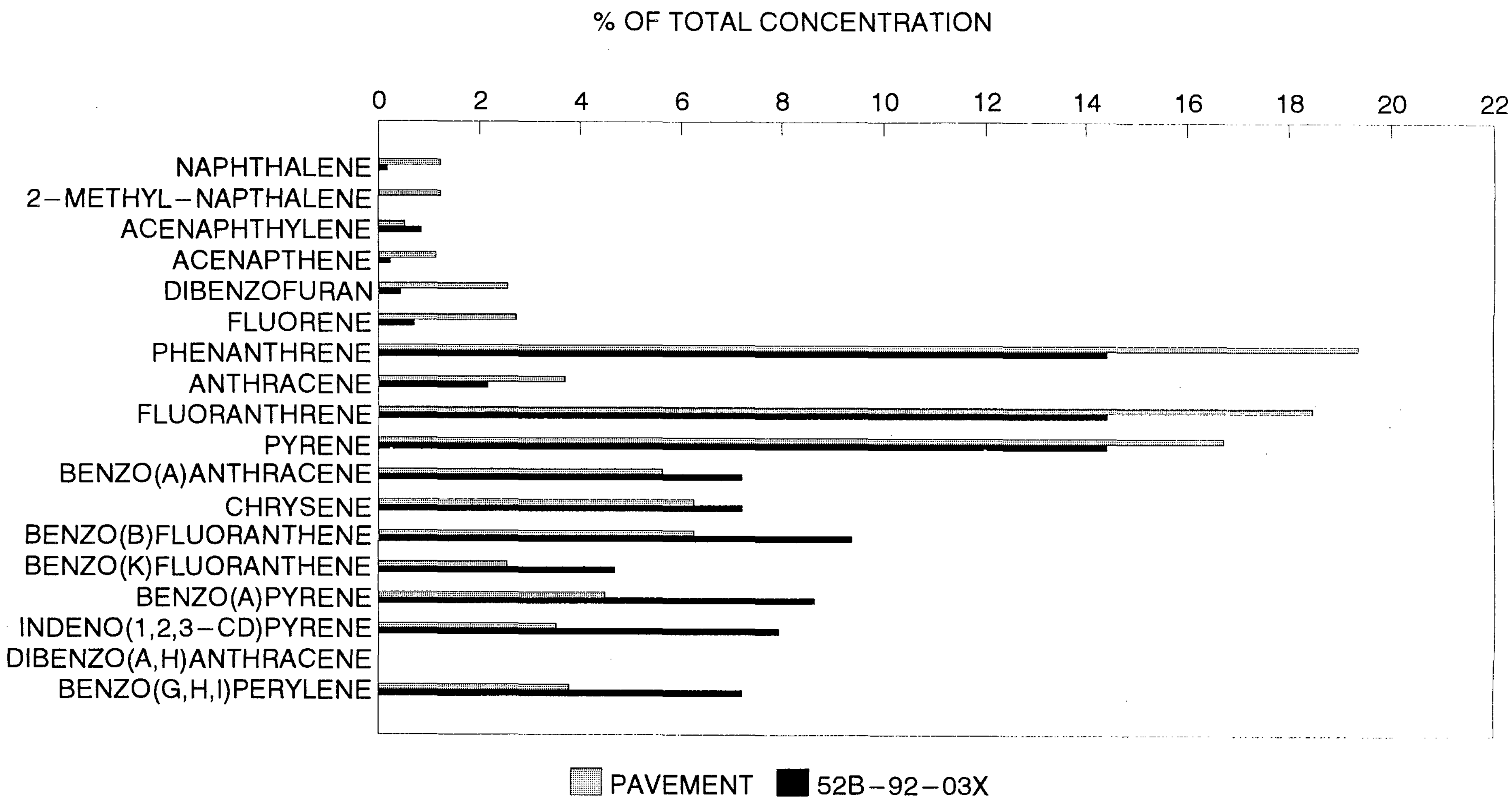


FIGURE 1-23
ANALYTICAL COMPARISON
PAVEMENT vs 52B-92-03X
AOCs 44 & 52
FORT DEVENS, MA

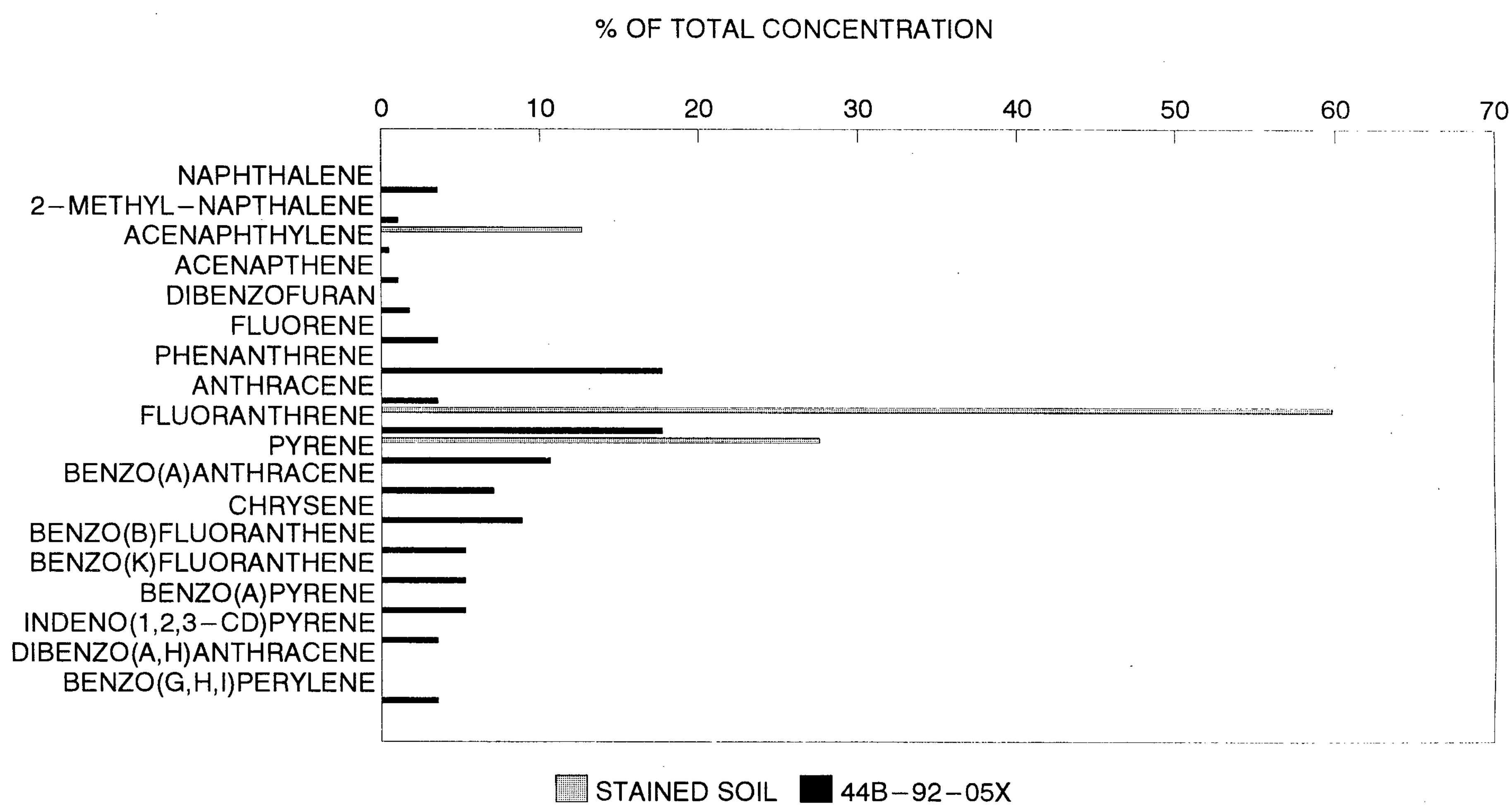


FIGURE 1-24
ANALYTICAL COMPARISON
STAINED SOIL vs 44B-92-05X
AOCs 44 & 52
FORT DEVENS, MA

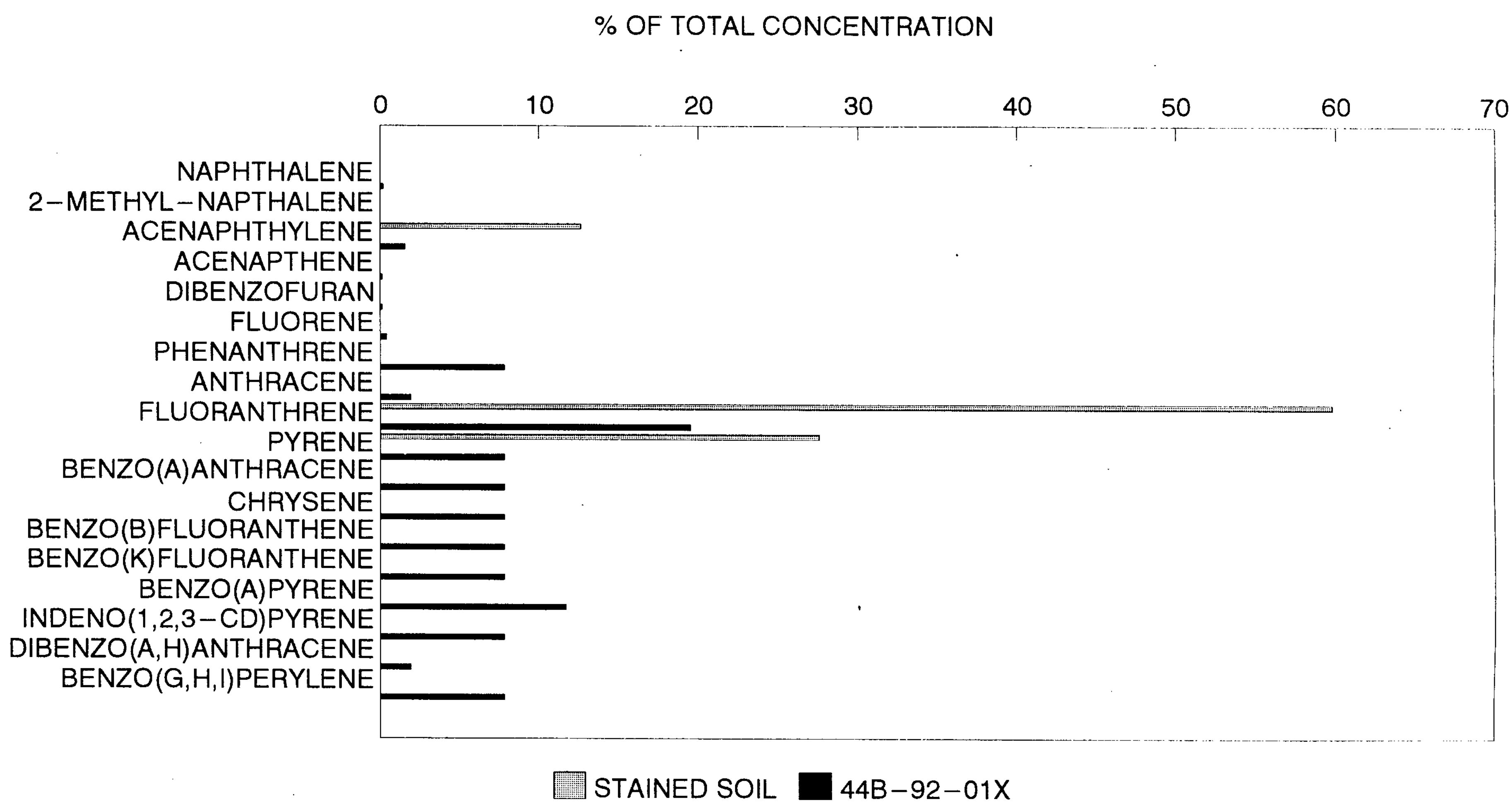


FIGURE 1-25
ANALYTICAL COMPARISON
STAINED SOIL vs 44B-92-01X
AOCs 44 & 52
FORT DEVENS, MA

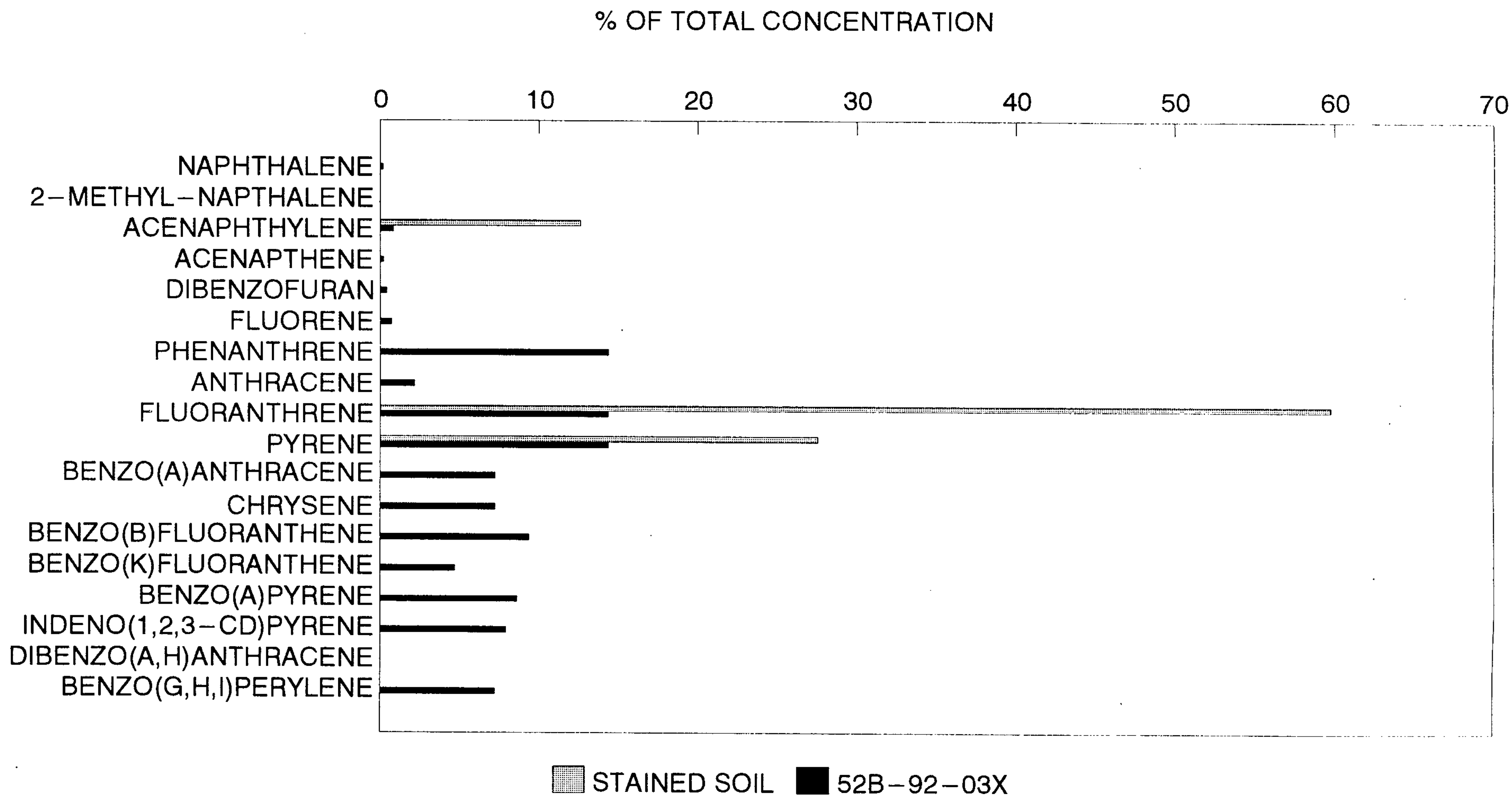


FIGURE 1-26
ANALYTICAL COMPARISON
STAINED SOIL vs 52B-92-03X
AOCs 44 & 52
FORT DEVENS, MA

TABLE 1-1
ORGANIC COMPOUNDS IN SOIL
AOC 44 – CANNIBALIZATION YARD

FEASIBILITY STUDY
FORT DEVENS

ANALYTE / BORING	44B-92-01X			44B-92-02X			44B-92-03X			44B-92-04X			44B-92-05X			44B-92-06X			
DEPTH	0	5	10	0	5	10	0	5	10	0	5	10	0	5	10	0	5	5D	10
VOLATILES (ug/g)																			
ETHYLBENZENE	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0080	0.500	<0.0017
TOLUENE	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< .00078	< 0.0040	0.050	< .00078
XYLENES	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.040	4.00	< 0.0015
SEMIVOLATILES (ug/g)																			
2-METHYLNAPHTHALENE	< 0.200	<0.100	< 0.049	< 0.049	< 0.049	< 0.049	< 0.049	< 0.049	< 0.049	< 1.00	< 0.049	< 0.200	6.00	< 0.049	< 0.049	0.700	30.0	30.0	3.00
ACENAPHTHENE	0.400	<0.070	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.700	< 0.036	< 0.200	6.00	< 0.036	< 0.036	< 0.400	< 0.400	< 0.400	< 0.200
ACENAPHTHYLENE	4.00	0.300	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.700	< 0.033	< 0.200	3.00	< 0.033	< 0.033	< 0.300	< 0.300	< 0.300	< 0.200
ANTHRACENE	5.00	0.700	< 0.036	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	1.00	< 0.033	< 0.200	20.0	< 0.033	< 0.033	< 0.300	< 0.300	< 0.300	< 0.200
BIS(2-ETHYLHEXYL)PHTHALAT	< 3.00	<1.00	< 0.620	< 0.620	< 0.620	< 0.620	< 0.620	< 0.620	< 0.620	< 10.0	< 0.620	< 3.00	< 30.0	< 0.620	1.10	< 6.00	< 6.00	< 6.00	< 3.00
BENZO[A]ANTHRACENE	20.0	2.00	< 0.170	< 0.170	< 0.170	< 0.170	< 0.170	< 0.170	< 0.170	< 3.00	< 0.170	< 0.800	40.0	< 0.170	< 0.170	< 2.00	< 2.00	< 2.00	< 0.800
BENZO[A]PYRENE	30.0	2.00	< 0.250	< 0.250	< 0.250	< 0.250	< 0.250	< 0.250	< 0.250	< 5.00	< 0.250	< 1.00	30.0	< 0.250	< 0.250	< 2.00	< 2.00	< 2.00	< 1.00
BENZO[B]FLUORANTHENE	20.0	3.00	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 4.00	< 0.210	<1.00	30.0	< 0.210	< 0.210	< 2.00	< 2.00	< 2.00	< 1.00
BENZO[G,H,I]PERYLENE	20.0	3.00	< 0.250	< 0.250	< 0.250	< 0.250	< 0.250	< 0.250	< 0.250	< 5.00	< 0.250	< 1.00	20.0	< 0.250	< 0.250	< 2.00	< 2.00	< 2.00	< 1.00
BENZO[K]FLUORANTHENE	20.0	2.00	0.110	< 0.066	< 0.066	< 0.066	0.170	< 0.066	< 0.066	4.00	< 0.066	< 0.300	30.0	< 0.066	< 0.066	< 0.700	< 0.700	< 0.700	< 0.300
CARBAZOLE	2.00	0.500	ND 0.033	ND 0.033	ND 0.033	ND 0.033	ND 0.033	ND 0.033	ND 0.033	ND 0.700	ND 0.033	ND 0.200	20.0	ND 0.033	ND 0.033	ND 0.033	ND 0.033	ND 0.300	ND 0.200
CHRYSENE	20.0	3.00	0.160	< 0.120	< 0.120	< 0.120	0.160	< 0.120	< 0.120	5.00	< 0.120	< 0.600	50.0	< 0.120	< 0.120	< 1.00	< 1.00	< 1.00	< 0.600
DIBENZO[A,H]ANTHRACENE	5.00	0.900	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 4.00	< 0.210	< 1.00	< 10.0	< 0.210	< 0.210	< 2.00	< 2.00	< 2.00	< 1.00
DIBENZOFURAN	0.400	0.200	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.700	< 0.035	<0.200	10.0	< 0.035	< 0.035	< 0.400	0.600	0.600	< 0.200
FLUORANTHENE	50.0	7.00	0.250	0.085	0.088	< 0.068	0.280	< 0.068	< 0.068	10.0	< 0.068	< 0.300	100	< 0.068	< 0.068	< 0.700	< 0.700	< 0.700	< 0.300
FLUORENE	1.00	0.300	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.700	< 0.033	< 0.200	20.0	< 0.033	< 0.033	< 0.300	1.00	1.00	0.300
INDENO[1,2,3-C,D]PYRENE	20.0	3.00	< 0.290	< 0.290	< 0.290	< 0.290	< 0.290	< 0.290	< 0.290	< 6.00	< 0.290	< 1.00	20.0	< 0.290	< 0.290	< 3.00	< 3.00	< 3.00	< 1.00
NAPHTHALENE	0.600	<0.070	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.700	< 0.037	< 0.200	20.0	< 0.037	< 0.037	< 0.400	6.00	6.00	0.300
PHENANTHRENE	20.0	3.00	< 0.033	< 0.033	< 0.033	< 0.033	0.078	< 0.033	< 0.033	4.00	< 0.033	< 0.200	100	< 0.033	< 0.033	< 0.300	0.900	0.600	0.200
PYRENE	20.0	3.00	0.190	0.049	0.089	< 0.033	0.220	< 0.033	< 0.033	7.00	< 0.033	< 0.200	60.0	< 0.033	< 0.033	< 0.300	< 0.300	< 0.300	< 0.200
OTHER (ug/g)																			
TRICHLOROFLUOROMETHANE	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	< 0.0300	< 0.0059
TPHC	714	76.2	< 27.9	< 27.9	< 27.9	< 27.9	34.7	< 27.7	40.3	465	< 27.7	33.8	1210	<28.1	<27.7	8520	7680	7310	1560

NOTES: TABLE LISTS DETECTED ANALYTES ONLY – SEE PROJECT ANALYTE LIST IN SI REPORT FOR SUMMARY
ND = NOT DETECTED

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TABLE 1-2
ORGANIC COMPOUNDS IN SOIL
AOC 52 - TDA MAINTENANCE YARD

FEASIBILITY STUDY
FORT DEVENS

ANALYTE BORING	52B-92-01X			52B-92-02X			52B-92-03X			52B-92-04X				52B-92-05X		
DEPTH	0	5	10	0	5	10	0	5	10	0	0D	5	10	0	5	10
VOLATILES (ug/g)																
ETHYLBENZENE	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170
TOLUENE	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078
XYLENES	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150
SEMIVOLATILES (ug/g)																
ACENAPHTHENE	<0.900	< 0.036	< 0.036	< 0.900	< 0.900	< 0.180	0.315	< 0.200	< 0.036	< 0.072	< 0.900	< 0.036	< 0.036	< 0.070	< 0.072	< 0.072
ACENAPHTHYLENE	<0.825	< 0.033	< 0.033	< 0.825	< 0.825	< 0.165	1.18	< 0.200	< 0.033	0.193	< 0.825	< 0.033	< 0.033	0.500	0.142	0.090
ANTHRACENE	<0.825	< 0.033	< 0.033	< 0.825	< 0.825	< 0.165	2.99	< 0.200	< 0.033	0.171	< 0.825	< 0.033	< 0.033	0.500	0.143	0.100
BIS(2-ETHYLHEXYL)PHTHALATE	<15.5	< 0.620	< 0.620	< 15.5	< 15.5	< 3.10	< 3.10	< 3.00	< 0.620	< 1.24	< 15.5	< 0.620	< 0.620	< 1.00	< 1.24	< 1.24
BENZO[A]ANTHRACENE	<4.25	< 0.170	< 0.170	< 4.25	< 4.25	< 0.800	10.0	< 0.800	< 0.170	0.803	< 4.25	< 0.170	< 0.170	1.00	0.392	< 0.340
BENZO[A]PYRENE	< 6.25	< 0.250	< 0.250	< 6.25	< 6.25	< 1.25	12.4	< 1.00	< 0.250	1.01	< 6.25	< 0.250	< 0.250	2.00	0.743	< 0.500
BENZO[B]FLUORANTHENE	< 5.25	< 0.210	< 0.210	< 5.25	< 5.25	< 1.05	13.3	< 1.00	< 0.210	1.63	< 5.25	< 0.210	< 0.210	3.00	1.06	0.527
BENZO[G,H,I]PERYLENE	< 6.25	< 0.250	< 0.250	< 6.25	< 6.25	< 1.25	10.2	< 1.00	< 0.250	1.04	< 6.25	< 0.250	< 0.250	1.00	0.611	< 0.500
BENZO[K]FLUORANTHENE	< 1.65	0.085	< 0.066	< 1.65	< 1.65	< 0.330	6.48	0.500	< 0.066	0.883	< 1.65	< 0.066	0.087	1.00	0.647	0.430
CARBAZOLE	ND 0.825	ND 0.033	ND 0.033	ND 0.825	ND 0.825	ND 0.165	2.00	ND 0.200	ND 0.033	0.106	ND 0.825	ND 0.033	ND 0.033	0.500	0.104	ND 0.066
CHRYSENE	< 3.00	0.191	< 0.120	< 3.00	< 3.00	< 0.600	10.0	< 0.600	< 0.120	1.04	< 3.00	< 0.120	< 0.120	2.00	0.764	0.507
DIBENZO[A,H]ANTHRACENE	< 5.25	< 0.210	< 0.210	< 5.25	< 5.25	< 1.05	< 1.00	< 1.00	< 0.210	< 0.420	< 5.25	< 0.210	< 0.210	0.600	< 0.420	< 0.420
DIBENZOFURAN	< 0.875	< 0.035	< 0.035	< 0.875	< 0.875	< 0.175	0.600	< 0.200	< 0.035	< 0.070	< 0.875	< 0.035	< 0.035	< 0.070	< 0.070	< 0.070
FLUORANTHENE	< 1.70	0.288	< 0.068	< 1.70	< 1.70	< 0.340	20.0	1.00	0.200	2.22	< 1.70	< 0.068	0.230	4.85	1.69	1.20
FLUORENE	< 0.825	< 0.033	< 0.033	< 0.825	< 0.825	< 0.165	1.00	< 0.200	< 0.033	< 0.066	< 0.825	< 0.033	< 0.033	0.100	< 0.066	< 0.066
INDENO[1,2,3-C,D]PYRENE	< 7.25	< 0.290	< 0.290	< 7.25	< 7.25	< 1.45	11.0	< 1.00	< 0.290	1.57	< 7.25	< 0.290	< 0.290	2.21	0.658	< 0.580
NAPHTHALENE	< 0.900	< 0.037	< 0.037	< 0.900	< 0.900	< 0.185	0.243	< 0.200	< 0.037	< 0.074	< 0.900	< 0.037	< 0.037	< 0.074	< 0.074	< 0.074
PHENANTHRENE	< 0.825	0.092	< 0.033	< 0.825	< 0.825	< 0.165	20.0	0.500	0.074	0.659	< 0.825	< 0.033	0.076	1.51	0.429	0.400
PYRENE	2.18	0.282	< 0.033	< 0.825	< 0.825	< 0.165	20.0	1.00	0.109	1.51	< 0.825	< 0.033	0.150	2.48	1.00	0.700
OTHER (ug/g)																
TOTAL ORGANIC CARBON	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPHC	142	65.1	51.5	304	129	60.8	98.0	30.2	29.8	79.8	80.4	39.9	<27.7	647	170	119

NOTES: TABLE LISTS DETECTED ANALYTES ONLY - SEE PROJECT ANALYTE LIST IN SI REPORT FOR SUMMARY
ND = NOT DETECTED
NA = NOT ANALYZED

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TABLE 1–2 (continued)
ORGANIC COMPOUNDS IN SOIL
AOC 52 – TDA MAINTENANCE YARD

FEASIBILITY STUDY
FORT DEVENS

ANALYTE	BORING	52B–92–06X				52B–92–07X			52B–92–08X			52B–92–09X			G3M–92–04X		
	DEPTH	0	5	5D	10	0	5	10	0	5	10	0	5	10	0	12	26
VOLATILES (ug/g)																	
ETHYLBENZENE		< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	< 0.00170	0.0049	< 0.00170	< 0.00170
TOLUENE		< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	0.00086	< 0.00078	< 0.00078	< 0.00078	< 0.00078	< 0.00078	0.0023	< 0.00078	< 0.00078
XYLENES		< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	< 0.00150	0.00510	<0.00510	< 0.00150	< 0.00150	< 0.00150	< 0.00150	0.0220	< 0.00150	< 0.00150
SEMIVOLATILES (ug/g)																	
ACENAPHTHENE		< 0.072	< 0.072	< 0.180	< 0.036	< 0.036	< 0.070	< 0.072	< 0.900	< 0.180	< 0.180	< 0.072	< 0.036	< 0.036	< 0.900	< 0.036	< 0.036
ACENAPHTHYLENE		0.168	< 0.066	< 0.165	< 0.033	0.144	< 0.070	< 0.066	< 0.825	< 0.165	< 0.165	0.469	< 0.033	< 0.033	< 0.825	< 0.033	< 0.033
ANTHRACENE		0.122	0.143	< 0.165	< 0.033	0.121	< 0.070	< 0.066	< 0.825	< 0.165	< 0.165	0.475	< 0.033	< 0.033	< 0.825	< 0.033	< 0.033
BIS(2–ETHYLHEXYL)PHTHALATE		< 1.24	< 1.24	< 3.10	< 0.620	< 0.620	< 1.00	< 1.24	< 15.5	< 3.10	< 3.10	< 1.24	0.974	< 0.620	< 15.5	< 0.620	< 0.620
BENZO[A]ANTHRACENE		0.399	0.391	< 0.800	< 0.170	0.239	< 0.300	< 0.340	< 4.25	< 0.800	< 0.800	0.780	< 0.170	< 0.170	4.95	< 0.170	< 0.170
BENZO[A]PYRENE		< 0.500	< 0.500	< 1.25	< 0.250	0.376	< 0.500	< 0.500	< 6.25	< 1.25	< 1.25	1.00	< 0.250	< 0.250	< 6.25	< 0.250	< 0.250
BENZO[B]FLUORANTHENE		1.08	< 0.420	< 1.05	< 0.210	0.980	0.800	< 0.420	< 5.25	2.04	< 1.05	1.32	< 0.210	< 0.210	10.0	< 0.210	< 0.210
BENZO[G,H,I]PERYLENE		0.622	< 0.500	< 1.25	< 0.250	0.682	< 0.500	< 0.500	< 6.25	< 1.25	< 1.25	1.01	< 0.250	< 0.250	< 6.25	< 0.250	< 0.250
BENZO[K]FLUORANTHENE		0.439	0.430	< 0.330	< 0.066	0.339	0.200	< 0.132	< 1.65	0.499	< 0.330	0.643	0.076	< 0.066	2.18	< 0.066	< 0.066
CARBAZOLE		ND 0.066	ND 0.066	ND 0.165	ND 0.033	0.063	ND 0.070	ND 0.066	ND 0.825	ND 0.165	ND 0.165	0.083	ND 0.033	ND 0.033	ND 0.825	ND 0.033	ND 0.033
CHRYSENE		0.777	0.761	< 0.600	< 0.120	0.581	0.500	< 0.240	3.41	1.31	1.29	1.52	< 0.120	< 0.120	10.0	< 0.120	< 0.120
DIBENZO[A,H]ANTHRACENE		< 0.420	< 0.420	< 1.05	< 0.210	< 0.210	< 0.420	< 0.420	< 5.25	< 1.05	< 1.05	< 0.420	< 0.210	< 0.210	< 5.25	< 0.210	< 0.210
DIBENZOFURAN		< 0.070	< 0.070	< 0.175	< 0.035	< 0.035	< 0.070	< 0.070	< 0.875	< 0.175	< 0.175	< 0.070	< 0.035	< 0.035	< 0.875	< 0.035	< 0.035
FLUORANTHENE		1.71	1.92	< 0.340	< 0.068	0.965	0.720	0.217	6.45	2.48	1.22	2.39	0.109	< 0.068	15.2	< 0.068	< 0.068
FLUORENE		< 0.066	< 0.066	< 0.165	< 0.033	< 0.033	< 0.066	< 0.066	< 0.825	< 0.165	< 0.165	0.169	< 0.033	< 0.033	< 0.825	< 0.033	< 0.033
INDENO[1,2,3–C,D]PYRENE		0.669	< 0.580	< 1.45	< 0.290	0.911	< 0.580	< 0.580	< 7.25	< 1.45	< 1.45	1.31	< 0.290	< 0.290	< 7.25	< 0.290	< 0.290
NAPHTHALENE		< 0.074	< 0.074	< 0.185	< 0.037	< 0.037	< 0.070	< 0.074	< 0.900	< 0.185	< 0.185	< 0.074	< 0.037	< 0.037	< 0.900	< 0.037	< 0.037
PHENANTHRENE		0.400	1.28	< 0.165	< 0.033	0.228	0.200	< 0.066	2.87	1.10	0.545	1.49	< 0.033	< 0.033	10.8	< 0.033	< 0.033
PYRENE		1.00	1.00	< 0.165	0.049	0.736	0.500	0.148	6.59	2.53	1.87	2.20	0.086	< 0.033	21.7	< 0.033	< 0.033
OTHER (ug/g)																	
TOTAL ORGANIC CARBON		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	283
TPHC		131	58.3	48.5	39.1	89.1	97.5	30.2	73.1	34.5	< 28.1	33.4	33.7	33.4	716	51.5	61.1

NOTES: TABLE LISTS DETECTED ANALYTES ONLY – SEE PROJECT ANALYTE LIST IN SI REPORT FOR SUMMARY
ND = NOT DETECTED
NA = NOT ANALYZED

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TABLE 1-3
INORGANIC ANALYTES IN SOIL
AOC 44 – CANNIBALIZATION YARD

FEASIBILITY STUDY
FORT DEVENS

ANALYTE (ug/g)	BACK-GROUND	BORING DEPTH	44B-92-01X			44B-92-02X			44B-92-03X			44B-92-04X			44B-92-05X			44B-92-06X			
			0	5	10	0	5	10	0	5	10	0	5	10	0	5	10	0	5	5D	10
ALUMINUM	15000		7030	5270	3940	7070	3940	3090	9550	4240	3840	7270	3920	3630	9470	4000	2890	15800	5040	4820	3720
ANTIMONY	NA		< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	1.96	< 1.09	< 1.09	< 1.09
ARSENIC	21		7.34	14.2	16.0	7.42	9.76	8.88	10.6	9.51	8.54	15.0	10.8	15.0	16.0	9.33	12.0	30.0	11.5	10.3	9.51
BARIUM	42.5		48.1	18.1	18.4	15.0	13.9	14.6	34.6	13.2	17.5	31.2	16.0	16.0	30.7	18.1	12.9	79.0	14.7	15.9	18.4
BERYLLIUM	0.347		0.92	< 0.500	0.653	0.740	0.712	0.627	1.15	< 0.500	0.718	0.851	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	0.786	< 0.500	< 0.500	< 0.500
CADMIUM	2.00		2.14	<0.700	<0.700	<0.700	<0.700	<0.700	<0.700	<0.700	<0.700	2.59	<0.700	<0.700	8.85	<0.700	<0.700	1.03	<0.700	<0.700	<0.700
CALCIUM	1400		922	307	334	140	141	304	404	130	378	724	546	342	1260	322	262	1690	214	249	362
CHROMIUM	31		37.2	13.3	12.2	8.20	9.15	8.90	22.2	7.47	12.3	33.0	7.72	8.73	28.6	10.3	5.92	63.9	10.1	10.6	9.06
COBALT	NA		5.26	4.68	3.97	2.15	3.12	3.27	5.44	2.09	3.46	5.17	3.36	2.79	6.58	3.69	2.50	9.82	2.70	3.33	3.20
COPPER	8.39		20.6	10.8	9.90	4.43	8.04	12.7	9.56	5.00	10.8	11.9	8.07	5.19	12.8	7.29	5.33	17.1	6.62	6.72	6.81
IRON	15000		11100	8830	7400	6400	6560	6290	11100	5240	6170	11800	7340	6410	14800	7340	6000	19900	8400	7560	6530
LEAD	34.4		53.0	15.2	4.96	4.44	7.45	3.23	6.87	3.70	3.81	73.0	3.73	6.41	21.0	4.21	3.09	22.0	5.12	4.40	3.83
MAGNESIUM	5600		3600	2010	1990	1030	1560	1460	3100	1100	1630	4240	1490	1510	5020	1860	1200	9670	1890	1840	1650
MANGANESE	300		181	173	162	57.3	106	147	187	68.3	159	211	140	114	247	142	129	423	148	118	138
NICKEL	14.0		21.5	13.4	11.4	7.91	9.40	10.5	21.8	7.02	11.7	25.5	10.9	9.16	26.1	10.5	7.59	44.6	9.52	9.93	10.8
POTASSIUM	1700		1480	551	1000	274	420	526	1260	346	779	1040	356	510	1130	424	319	4400	395	338	600
SODIUM	131		157	173	138	151	140	117	167	< 100	148	186	175	174	206	158	181	245	138	152	161
VANADIUM	28.7		19.3	8.39	8.56	7.42	6.54	5.40	15.5	5.83	6.88	15.1	5.24	5.84	18.0	6.34	4.07	37.6	6.75	7.64	6.66
ZINC	35.5		92.9	32.0	21.3	16.0	19.1	21.8	24.6	12.8	21.3	48.8	18.9	22.2	53.4	20.0	17.0	56.9	18.8	18.3	21.6

NOTES: TABLE LISTS DETECTED ANALYTES ONLY – SEE PROJECT ANALYTE LIST IN SI REPORT FOR SUMMARY
NA = NOT ANALYZED

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TABLE 1-4
INORGANIC ANALYTES IN SOIL
AOC 52 – TDA MAINTENANCE YARD

FEASIBILITY STUDY
FORT DEVENS

ANALYTE	BACK-	BORING	52B-92-01X			52B-92-02X			52B-92-03X			52B-92-04X				52B-92-05X		
(ug/g)	GROUND	DEPTH	0	5	10	0	5	10	0	5	10	0	0D	5	10	0	5	10
ALUMINUM	15000		14700	5070	5120	10200	8150	4540	11500	3130	2930	10400	11500	2870	4080	8210	4360	4300
ARSENIC	21		29.0	9.54	10.6	17.0	18.0	10.6	20.0	8.82	10.9	19.0	20.0	12.0	9.88	14.0	10.5	10.5
BARIUM	42.5		95.3	16.5	37.4	38.4	36.4	20.2	64.4	15.2	17.4	47.2	49.8	9.35	14.0	24.3	16.5	18.7
BERYLLIUM	0.347		0.879	< 0.500	< 0.500	0.92	1.01	< 0.500	0.821	< 0.500	< 0.500	0.638	0.795	< 0.500	< 0.500	1.06	0.569	< 0.500
CADMIUM	2.00		< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	1.23	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700
CALCIUM	1400		1690	689	583	659	727	557	871	220	312	603	659	396	237	594	282	483
CHROMIUM	31		58.7	13.1	25.5	32.6	30.1	15.7	46.2	9.20	8.68	36.3	42.0	<4.05	9.51	18.9	12.1	14.8
COBALT	NA		9.18	3.01	4.24	6.73	6.05	4.19	10.7	3.24	3.54	7.19	8.03	1.78	3.18	4.56	3.95	3.78
COPPER	8.39		16.4	6.72	8.41	10.6	11.8	6.76	18.7	6.54	8.24	10.3	12.0	4.53	6.72	10.8	7.78	8.13
IRON	15000		18900	7700	8880	13000	12300	7810	16300	5470	5670	12300	14400	3990	6500	11000	7030	6840
LEAD	34.4		13.0	4.00	8.38	10.4	6.45	3.67	16.0	3.35	3.68	8.84	9.18	2.65	3.63	20.0	19.0	8.36
MAGNESIUM	5600		9210	2210	2890	5440	4480	2360	7590	1420	1450	5040	6010	696	1740	3140	1710	2040
MANGANESE	300		313	128	203	273	260	163	268	137	234	202	220	48.5	118	172	142	134
NICKEL	14.0		41.8	11.6	16.6	28.0	24.1	13.1	36.5	9.77	10.6	28.6	35.0	4.76	10.5	18.5	12.4	12.0
POTASSIUM	1700		4820	619	1670	1830	1530	964	4000	564	690	2370	2820	229	528	878	530	1030
SODIUM	131		316	164	176	189	189	<100	166	<100	115	154	178	132	133	154	152	154
VANADIUM	28.7		34.9	7.61	10.8	20.3	18.0	8.74	32.3	5.86	6.07	21.2	25.3	<3.39	6.40	14.0	7.31	9.34
ZINC	35.5		46.4	18.8	25.5	35.5	34.3	21.0	62.9	17.7	16.2	37.0	43.3	11.2	18.1	35.6	20.8	21.1

NOTES: TABLE LISTS DETECTED ANALYTES ONLY – SEE PROJECT ANALYTE LIST IN SI REPORT FOR SUMMARY
NA = NOT ANALYZED

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TABLE 1–4 (continued)
INORGANIC ANALYTES IN SOIL
AOC 52 – TDA MAINTENANCE YARD

FEASIBILITY STUDY
FORT DEVENS

ANALYTE	BACK-	BORING	52B–92–06X				52B–92–07X			52B–92–08X			52B–92–09X			G3M–92–04X		
(ug/g)	GROUND	DEPTH	0	5	5D	10	0	5	10	0	5	10	0	5	10	0	12	26
ALUMINUM	15000		14200	5160	4390	3930	7010	5160	3550	6370	4210	2960	5410	3390	3900	7360	2690	4740
ARSENIC	21		21.0	16.0	19.0	15.0	9.04	10.7	14.0	5.81	6.80	6.78	7.03	8.21	15.0	11.2	7.11	7.54
BARIUM	42.5		80.7	21.0	19.5	15.2	19.0	16.1	15.2	20.6	16.6	12.6	11.3	12.0	17.8	19.6	14.2	19.9
BERYLLIUM	0.347		0.939	< 0.500	0.628	0.550	< 0.500	0.549	< 0.500	< 0.500	0.637	< 0.500	< 0.500	<0.500	< 0.500	0.674	< 0.500	1.13
CADMIUM	2.00		< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700	< 0.700
CALCIUM	1400		1280	439	386	358	196	326	426	292	361	365	< 100	178	450	304	322	446
CHROMIUM	31		47.7	15.2	13.3	11.5	12.5	12.9	11.6	9.52	7.07	5.17	7.49	7.01	10.7	18.3	5.15	12.3
COBALT	NA		8.66	4.35	3.9	3.65	3.68	4.00	3.59	2.74	2.25	2.26	2.50	2.30	3.80	4.54	2.60	4.22
COPPER	8.39		15.1	9.11	9.14	7.97	6.60	7.37	7.96	5.22	4.47	4.09	5.56	5.70	9.92	8.07	6.33	8.14
IRON	15000		16900	7910	6760	7580	8300	7790	6480	6410	5020	4280	6640	5220	8470	9280	5070	14600
LEAD	34.4		17.0	8.10	6.27	5.58	8.97	6.77	4.58	19.0	12.4	5.84	5.43	3.78	4.53	8.76	3.49	3.73
MAGNESIUM	5600		8190	2590	2130	1990	2240	2080	1790	1080	1010	789	1250	1150	1700	2900	1030	2570
MANGANESE	300		293	162	149	125	129	147	150	97.4	91.3	76.2	91.2	83.6	302	155	104	247
NICKEL	14.0		38.4	14.2	12.7	10.8	12.4	12.4	12.9	7.35	5.70	4.96	7.34	7.04	14.6	16.5	6.86	16.7
POTASSIUM	1700		4370	912	858	551	528	506	612	344	480	417	242	339	533	855	396	977
SODIUM	131		296	165	150	140	145	148	138	157	160	152	142	136	165	<100	158	192
VANADIUM	28.7		32.1	10.2	8.61	7.99	10.4	8.25	6.74	8.29	6.31	4.48	5.87	5.04	6.40	12.4	3.97	8.97
ZINC	35.5		41.3	21.4	19.2	19.8	22.0	21.0	21.2	24.1	17.7	14.5	18.0	14.1	21.0	20.9	14.9	28.4

NOTES: TABLE LISTS DETECTED ANALYTES ONLY – SEE PROJECT ANALYTE LIST IN SI REPORT FOR SUMMARY
ND = NOT DETECTED
NA = NOT ANALYZED

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TABLE 1-5
ANALYTES IN GROUNDWATER - ROUND 1 (June 1993) AND ROUND 2 (September 1993)
AOC 44 GROUNDWATER MONITORING WELLS

FEASIBILITY STUDY REPORT
FORT DEVENS

ANALYTE	BACK-GROUND	ROUND 1		ROUND 2			
		G3M-93-10X	G3M-93-11X	G3M-93-10X	G3M-93-10X filtered	G3M-93-11X	G3M-93-11X filtered
ORGANICS (ug/L)							
BIS(2-ETHYLHEXYL)PHTHALATE		22	< 4.80	<4.8	NA	<4.8	NA
TETRACHLOROETHENE		<1.6	<1.6	2.6	NA	<1.6	NA
TOLUENE		<0.5	<0.5	2.31	NA	1.25	NA
TPHC		< 178	< 178	<173	NA	<178	NA
INORGANICS (ug/L)							
ALUMINUM	6870	6310	41600	16600	<141	18900	<141
ANTIMONY	3.03	<3.0	4.2	<3.0	<3.0	43.0	<3.0
ARSENIC	10.5	49.1	157	93.6	<2.54	130	<2.54
BARIUM	39.6	44.4	250	76.2	9.63	114	6.46
CALCIUM	14700	13000	13900	7630	6790	9220	7750
CHROMIUM	14.7	10.4	74.9	29.6	<6.02	34.0	<6.02
COBALT	25.0	<25.0	70.0	<25.0	<25.0	32.8	<25.0
COPPER	8.09	16.7	113	44.1	<8.09	52.6	<8.09
IRON	9100	13200	86300	31400	<38.8	36100	<38.8
LEAD	4.25	14.9	103	25.3	<1.3	38.4	<1.3
MAGNESIUM	3480	3030	13500	5500	716	6180	791
MANGANESE	291	510	9500	1100	25.6	3250	9.8
NICKEL	34.3	<34.3	140	56.1	<34.3	59.9	<34.3
POTASSIUM	2370	3710	9330	4390	1350	5360	1860
SODIUM	10800	24500	16900	16400	13800	18200	16800
VANADIUM	11.0	14.9	73.1	25.2	<11.0	29.1	<11.0
ZINC	21.1	27.8	157	73.0	<21.1	70.3	<21.1
ANIONS/CATIONS (ug/L)							
BICARBONATE		NA	NA	NA	NA	NA	NA
CHLORIDE		NA	NA	NA	NA	NA	NA
SULFATE		NA	NA	NA	NA	NA	NA
NITRATE/NITRITE		NA	NA	NA	NA	NA	NA
ALKALINITY		NA	NA	NA	NA	NA	NA
OTHER (mg/L)							
TSS		206	1110	569	NA	489	NA

NOTES:
TABLE LISTS DETECTED ANALYTES ONLY - SEE PROJECT ANALYTE LIST IN SI REPORT (ABB-ES, 1993).

NA = Not Analyzed

TABLE 1-6
ANALYTES IN SOIL
AOC 44 - CANNIBALIZATION YARD

FEASIBILITY STUDY REPORT
FORT DEVENS

ANALYTE	BACK-	BORING	44B-93-07X			44B-93-08X				44B-93-09X					44B-93-10X			
(ug/g)	GROUND	DEPTH	15	21	24	5	10	15	25	5	5D	10	15	25	5	10	15	25
ORGANICS																		
BIS(2-E-H)PHTHALATE			< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62	1.4	< 0.62	< 0.62	< 0.62	< 0.62
FLUORANTHENE			< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	0.25	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07
PHENANTHRENE			< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.09	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
PYRENE			< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.12	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
TPHC			< 30	< 29.7	< 29.8	< 31.2	121	< 29.5	< 34.4	< 29.6	38.1	< 29.6	< 29.5	< 33.1	< 29.4	< 29.6	< 29.6	< 35.1
INORGANICS																		
ALUMINUM	15000		4280	5660	2840	2670	2690	5700	2690	NA	NA	NA	NA	NA	NA	NA	NA	NA
ANTIMONY	NA		< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	NA	NA	NA	NA	NA	NA	NA	NA	NA
ARSENIC	21		12.3	25.4	9.38	4.34	11.4	21.2	8.78	NA	NA	NA	NA	NA	NA	NA	NA	NA
BARIUM	42.5		10.4	18.6	11.4	16.1	9.8	18.1	9.28	NA	NA	NA	NA	NA	NA	NA	NA	NA
BERYLLIUM	0.347		0.888	1.05	0.633	< 0.5	< 0.50	0.638	< 0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
CADMIUM	2.00		< 0.70	< 0.70	< 0.70	< 0.70	< 0.70	< 0.70	< 0.70	NA	NA	NA	NA	NA	NA	NA	NA	NA
CALCIUM	1400		388	481	337	484	462	576	279	NA	NA	NA	NA	NA	NA	NA	NA	NA
CHROMIUM	31		12.5	17.5	7	5.27	5.04	20.5	6.73	NA	NA	NA	NA	NA	NA	NA	NA	NA
COBALT	NA		3.44	4.39	2.48	< 1.42	2.34	5.33	2.42	NA	NA	NA	NA	NA	NA	NA	NA	NA
COPPER	8.39		5.8	9.9	4.86	3.88	5.39	11.8	4.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
IRON	15000		8930	10900	6230	6740	5030	10500	5260	NA	NA	NA	NA	NA	NA	NA	NA	NA
LEAD	34.4		3.28	5.63	2.33	4.36	3.01	2.94	4.91	3.14	4.19	8.69	5.11	4.63	2.78	9.51	6.34	2.65
MAGNESIUM	5600		2460	3640	1350	1200	1060	3910	1360	NA	NA	NA	NA	NA	NA	NA	NA	NA
MANGANESE	300		175	194	110	53	121	239	106	NA	NA	NA	NA	NA	NA	NA	NA	NA
NICKEL	14.0		12.8	17.8	7.61	< 1.71	6.76	20.8	7.11	NA	NA	NA	NA	NA	NA	NA	NA	NA
POTASSIUM	1700		485	993	470	1480	471	1020	450	NA	NA	NA	NA	NA	NA	NA	NA	NA
SODIUM	131		200	193	168	190	165	305	209	NA	NA	NA	NA	NA	NA	NA	NA	NA
VANADIUM	28.7		8.95	11.5	5.33	10.3	4.69	13.5	5.53	NA	NA	NA	NA	NA	NA	NA	NA	NA
ZINC	35.5		17.5	23.4	12.9	11.4	12.1	24.1	11.7	NA	NA	NA	NA	NA	NA	NA	NA	NA

NOTES: TABLE LISTS DETECTED ANALYTES ONLY - SEE PROJECT ANALYTE LIST IN SI REPORT (ABB-ES, 1993)
NA = NOT ANALYZED

TABLE 1-7
ANALYTICAL COMPARISONS
PAVEMENT / STAINED SOIL / SI BORING SAMPLES

ANALYTE	PAVEMENT (ppm)	STAINED SOIL (ppm)	44B-92-05X (ppm)	44B-92-01X (ppm)	52B-92-03X (ppm)	PAVEMENT % OF TOTAL	STAINED SOIL % OF TOTAL	44B-92-05X % OF TOTAL	44B-92-01X % OF TOTAL	52B-92-03X % OF TOTAL
NAPHTHALENE	140	ND	20	0.6	0.24	1.2	0.0	3.5	0.2	0.2
2-METHYL-NAPTHALENE	140	ND	6	ND	ND	1.2	0.0	1.1	0.0	0.0
ACENAPHTHYLENE	60	0.55	3	4	1.18	0.5	12.6	0.5	1.6	0.8
ACENAPHTHENE	130	ND	6	0.4	0.32	1.1	0.0	1.1	0.2	0.2
DIBENZOFURAN	290	ND	10	0.4	0.6	2.5	0.0	1.8	0.2	0.4
FLUORENE	310	ND	20	1	1	2.7	0.0	3.5	0.4	0.7
PHENANTHRENE	2200	ND	100	20	20	19.3	0.0	17.7	7.8	14.4
ANTHRACENE	420	ND	20	5	3	3.7	0.0	3.5	2.0	2.2
FLUORANTHENE	2100	2.6	100	50	20	18.5	59.8	17.7	19.5	14.4
PYRENE	1900	1.2	60	20	20	16.7	27.6	10.6	7.8	14.4
BENZO(A)ANTHRACENE	640	ND	40	20	10	5.6	0.0	7.1	7.8	7.2
CHRYSENE	710	ND	50	20	10	6.2	0.0	8.8	7.8	7.2
BENZO(B)FLUORANTHENE	710	ND	30	20	13	6.2	0.0	5.3	7.8	9.4
BENZO(K)FLUORANTHENE	290	ND	30	20	6.5	2.5	0.0	5.3	7.8	4.7
BENZO(A)PYRENE	510	ND	30	30	12	4.5	0.0	5.3	11.7	8.6
INDENO(1,2,3-CD)PYRENE	400	ND	20	20	11	3.5	0.0	3.5	7.8	7.9
DIBENZO(A,H)ANTHRACENE	ND	ND	ND	5	ND	0.0	0.0	0.0	2.0	0.0
BENZO(G,H,I)PERYLENE	430	ND	20	20	10	3.8	0.0	3.5	7.8	7.2
TOTAL CONCENTRATION	11380	4.35	565	256.4	138.84	100	100	100	100	100
TPHC	8800	21000	1210	714	98	DNA	DNA	DNA	DNA	DNA

2.0 REMEDIAL ACTION OBJECTIVES/ GENERAL RESPONSE ACTION IDENTIFICATION

Remedial action objectives and general response actions form the basis for developing remedial technologies and detailed remedial alternatives. Section 2.1 discusses remedial action objectives and Section 2.2 identifies the general response actions available to achieve the remedial action objectives. Section 2.3 evaluates several methods for establishing a cleanup level to achieve a cancer risk that is within the USEPA Superfund target risk range. Section 2.4 discusses waste volume and distribution at AOCs 44 and 52.

2.1 REMEDIAL ACTION OBJECTIVES

Remedial action objectives are medium- or operable unit-specific, qualitative goals defining the extent of cleanup required for protecting human health and the environment. These objectives identify the contaminants of concern, exposure routes, media and an acceptable contaminant level for each exposure route and medium.

With the exception of a few inorganic substances, all of the analytes reported in Section 1.3.2 of this FS are contaminants of potential concern. Primary exposure routes for humans are dermal contact and ingestion. As presented in the quantitative risk evaluation summarized in Section 1.4, there is little threat to public health based on a construction worker scenario from the soils at AOCs 44 and 52 via these exposure routes. However, risk estimates made under a long-term worker exposure scenario (25 year exposure to the top two feet of soil) do exceed the USEPA Superfund target risk range of 1E-4 to 1E-6 excess cancer risk for carcinogens. Using EPA Region I B(a)P approach, the cancer risk estimates assuming exposure to average and maximum contaminant concentrations range from 7E-4 to 4E-3. Due to limited habitat in the vicinity of AOCs 44 and 52, analyte concentrations found at AOCs 44 and 52 do not pose a significant risk to ecological receptors under foreseeable land use scenarios which are expected to remain commercial/industrial in nature. Therefore, based on estimated risk, remedial methods will focus on treatment of, and/or minimizing exposure to contaminants within the top two feet such that the cancer risk estimates fall within USEPA Superfund target risk range.

Contaminants which drive the risk in the top 2 feet of soil are predominantly cPAHs. Arsenic and beryllium also are carcinogenic compounds but only contribute approximately 5 percent to the cancer risk estimate and are believed to be naturally occurring. Therefore, based on estimated risk, remedial methods will focus on the organic contaminants present, primarily cPAHs.

However, in addition to focusing on the top two feet of soil, remedial response actions should reduce the potential migration of contaminants by surface run-off and infiltration where there could be an increase in risk to public health and the environment.

Consequently, primary remedial action objectives at the site are to:

- Minimize direct contact/ingestion and inhalation with AOCs 44 and 52 surface soils which are estimated to exceed the USEPA Superfund target range of 1E-4 to 1E-6 excess cancer risk for carcinogens.

- Reduce off-site run-off of contaminants that might result in concentrations in excess of ambient surface water quality standards and in background concentrations in sediments.

- Reduce or contain the source of contamination to minimize potential migration of contaminants of concern which might result in groundwater concentrations in excess of the MCLs.

2.2 General Response Actions

General response actions describe categories of remedial actions that may be employed to satisfy remedial action objectives. General response actions provide the basis for identifying specific remedial technologies. Applicable remedial response actions for AOCs 44 and 52 unsaturated soils include:

No-Action/Limited Actions. The no-action category does not consider the implementation of any remedial technologies or process options. The no-action option is established to provide a baseline of comparison for other technologies and process options. Limited actions may incorporate access restrictions and/or short- or long-term monitoring.

Containment. Containment actions include technologies that involve little or no treatment but reduce the mobility of contaminants. Thus containment technologies attempt to reduce potential migration of contaminants by isolation. Containment actions may consist of measures which physically minimize the potential for direct contact/ingestion and inhalation of contaminants. They also include measures to minimize surface run-off from carrying contaminated sediments off-site and migration of contaminants towards groundwater.

Collection/Removal. Collection or removal actions do not involve treatment but may be used in conjunction with treatment and disposal methods when developing alternatives. The removal technology for AOCs 44 and 52 soils would be excavation.

In-Situ Treatment. In-situ treatment actions include technologies that specifically act to reduce the mobility, toxicity, and/or volume of contaminants by biological, physical, chemical or thermal technologies. These treatment actions would treat the contaminated soil in place (in-situ). Examples of in-situ soil treatment processes include soil flushing, soil venting, stabilization, bioventing/ biodegradation, vitrification, and radio frequency heating.

Treatment. Treatment actions typically include technologies that specifically act to reduce the toxicity, mobility and/or volume of contaminants but require prior collection/removal of the contaminated media. CERCLA, as amended, favors treatment processes that achieve a reduction in contaminant mobility, toxicity, or volume, unless site conditions limit feasibility. Examples of treatment processes for contaminated soils include land farming, composting, stabilization, soil washing, asphalt batching, incineration, and thermal desorption.

Disposal. Disposal actions address the ultimate fate of the treated or untreated soil. An important factor in evaluating the effectiveness of a technology is to consider the volume of residual waste (if any) that could be produced and the way to safely handle and dispose of it.

2.3 CLEANUP LEVELS

2.3.1 cPAH Risk-Based Cleanup Levels

As detailed in the quantitative risk evaluation in Section 1.5, risk estimates made for a long-term worker/top 2 feet of soil exposure scenario exceeded the USEPA Superfund target risk range of 1E-4 to 1E-6. The estimated risk associated with the top 2 feet of soil at the site is caused predominantly by elevated PAH concentrations detected in approximately 4 of the 16 surficial surface samples analyzed. As part of the baseline risk evaluation in Section 1.5, risk estimates for cPAHs were developed using USEPA Region IV's Toxic Equivalency Factor (TEF) approach and using USEPA Region I's approach that assumes all cPAHs are as potent as B(a)P. Appendix A tables list the carcinogenic contaminants detected at AOCs 44 and 52 along with the average concentration and total cancer risk for each contaminant for each exposure scenario using the TEF approach and B(a)P approach. Beryllium and arsenic are also carcinogenic compounds which were detected but are believed to be naturally occurring. Beryllium is detectable on a random basis and in instances at higher concentrations at greater depth. The average arsenic concentration is below background levels. For these reasons beryllium and arsenic have been deleted as carcinogenic compounds for establishing cleanup levels. This has been accepted as a risk management decision by USEPA and MADEP.

Several methods were investigated for establishing a cleanup level to achieve a cancer risk that is within the USEPA Superfund target risk range. Appendix B contains a target level equation and parameters, target level spreadsheets and target level summary for the methods investigated. Method A, summarized in Table B-1 in Appendix B, establishes a cleanup level based on the cPAHs detected at AOCs 44 and 52 which contribute significantly (5%) or more to the baseline risk. (Five cPAHs contribute significantly to the baseline risk.) The target risk of 1.0E-04 is distributed equally among the 5 contaminants (2.0E-05 for each of the 5 contaminants which totals to 1.0E-04). The individual contaminant target levels are then computed using the equation in Appendix B such that each of the contaminants would contribute 2.0E-05 risk to the total target risk of 1.0E-4. Method A uses the USEPA Region IV TEF approach for computing the cancer slope factor. Method B, summarized in Table B-2 in Appendix B, uses the same calculations as Method A except that the USEPA Region I B(a)P approach is used for computing the cancer slope factor and the target risk of 1-0E-04 is distributed equally among all seven cPAHs. Method C, summarized in Table B-3 in Appendix B, establishes a cleanup level based on all seven cPAH compounds detected at AOC 44 and 52. The target risk of 1.0E-04 is distributed in proportion to the magnitude of the cancer risk that each compound contributes at AOCs 44 and 52 as calculated in the baseline risk. For instance, B(a)P accounts for approximately 70 percent of the baseline total cancer risk in the worker/TEF scenario. Therefore, 70 percent of the target risk (1.0E-04) will be assigned to B(a)P to compute its target concentration level. As with Method A, Method C uses the TEF approach for computing the cancer slope factor. Method D, summarized in Table B-4 in Appendix B, establishes a cleanup level by using B(a)P as the sole target contaminant. B(a)P might be an appropriate indicator for PAH contamination since it was present in all the areas of high cPAHs, it is one of the most toxic compounds and it is difficult to biodegrade. Resultant target levels for each of the methods are summarized in Table B-5 in Appendix B.

The computed target levels for total cPAHs range from 37 ppm (Method A using 1.0E-04 risk) down to 0.06 ppm (Method D using 1.0E-06 risk). Studies indicate that average background soil concentrations of cPAHs in urban soils may range from 24 ppm to 200 ppm (U.S. Public Health Service, 1990). The higher range may be largely attributed to road dust which can contain 8 to 336 ppm total cPAHs (Menzie, 1992). The cPAH concentrations which have been detected within the AOCs 44 and 52 soils (maximum of approximately 225 ppm at 44B-92-05X) are within the average background concentrations reported for urban soils and road dust. However, in compliance with CERCLA guidance, cleanup levels are determined based on achieving a carcinogenic risk that falls within the USEPA Superfund target risk range of 1E-04 to 1E-06.

The USEPA stated during the June 28, 1993 Draft FS Report review meeting that the TEF approach is not yet an acceptable method in Region I. Only Methods B and D utilize the USEPA Region I B(a)P approach. Method D, which uses B(a)P as a target compound, may not adequately represent the risk at the site and offers no significant sampling and analytical cost advantage over Method B since laboratory methods analyze for all cPAHs. During a July 12, 1993 Draft FS Report review meeting, a cleanup level of 7 ppm average total cPAHs was selected for this FS from the computed target range. This level achieves a total target risk of 1.0E-04 using Method B.

2.3.2 TPHC Cleanup Levels

TPHC cleanup levels for AOC 44 and 52 soils are established based on guidance from the MCP. The MCP establishes 500 ppm as the cleanup criteria for TPHC using MCP Method 1 and S-1 Soil and GW-1 groundwater categories.

As noted in the footnote to Table 2 in the MCP regulations (310 CMR 40.0975(6)(a)), entitled "MCP Method 1: Soil Category S-1 Standards", the Method 1 S-1 soil standard for TPHC does not apply to benzene, toluene, ethylbenzene, and xylene (BTEX) compounds or specific PAH compounds. Therefore, the S-1 soil standard for TPHC is used for AOC 44 and 52 soils in conjunction with the site-specific cleanup level for cPAHs identified above. Benzene was not detected in AOC 44 and 52 soil. As seen in the risk spreadsheets in Appendix A, the risks associated with toluene, ethylbenzene, and xylenes in AOC 44 and 52 soils fall well outside the Superfund target HI of one; assuming worker exposure to the maximum detected concentrations of these compounds results in hazard quotients on the order of $3x10^7$ or less.

Use of the TPHC soil standard under the Method 1, S-1 soil and GW-1 groundwater categories results in the most health-protective of the Method 1 standards. This is because S-1 soil is, by definition, the most accessible and therefore presents the greatest potential for exposure, and GW-1 groundwater is assumed to be potable.

2.4 WASTE VOLUME/DISTRIBUTION

As discussed in Section 2.3, the target cleanup level established for AOCs 44 and 52 soils for this FS is an average of 7 ppm total cPAHs. Based on the SI sampling results, a minimum of 6 and possibly 11 of 16 surficial samples exceed this level. However, because the cPAHs occur randomly and potentially across all the yards, the entire area of AOCs 44 and 52 to a 2 foot depth will be addressed for PAH contamination to meet the objective of being protective to human health. This amounts to a total unexcavated soil volume of 28,400 cubic yards (cy) or 38,400 tons (assuming a bulk density of 1.35 tons/cy).

Also as discussed in Section 2.3, the target cleanup level established for AOCs 44 and 52 soils for TPHC is 500 ppm. Based on the SI sampling results, the average

TPHC concentrations across the site at the 0 to 2 foot, 5 to 7 foot and 10 to 12 foot ranges are 315 ppm, 52 ppm and 33 ppm respectively. Maximum concentrations are 1210 ppm, 170 ppm and 119 ppm respectively. These values exclude the TPHC concentrations at boring 44B-92-06X (that may be associated with the mogas spill) and TPHC concentrations associated with the waste oil UST. Excluding these two areas, TPHC concentrations from the SI that exceed the 500 ppm target level are found only in the top 2 foot sampling level. Only 4 of 16 surficial samples exceed the 500 ppm level. However, due to the random distribution of cPAHs and TPHC, the entire area of AOCs 44 and 52 to a 2 foot depth will be addressed for TPHC as well as PAH contamination.

Based on the SI and the Supplemental Site Investigations discussed in Section 1.4, it is assumed for this FS that a total unexcavated soil volume of 700 cu yds in the hot spot areas exceeds the 500 ppm cleanup level for TPHC and will require remediation. This is based on a worst case assumption that boring 44B-92-06X is located on the southern edge of a spill unrelated to the mogas spill (an assumed 300 cy of soil exceeding 500 ppm) located in the north corner of the Cannibalization Yard and that boring 44B-93-10X is located off the northern edge of the mogas spill requiring remediation of an equal soil volume. It also assumes that approximately 100 cy of soil in the UST area will require excavation and treatment. Alternatives selected for treatment of the hot spot areas will entail pre-excavation sampling radially southeast to southwest of boring 44B-93-10X to define the location where there was believed to be a mogas spill (centrally in the Cannibalization Yard). Based on the Army Incident Report (ABB-ES, 1993a) cleanup of this spill was immediate which may have prevented contamination of soils at greater depth. Another possibility is that the mogas spill actually occurred in the vicinity of 44B-92-06X. Remediation and confirmation sampling will also be performed in the tank excavation area and in the vicinity of boring 44B-92-06X. Remediation/sampling in these three areas will be collectively referred to as remediation of the hot spot areas.

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3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This section identifies technology types and process options that address the general response actions and remedial action objectives discussed in Section 2.0. For each general response action identified, there are several remedial technologies and process options. These remedial technologies are identified and screened in the following sections to develop potential remedial alternatives that will achieve the remedial action objectives. Technologies and process options considered applicable are screened based on the waste characteristics (effectiveness) and applicability to the site (implementability). The purpose of this screening is to produce an inventory of suitable technologies and process options that can be assembled into complete remedial action alternatives capable of meeting remedial action objectives at AOCs 44 and 52.

3.1 TECHNOLOGY AND PROCESS OPTION IDENTIFICATION

Technologies and process options were identified based on a review of literature, vendor information, performance data, and experience in developing remedial alternatives under CERCLA. Over 20 technologies and process options were determined to be potentially applicable to meet the remedial action objectives.

Table 3-1 presents potentially applicable technologies and process options under seven possible general response actions: No Action, Limited Action, Containment, Collection/Removal, In-Situ Treatment, Treatment, and Disposal. These general response actions are consistent with those presented in USEPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final" (USEPA, 1988). Table 3-1 also identifies those technologies and process options which have been retained after the screening process. The following section discusses the general screening process and rationale for eliminating some of the technologies and process options.

3.2 TECHNOLOGY AND PROCESS OPTION SCREENING

The screening process reduces the number of potentially applicable technologies and process options by evaluating the applicable technology or process with waste and site characteristics that may influence effectiveness and implementability. This overall screening is consistent with the guidance provided under CERCLA (USEPA, 1988).

Applicability to waste characteristics pertains to the effectiveness of a technology based on contaminants identified at AOCs 44 and 52 as described in Section 1.3.2 of this FS.

Site characteristics, including operational limitations, may affect the effectiveness and implementability of the technology or process option. Operational limitations for the Maintenance Yards include ongoing operations at a normal to accelerated pace despite the proposed base closure.

Technologies were considered effective if they provided environmental or public health benefits and reduced either the mobility, toxicity, or volume of waste, or reduced the potential for exposure of contaminants. However, long-term management requirements for residual contamination and/or untreated wastes reduce the effectiveness of a technology. The following subsections discuss the results of the screening process in relation to the seven possible general response actions.

3.2.1 No Action

The No Action response category does not consider implementation of any remedial technologies. Therefore, public health and environmental risks from exposure to existing contamination at AOCs 44 and 52 would not change. The No Action response provides a baseline for comparison with other remedial actions.

Remedial technologies were not screened for the No Action general response category, by definition. However, the No Action option is retained for further consideration in accordance with the National Contingency Plan (NCP) regulations and CERCLA, as amended.

3.2.2 Limited Action

Limited action technologies (i.e., environmental monitoring, institutional control and access control) were evaluated as a means of monitoring contaminant migration or limiting exposure to contaminated soil. None of these technologies alone meet all the stated remedial action objectives of this FS. None reduce or contain the contamination source to prevent migration as off-site runoff.

Monitoring was retained as a means of assessing the impact (if any) of AOCs 44 and 52 soils, if left untreated, on groundwater over time. The need to install additional wells would be minimal.

Institutional controls were evaluated as a means of minimizing potential exposure pathways. Since the risk evaluation was based on the premise that the area is to be zoned for commercial/industrial use, the process option of land use restrictions has been retained for further evaluation. The area at Fort Devens reportedly is to be zoned for commercial/industrial use. Additionally, depending on the remedial alternative selected, certain site activities may require control (i.e., maintaining a pavement cap) using deed restrictions or other institutional methods. Implementing these controls would require coordination among property owners, state and local agencies.

Access control in the form of fencing was retained as a means of restricting unauthorized entry, thus minimizing the potential exposure pathways assumed to exist for the risk evaluation. Fencing with the intention of excluding all entry would not be implementable if the Maintenance Yards continue to be in operation. However, fencing would continue to exclude unauthorized entry while the yards are being used and could be potentially used to exclude all entry once Fort Devens closes. Fencing would need to be combined with a deed restriction stipulating that the fence be maintained to exclude unauthorized entry. This would restrict future development of the site areas.

3.2.3 Containment

Containment technologies were evaluated to address the remedial action objectives of limiting migration of contaminants via surface water run-off to off-site locations and minimizing the exposure to the contaminated soils.

Capping is the principal technology required to limit the migration of contaminants. A number of capping process options exist. These include clay and compacted soil liners, multimedia caps which usually have a flexible membrane as a component, and formed-in-place liners which include application of an asphalt or concrete surface. Only paving and concrete capping systems were considered compatible with the Maintenance Yards vehicle traffic and parking and were retained for further evaluation. Clay and soil, and multimedia caps would not be as compatible with the present use of the yards and were eliminated.

3.2.4 Collection/Removal

The removal technology for AOCs 44 and 55 soils would be excavation by using bulldozers, excavators, front-end loaders and dump trucks. Excavation has been retained since it is required for other technologies, specifically with ex-situ treatment technologies. Since the contaminated soils at AOCs 44 and 55 extend over a large area, the feasibility of excavating the full depth of contaminated soil is questionable. However, feasibility will be evaluated during the screening of alternatives.

3.2.5 In-Situ Treatment

In-situ treatment actions include technologies that specifically act to reduce the mobility, toxicity, and/or volume of contaminants. Seven potential in-situ treatment technology process options were identified.

The biological treatment technology (bioventing and landfarming process options) was retained for further evaluation. Biological techniques have proven successful in treating petroleum contaminated soils and reducing PAH concentrations at a number of sites. Laboratory tests have been conducted to evaluate the effectiveness for treating AOCs 44 and 52 soils as summarized in Section 1.4.3. Biological treatment will not reduce metal contaminants; however metal contaminants only minimally influence the carcinogenic risk at AOCs 44 and 52. Bioventing is a bioremedial system which entails applying air and moisture/nutrients as required, below grade via extraction wells and piping. As a result, soil bacteria proliferate under the aerobic conditions, biodegrading the organic contaminants. Landfarming is a similar process, but oxygen would be delivered to the AOC 44 and 52 soils in-situ by tilling the surface. Nutrients/moisture would be applied to the soil surface.

Process options assessed for the physical treatment technology would not be effective or would be difficult to implement for soil contaminants and conditions at AOCs 44 and 52. Soil flushing entails injection of water and chemical additives, if necessary, through the vadose zone and collecting the leachate at well points. This technology is more often used where the groundwater is already contaminated and a groundwater treatment system is utilized. Collection of leachate would be difficult to control and would subsequently require treatment prior to disposal. Soil venting involves installing vapor extraction wells and mechanically drawing air through the soils along with VOC vapors. This process option is not effective for removing semivolatile contaminants found at AOC 44 and 52. Stabilization/solidification is achieved by mixing soils in place with typically cement-based or silicate-based setting agents. This technique has been widely successful when applied to immobilizing inorganic contaminants to minimize leaching potential. However, this is not a primary remedial action objective at AOCs 44 and 52. Additionally, the effect of organic contaminants on the short- and long-term integrity of the solidified material is difficult to quantify and not conclusive. Based on the above evaluation, the physical treatment technology was eliminated.

Two in-situ thermal treatment process options (vitrification and radio frequency) were evaluated. Vitrification is a process of melting soils in-place to bind the contaminants in a glassy, solid matrix resistant to leaching. The melt temperatures are sufficiently high to destroy organic contaminants by pyrolysis. Although the technology would be effective and, in theory, could be implemented at AOCs 44 and 52, other technologies exist which would be equally effective and less costly. Radio frequency heating is a process option which is reportedly only in the demonstration study stage for treatment of organic contaminants. Electromagnetic energy is used to heat the surrounding soil to 150 to 400 degrees Celsius. Organic contaminants are not destroyed but are collected as liquid condensate or uncondensed gases and must be treated or disposed of off-site. The process is potentially more effective in treating VOCs. SVOCs, with higher boiling points would be more difficult to remove. Effectiveness and implementability of this treatment process at a site as large as AOCs 44 and 52 is questionable. Based on the above evaluation, the thermal treatment technology (vitrification and radio frequency process options) was eliminated.

3.2.6 Treatment (Ex-Situ)

Ex-situ treatment technologies include those technologies which act to reduce the toxicity, mobility and/or volume of contaminants but require prior excavation of the soil. Seven potential treatment technology process options were identified.

The biological treatment technology (composting process option) was retained for further evaluation. As with the in-situ biological treatment processes, composting has been demonstrated as being effective in reducing petroleum and PAH contamination in soils. The treatment process uses naturally occurring soil microorganisms to transform the organic contaminants into nontoxic materials (e.g., carbon dioxide, water and biomass). Laboratory tests have been conducted to evaluate the effectiveness of the treatment on AOCs 44 and 52 soils as summarized in Section 1.4.3. Composting will not reduce the metal contaminants; but as previously mentioned, the metal contaminants only minimally influence the carcinogenic risk at AOCs 44 and 52 and would not pose a health risk above action levels. Composting AOCs 44 and 52 soils would entail excavating the soil and distributing it in the form of windrows over a designated plot of land. Depending upon site location, a liner would most likely be required to prevent migration of contaminants to the native soil below. The soil is turned over to aerate and water and nutrients applied. Composting also permits flexibility for mixing in bulking agents (manure, wood chips). However, because AOCs 44 and 52 soil is very sandy, use of significant quantities of bulking agents is not expected to be necessary.

The physical treatment technology was also retained for further evaluation of the selected process options of off-site and on-site asphalt batching, and mechanical screening. Asphalt batching is a process option which entails recycling petroleum contaminated soil into a bituminous paving or road base product. There are two basic types of asphalt batching techniques; a hot mix asphalt process and a cold mix process. These can be further categorized into on-site and off-site process options as described herein. The hot mix asphalt process is performed off-site at a hot top plant. The contaminated soil is processed through the plant with uncontaminated aggregate to produce bituminous concrete or bituminous aggregate suitable for road base material. During the process, most of the organic contaminants are destroyed or volatilized by the heat used in the mixing process. Volatilized contaminants are then destroyed as emissions in an after-burner or thermal oxidizer. Cold mix processes are performed on-site or off-site at ambient temperatures. The asphalt binder is an asphalt emulsion employing water and surfactants as a softening agent. In returning to a solid or cured state, the asphalt acts to bind the soil and stone aggregate into a solid concrete-like material. The petroleum contaminants in the soil aggregate are immobilized during the curing process via physical and chemical processes.

Mechanical screening is a process option which physically removes rocks and other debris from soil. It does not remove the contaminants of concern but is often used as a pre-treatment process to improve the effectiveness of treatment processes to follow. For the retained remedial technologies and process options for AOCs 44 and 52 shown in Table 3-1, mechanical screening would most likely be used as a pre-treatment process for composting, landfarming and thermal desorption. As detailed in Section 1.4.4, broken-up bituminous pavement is present in portions of AOCs 44 and 52. Bituminous pavement also contains cPAHs which are the contaminants of concern. Mechanical screening would be performed to remove the large sized pieces of pavement from the soil. This would minimize the possibility of introducing additional small sized chips of pavement (containing cPAHs) into the soil during the treatment processes which could otherwise adversely impact confirmation sampling results.

Two other physical treatment process options which were screened, but were eliminated were stabilization and soil washing. Ex-situ stabilization is essentially the same process as the in-situ process except that soil is excavated and mixed with stabilizing agents in mobile batch mixers. Ex-situ stabilization may be more effective than in-situ stabilization, because the process is more easily controlled and more thorough mixing can occur. However, this process was eliminated for the same reasons as previously discussed under the in-situ stabilization process option evaluation. Principally, the process has not been conclusively proven effective in immobilizing organic contaminants. Soil washing extracts contaminants from the soil using a liquid medium as a washing solution. Soil is excavated and fed into a contractor or washing unit. Once the soil is washed, the washing solution must be treated via a waste water treatment system. Silts remaining from the wash may also require additional treatment or disposal. There is little full-scale experience with this technology so it is not likely to be readily implementable for treatment of AOCs 44 and 52 soils.

A chemical extraction treatment technology, solvent extraction, was screened and eliminated from consideration. Solvent extraction does not destroy the contaminants, but it concentrates them by using a solvent for which the contaminant material has a greater affinity than the contaminated material. Pre-treatment and post-treatment processes are frequently required to be performed for the effectiveness of this technology. Physical processing and chemical conditioning would be required in this application, as a pumpable slurry is required for treatment. Solvent extraction is not a stand-alone technology. Concentrated contaminants, fine soil, and separated water are subject to further specific treatment and disposal techniques. Several sidestreams are often generated during this treatment such as spent solvents, spent activated carbon, and air emissions. The concentrated contaminant residuals may or may not meet the required specifications for disposal, recycling or reuse of the material and would therefore need further treatment with another technology. Organically bound metals can be extracted with the target organic pollutants and could restrict disposal options. In addition, few vendors are available and the technology has not been proven at full-scale for cPAHs. For these reasons solvent extraction has been deemed not feasible for treatment of AOCs 44 and 52 soils.

The thermal treatment technology (incineration and thermal desorption process options) was also retained. Incineration has been well documented as a process which is readily implementable and will effectively destroy organic contaminants. High temperatures are used as the principal means of destroying or detoxifying organic contaminants. Inorganic contaminants will not be reduced; however treated residual soil from AOCs 44 and 52 would be expected to pass TCLP tests. Thermal desorption is also a demonstrated process for treating petroleum and PAH contaminated soil. Treatment is accomplished by processing contaminated soils through a pug mill or rotary drum system equipped with heat transfer surfaces. An induced air flow conveys desorbed organic/air mixture through a carbon adsorption unit or combustion afterburner for the destruction of the organics. Higher temperatures are required for semivolatile organic contaminants. As described for the incineration process, inorganic contaminants will not be reduced.

3.2.7 Disposal

The disposal technologies of on-base and off-base disposal were both retained for further evaluation. Fort Devens does not currently have an area on-base that meets the requirements of a permitted landfill for disposal of soil contaminated with waste oil. This disposal option could be combined with other remedial technologies that reduce the toxicity and/or mobility of the contaminants and is therefore considered in the screening of other remedial alternatives. Off-base disposal of the treated or untreated soils was also retained for further evaluation.

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TABLE 3-1
SCREENING OF SOIL REMEDIATION TECHNOLOGIES
MAINTENANCE YARDS
FORT DEVENS, MASSACHUSETTS

RESPONSE ACTION / REMEDIAL TECHNOLOGY	PROCESS OPTION	WASTE AND SITE LIMITING CHARACTERISTICS AND OTHER CHARACTERISTICS	INITIAL SCREENING STATUS
NO ACTION :			
NONE	NOT APPLICABLE	None	Required for baseline evaluation under NCP.
LIMITED ACTION :			
ENVIRONMENTAL MONITORING	GROUNDWATER MONITORING	None	Retained
INSTITUTIONAL CONTROL	LAND USE		Retained
ACCESS CONTROL	FENCING AND SIGNS	None	Retained
CONTAINMENT:			
CAPPING	CLAY AND SOIL	Surface incompatable with present use.	Eliminated
	ASPHALT	None	Retained
	CONCRETE	None	Retained
	MULTIMEDIA	Surface incompatable with present use.	Eliminated
COLLECTION:			
EXCAVATION	BULLDOZER & BACKHOE	May become impractical over an 8.8 acre site depending upon the depth of excavation required.	Retained
IN-SITU TREATMENT:			
BIOLOGICAL	BIOVENTING	Lab tests are being conducted to confirm effectiveness on organics in AOCs 44 and 52 soils.	Retained
	LANDFARMING	Lab tests are being conducted to confirm effectiveness on organics in AOCs 44 and 52 soils.	Retained
PHYSICAL	SOIL FLUSHING	Collection of leachate is difficult to control. Leachate would require treatment prior to disposal.	Eliminated
	SOIL VENTING	Not effective on semivolatile organics.	Eliminated
	STABILIZATION	Effective for reducing leaching of inorganic contaminants, however this is not a primary objective at AOCs 44 and 52.	Eliminated

(hatched box) Technologies or process options that are screened out.

TABLE 3-1 (continued)
SCREENING OF SOIL REMEDIATION TECHNOLOGIES
MAINTENANCE YARDS
FORT DEVENS, MASSACHUSETTS

RESPONSE ACTION / REMEDIAL TECHNOLOGY	PROCESS OPTION	WASTE AND SITE LIMITING CHARACTERISTICS AND OTHER CHARACTERISTICS	INITIAL SCREENING STATUS
IN-SITU TREATMENT:			
THERMAL	VITRIFICATION	Competitive alternative for sites heavily contaminated with both organic and inorganic contaminants, however impractical for AOCs 44 and 52 compared with other available technologies.	Eliminated
	RADIO FREQUENCY HEATING	Not fully developed. By-products would require disposal.	Eliminated
TREATMENT (EX-SITU):			
BIOLOGICAL	COMPOSTING	Lab tests are being conducted to confirm effectiveness on organics in AOCs 44 and 52 soils.	Retained
PHYSICAL	STABILIZATION	Effective for reducing leaching of inorganic contaminants, however this is not a primary objective at AOCs 44 and 52.	Eliminated
	SOIL WASHING	Requires several stages of material handling. Once soil is washed, further treatment of soil silt and wash water is required. Little full scale experience. Implementation problems likely.	Eliminated
	OFF-SITE ASPHALT BATCHING	Many off-site facilities are not licensed to treat soils contaminated with waste oil.	Retained
	ON-SITE ASPHALT BATCHING	Resultant paving will need to be used.	Retained
	SCREENING	Removes only rocks and other debris (not soil contaminants).	Retained
CHEMICAL	SOLVENT EXTRACTION	Requires pre- and post treatment processes. Requires further treatment of generated sidestreams	Eliminated
THERMAL	INCINERATION	Will not treat metal contaminants, however, residual would be expected to pass TCLP.	Retained
	THERMAL DESORPTION	Will not treat metal contaminants, however, residual would be expected to pass TCLP.	Retained
DISPOSAL:			
ON-BASE DISPOSAL	LANDFILL	May be applicable with other technologies such as composting.	Retained
OFF-BASE DISPOSAL	LANDFILL	None.	Retained

Technologies or process options that are screened out.

4.0 PROCESS OPTION EVALUATION

Within each technology retained for further evaluation, there exists at least one process option or specific process within the technology type. For some technologies there may be more than one process option retained for the technology type. An example of this is capping (technology) by using asphalt or concrete (process options). These technologies and process options are evaluated in more detail within this section and in general, a single process option is retained for each technology. In some instances, more than one process option may be retained if the processes are sufficiently different in their performance that one would not adequately represent the other. CERCLA guidance recommends that these process options be evaluated based on their effectiveness, implementability and relative cost. The remaining technologies and process options retained from this evaluation will be used to develop remedial alternatives for the soils at AOCs 44 and 52. This intermediate evaluation step is performed to select a representative process option for the remedial technologies and streamline the FS process by reducing the number of alternatives developed and evaluated (USEPA, 1988).

Table 4-1 presents the process options evaluated in this section and the results of this evaluation. These process options are for the capping, biological treatment, physical treatment and thermal treatment technologies. Where there was only one process option available for a given technology, the process option was retained with no further evaluation and shown in Table 4-1.

4.1 PROCESS OPTION SCREENING CRITERIA

Process options for each technology are evaluated and compared using the effectiveness, implementability and cost criteria established in the USEPA guidance (USEPA, 1988). These criteria are defined as follows:

Effectiveness: Each process option has been judged for its ability to effectively protect human health and the environment by reducing the toxicity, mobility, or volume of contaminants through treatment; reducing the risks to the community, workers, and environment during implementation of remedial actions; and meeting chemical-specific ARARs or complying with other criteria, advisories, or guidelines. The time required to achieve cleanup levels, the magnitude of residual risk, and long-term reliability of the alternative were also evaluated in the effectiveness criterion.

Implementability: Each process option has been evaluated for its implementability in terms of technical feasibility, administrative feasibility, and availability. Technical feasibility includes the ability to construct the remedy in the Maintenance Yards, the short- and long-term reliability, the ease of undertaking additional remedial action if necessary, the ability to monitor the effectiveness of the remedy, the ability to perform operation and maintenance functions, and the ability to comply with action-specific ARARs. Administrative feasibility includes the ability to obtain approvals from other agencies, the likelihood of favorable community response, and the need to comply with location-specific ARARs. The implementability of an alternative also depends on the availability of treatment, storage and disposal services, necessary equipment and specialists, and utilities.

Cost: Capital (equipment or construction) costs for the major system components and likely operation and maintenance (O&M) costs of each option are order-of-magnitude estimates. Present worth values are also calculated over the treatment duration and assuming a 10 percent interest rate. This present worth criterion permits equal evaluation of alternatives, technologies and process options by incorporating both their capital and annual O&M costs. This criterion was used to screen process options that are equally effective or implementable. More detailed cost estimates are developed for the retained process options in the detailed analysis of remedial alternatives (see Section 6).

4.2 CAPPING OF AOCS 44 AND 52 SOILS

The containment technology by itself provides no treatment of the contaminated soil, but does protect the public health and environment by reducing contact with surficial contaminants. It also is typically used to minimize migration of existing soil contaminants off-site via stormwater run-off. Capping also would minimize the potential for future soil contamination. However, for this purpose capping will also require expanding the existing stormwater collection system at the Maintenance Yards to facilitate stormwater collection off the cap. Leaking vehicles are now reportedly parked on the spill containment basin. However, stormwater might require treatment, such as oil/water separation. Additionally, investigations would need to be performed to determine what impacts the increased flow from stormwater runoff will have on the wetlands. Potentially, a retention basin and flow reducers will need to be incorporated into the design to minimize impacts on the wetlands. Treatment and ultimate disposal of this surface water is outside the scope of this FS but is being addressed by the Army under AREE 70 - Storm Water Discharge System.

However, since expansion of the existing stormwater collection system is considered an ancillary system to the capping technology to effectively prevent the build-up and/or uncontrolled run-off of stormwater, cost for installation of additional catch basins and storm drainage pipe will be included in the cost for alternatives using the capping technology.

The contaminated soil which would be capped covers an 8.8 acre area as described in Section 1.2. Two types of capping material (bituminous paving and concrete) have been retained and will be evaluated as process options in the following subsections.

The bituminous paving would entail utilizing a standard roadway mix design. The mix is compacted into a uniform dense mass which serves as a barrier. Paving would probably require both a binder course and wearing course to achieve the integrity required for an effective cap.

A concrete cap would consist of a mix of portland cement, aggregate and water with admixtures for severe freeze/thaw conditions. Steel reinforcement would be used. The concrete would be "poured" or placed as would be done in forming a floor or slab.

4.2.1 Effectiveness

Long-Term Effectiveness: Both bituminous paving and concrete are considered equally effective in meeting the protection remedial action objectives of this FS. Both capping systems limit the migration of contaminants via surface water run-off to off-site locations. Both systems will also minimize the potential risk to human health by reducing the exposure pathways from the surficial soils. Both capping systems are susceptible to cracking from temperature fluctuations and weathering over an extended period of time and require periodic maintenance.

Based on the Supplemental Site Investigations and Data Gathering detailed in Section 1.0, bituminous paving contains cPAHs; thus paving the site could introduce more contaminants to the site.

Short-Term effectiveness: Both capping systems would require similar levels of personal protection equipment for expansion of the existing stormwater collection system, grading and application of the capping material. Both capping systems would create similar exposures to the environment during construction from migrating contaminants in the form of dust and surface water run-off.

Reduction of Toxicity, Mobility, or Volume through Treatment: Neither of the capping systems treat the contaminated soil. Reduction in mobility is achieved solely by containment and is basically the same for either system.

4.2.2 Implementability

Technical feasibility: Both capping process options are potentially reliable for limiting the migration of contaminants and protecting public health and the environment by reducing contact with surficial soils. However, application of paving is slightly less labor-intensive than placing concrete because of the inherent characteristics of applying the materials. Both capping process options will require installing additional catch basins and storm drainage piping, grading the existing surface, removing and reinstalling fencing and adjusting existing manhole/catch basin frames as required to match new grades. Existing soils in the Maintenance Yards are primarily sand with up to 19 percent fines. It is expected that the existing soil is satisfactory as a subbase material but that both caps would require a minimum 6 inch crushed gravel or equivalent aggregate base material to support the paving or concrete surface with continued heavy vehicular use, and to minimize frost heaving. The base aggregate course would be applied over the existing surface minimizing the amount of contaminated soil excavated to only those soils removed for stormwater system expansion. This would result in the overall elevation of the Maintenance Yards to be raised approximately 1 foot higher than existing grade (i.e., 6-inch aggregate base and 5- to 6-inch thick cap material).

It is anticipated that the bituminous paving cap would consist of a minimum 2.5- to 3.5-inch base or binder course covered by a 1- to 2-inch wearing course. A concrete cap would be a minimum of 6 inches thick and would be reinforced with steel mesh. The concrete mix would be designed for severe freeze/thaw conditions.

Administrative Feasibility: Fort Devens is currently using all of the Maintenance Yards for parking vehicles. To permit continued operations, only portions of the yards would be capable of being closed for construction at a time. This continued usage requirement would favor the bituminous paving capping process option which can be implemented more quickly than concrete.

Availability of Services and Materials: Concrete and bituminous paving are both common materials in the construction industry.

4.2.3 Cost

Capital costs for the two capping systems are as follows:

Bituminous Paving Cap: $300,000
Concrete Cap: $850,000

Costs are for furnishing and installing only the specific cap material. Costs for stormwater system expansion, fence removal/reinstallation, grading, base aggregate course application and other work that is required and similar in magnitude for either cap system have not been included at this stage of the evaluation but will be included for the detailed alternative evaluation in Section 6.0. Additionally, operation and maintenance costs are considered insignificant and have not been included in the process option cost evaluation.

4.2.4 Process Option Selection

Bituminous pavement capping was retained for use in remediating soils at AOCs 44 and 52. This capping option is less expensive and is the quickest to implement, thereby minimizing exposure to construction workers and the environment.

4.3 IN-SITU BIOLOGICAL TREATMENT

In-Situ Bioremediation (ISB) is a process that can be implemented to stimulate biodegradation of organic soil contaminants by hydrocarbon-degrading soil microorganisms. These microorganisms are usually already present in the soils. Rapid biodegradation is limited by the insufficient soil moisture, oxygen, or mineral nutrients. ISB works by supplying these requirements to overcome the limitation and stimulate biodegradation. Every site varies in which combination and to what degree each factor is important. The rate and extent of treatment that can be achieved by ISB depends on several factors including the starting concentration of the contamination, the types of constituents, available inorganic nutrients, duration of treatment, etc. To design an ISB system, it is necessary to select appropriate oxygen, moisture and nutrient delivery systems. Since the soil conditions (permeability, moisture level, depth of contamination, nutrient concentrations, etc.) are different at every site, the design of an ISB system will differ as well.

The contaminated soils at AOCs 44 and 52 are sandy and relatively permeable to air and water. Virtually all of the organic compounds present in soil at AOCs 44 and 52 are biodegradable. The designated cPAHs are high molecular weight aromatic compounds that have four, five or six rings. The biodegradation of PAHs is strongly influenced by compound solubility and the number of aromatic rings. The lower molecular weight PAHs are much more biodegradable than the high molecular weight PAHs. The biodegradation half life of a PAH compound can range from a week to a year depending upon the composition of the PAH.

The biodegradability of specific PAHs are presented in Table 5 of the ABB-ES publication presented in Appendix C and can also be found in an EPA publication "Bioremediation of Contaminated Surface Soils" (EPA/600/9-89/073) also presented in Appendix C. These data show that PAH biodegradability is generally a function of molecular weight and the number of aromatic rings. Two ring PAHs can be biodegraded within a week and three ring PAHs after approximately one month. Four ring PAH compounds may have a biodegradation half life one to three months. The half life for many of the five and six ring PAHs is at least 3 months and may be as high as 10 to 15 months.

There are several factors that may effect the rate of biodegradation. These include:

- pH,
- moisture,
- temperature,

- available oxygen, and
- available nutrients.

During bioremediation these parameters are monitored and maintained at levels that would promote biological activity. Under well maintained conditions, the lower range of the biodegradation rates can be achieved.

The source of cPAHs found at Fort Devens appear to be from either crank case oil or asphalt. The type of PAHs that are associated with crank case oil are generally higher ring PAHs which are biodegradable, but at a much slower rate. It is anticipated that during bioremediation activities all of the PAHs with the exception of possibly benzoperylene, will exhibit some levels of PAH biodegradation.

PAHs associated with pavement contain 2-, 3-and 4-ring PAHs as well as the cPAHs found in the crank case oil. The lower ring PAHs will be initially be biodegraded very rapidly, where the five and six ring compounds will be degraded at rates similar to those in the crank case oil. It is important to note that biodegradation of the PAHs and cPAHs associated with pavement will occur only if the asphalt or pavement is present in small pieces. Those asphalt particles that are found in very small pieces (consistent with coarse sand) would likely be available to bacteria for biodegradation.

Treatment Time Estimation. Treatment time estimations have been made using data generated from an ABB-ES Florida landfarming project that was conducted on sandy soil contaminated with #6 fuel. Active landfarming took place over a six month period and reductions due to passive bioremediation were documented over the next 30 months. Carcinogenic PAH biodegradation rates were calculated using B(a)P data from this project. B(a)P is one of the more recalcitrant cPAHs, therefore the estimates used for the Fort Devens project are considered to be conservative.

PAH biodegradation data presented in an USEPA publication "Bioremediation of Contaminated Surface Soils" were reviewed and the results indicated that those data are generally consistent with data generated from ABB-ES field projects (Table C-1 in Appendix C). The USEPA report data show shorter half lives in some cases, however those data were produced from treatability studies rather than field projects. One of the half life values generated for benzo(a)anthracene was much higher than that from the Florida landfarming project (Appendix C) and other data in the EPA report indicating that there is some variability in PAH biodegradation. It is likely that these type of results can occur because of variations in treatment conditions, contaminant or soil type. Since the data presented in the USEPA report were from lab studies, ABB-ES chose to use the more conservative half life estimates derived from the Florida field project. The conditions of that project were similar to those at Fort Devens in that the soil type is sandy, the treatment approach uses landfarming and PAH biodegradation occurred in the presence of TPHC.

The highest concentration of cPAHs is anticipated to be between 60 and 200 milligram per kilogram (mg/kg) based on the three highest levels of PAHs measured in the soil during the SI. The estimated treatment time that would be required to bring the concentration of cPAHs below 7 mg/kg is approximately 3 to 5 years using landfarming. The five year value was generated using the upper concentration of 200 mg/kg. The half-life for B(a)P was calculated to be approximately 11.5 months based on the data from the Florida landfarming project (Table C-1 in Appendix C). This rate factors in the removal rates during passive remediation, therefore the half life value may be conservative. In addition, B(a)P is one of the least biodegradable cPAH compounds, therefore treatment time estimates using this value are considered to be conservative. The half life for other cPAHs such as benzo(a)anthracene are approximately three times faster and can be biodegraded to levels below 2 mg/kg.

As previously discussed in Section 1.4.3, bioventing is a less aggressive treatment than landfarming and is likely to take twice as long to achieve the 7 mg/kg cleanup level (10 years). Based on the biological treatability study report data (ABB-ES, 1993b), bioventing does not appear to be nearly as effective as landfarming and, in fact, may not be an effective treatment alternative.

Nutrients. The concentration of nutrients that will be added during the treatment process will be only what is needed for the bacteria to biodegrade the organic contaminants. The nutrient mixtures are fertilizers that are commonly used and may have a carbon:nitrogen:phosphorous nutrient ratio of approximately 106:16:1. The compounds that are used to make up the nutrient mixtures used by ABB-ES include:

- $(NH_4)_2HPO_4$

- $(NH_4)_2SO_4$
- urea
- K_2HPO_4
- $MgSO_4$

Nitrate is not used as a source of nitrogen in the nutrient mixture. Process monitoring data analyzed by ABB-ES from different lab and field projects do not show any evidence of nitrate generation during bioremediation. The nutrient loading rates are calculated based on the carbon content of the soil and thus will depend upon initial contaminant concentration. A loading rate for treatment of the hot spot soils (8520 ppm TPHC) might require approximately 100 mg/kg nitrogen and 50 mg/kg phosphate at initiation of treatment. The concentration of these nutrients would be monitored frequently and maintained at 50 to 125 mg/kg nitrogen and 30 to 50 mg/kg phosphate during the course of remediation.

The concentration of phosphate is not very high and would not be expected to increase the solubility of the cPAHs to any measurable extent. The addition of the mineral nutrients will serve to enhance the activity of bacteria. One of the limitations of PAH biodegradation is the PAH solubility. The PAH compounds have low solubility and are biodegraded very quickly once they partition into the aqueous phase under aerobic conditions. Treatment of AOCs 44 and 52 soils would not entail adding any wetting agent or surfactant amendments as part of the landfarming or bioventing operation.

Moisture. The moisture holding capacity or field capacity of the soil is optimum near or at 50%. This level of moisture is required to maintain biological activity. At 50%, the soil is not saturated, therefore there would not be any leaching but there would be sufficient moisture for biodegradation to occur. During treatment the moisture content will be monitored to ensure sufficient moisture is available to the bacteria without over-saturating the soil.

Process Options. The risk assessment of AOCs 44 and 52 has indicated the primary risk from these soils is associated with the top 2 feet of the soil column. Soil 2 to 10 feet bgs also has contamination, though not at levels that pose a health risk based on risk evaluation. Of the risk associated with organic compounds in the top 2 feet of soil, the major contribution to risk is from B(a)P. ISB can be implemented at AOCs 44 and 52 either through capping and

bioventing the soil or by **in-situ landfarming** of the soil. Both of these treatment technologies will be evaluated as process options in the following subsections.

Bioventing. This process option promotes ISB by delivering moisture and nutrients via wells or trenches and oxygen via a soil vapor extraction (SVE) system with soil vapor return wells or conduits. A bioventing system closely resembles an SVE system, however it is operated quite differently. The objective of bioventing is to provide as much opportunity as possible for biodegradation of the biodegradable soil contaminants (e.g., TPHCs) within the soil. To achieve this purpose, the SVE system is operated to ensure that oxygen is delivered to the soil bacteria and not to remove VOCs from the soil at a high rate. Most (greater than 80 percent) of the gases that are extracted from the soil are returned to the soil to provide greater opportunity for biodegradation; the remaining gases are treated (if necessary) and discharged. In this way, system operation and off-gas treatment costs (e.g., activated carbon) are minimized. Demonstrations of this technology have indicated that bioventing of biodegradable VOCs occurs faster than removal through SVE alone. In addition, bioventing also remediates soil containing biodegradable SVOCs (e.g., diesel compounds and PAHs).

A bioventing system at AOCs 44 and 52 would involve:

- preliminary injection of dissolved nutrients;
- installation of air injection and withdrawal trenches;
- capping of the soil with pavement to ensure that the air flows through the contaminated soil depth and to prevent short circuiting of air from the atmosphere to the withdrawal trenches;
- vapor extraction wells;

Full-scale system components are expected to include approximately 20 vapor extraction wells; a vacuum blower; humidification; and reinjection of 80 to 95 percent of the extracted soil gas through a network of 10 to 15 vapor extraction and injection trenches.

In-Situ Landfarming. Landfarming or land treatment has been used for many years for treatment of petroleum wastes such as refinery wastes. This process relies on naturally occurring soil microbiota to degrade and stabilize hydrocarbon wastes. Typically, landfarming of refinery wastes is accomplished by applying the wastes to prepared soil and then adding mineral nutrients, moisture, and air by tilling. Tilling is performed using disk plows, rototillers, and sometimes bulldozers to mix and aerate the soil. Nutrient addition, pH control, and moisture application can be accomplished by a variety of methods of fertilization and irrigation. Landfarming is primarily applicable for treatment of SVOC wastes, since VOC control is difficult or impossible. Landfarming would be applicable to AOCs 44 and 52 soils since only trace amounts of VOC contaminants have been detected.

At AOCs 44 and 52, a landfarming process can be used to remediate the contaminated soils. Nutrients and water can be applied to the soil and then the soil tilled (to approximately 18 inches) to mix and aerate the soil. Nutrients are typically applied upon initial tilling and thereafter applied as needed based upon analytical monitoring. This process will treat the top 2 feet of the AOCs which present the primary health risk. This relatively standard landfarming system can be modified to treat the deeper soil contamination by applying excess nutrients and water to the soil surface. Through percolation, the water will carry the nutrients deeper into the soil column for treatment of the soil interval between 2 and 10 feet. Oxygen could be delivered to the deeper soil layers, such as to the waste oil UST area and the mogas spill area, using vapor extraction wells (bioventing technology) screened from 6 to 10 feet. This modified landfarming system can aggressively reduce the risk from the top 2 feet of soil and more passively reduce the total levels of contamination in the soil from 2 to 10 feet. Although there is no risk from soils below two feet, landfarming provides the extra benefit of potentially reducing the concentration of contaminants at lower depths and remediating soils towards background levels.

4.3.1 Effectiveness

Long Term Effectiveness. Both bioventing and landfarming can be effective in mitigating the risks associated with the soil contamination at AOCs 44 and 52. The bioventing system requires capping the site with pavement or another impermeable material to prevent short circuiting of air flow through the soil and thereby would prevent exposure to the contaminated soil and migration of the contaminants. However, bioventing also would promote destructive biodegradation of the hazardous organic compounds which are creating the risk in the top 2 feet of the soil within an estimated 10 years of implementation to achieve a cleanup level of 7 ppm total cPAHs. However, treatability testing indicates that bioventing requires a longer time to achieve contaminant reduction than composting or landfarming which utilize a more aggressive treatment processes (ABB-ES, 1993b). This destruction of the contaminants would essentially eliminate the potential hazards of the site. In addition, bioventing would reduce the levels of contaminants in the soils beneath the two foot zone towards levels approaching background by delivering moisture, nutrients and air to these soils. As a minimum, monitoring would be performed in the top two feet of soil to ensure that reduction in carcinogenic risk is achieved. Additionally, monitoring would be performed in the spill and tank areas which would be representative of a worst case scenario to ensure cleanup levels of TPHC are achieved.

Landfarming would also promote biodegradation of the soil organic contaminants within 5 years of implementation (within 1 year for TPHC, chrysene and benzo(a)anthracene reduction and within 5 years for B(a)P, benzo(b&k)fluoranthene, etc.). Landfarming would aerate the soil in the top 2 feet of the AOCs more thoroughly and therefore treat the contamination in this zone approximately twice as fast as the bioventing option. In addition, landfarming will most likely achieve lower treatment levels of the more recalcitrant compounds than the bioventing process option because tilling will ensure intimate contact among contaminants, bacteria, nutrients, moisture, and oxygen. This process option would not be as effective as bioventing for remediating the soil below the top 2 feet. Landfarming would not require capping of the AOCs.

As with bioventing, monitoring would be performed in the top 2 feet of soil to ensure that reduction in carcinogenic risk is achieved. Additionally, monitoring would be performed in the hot spot areas which would be representative of the highest concentration of TPHC, to ensure cleanup levels of TPHC are achieved.

Short Term Effectiveness. The bioventing process option would be more effective at reducing risks and mitigating potential migration of the contamination in the short term (during treatment), due to the impermeable cap that would be placed atop the AOCs. Both systems would create similar exposures to workers during treatment system construction, however these exposures would continue for several years for the landfarming option.

Reduction of Toxicity, Mobility, or Volume through Treatment. Both of these options will result in destruction of the organic compounds in the soil at AOCs 44 and 52. Within an estimated three to five years by landfarming, the toxic organic compounds in the top 2 feet of soil will be reduced to levels which have risks that fall within the USEPA Superfund target risk range of 1E-4 to 1E-6 excess cancer risk. The total TPHC throughout the soil will be reduced by 50 to 90 percent within the same timeframe. Bioventing is expected to take twice the time for remediation. Mechanical screening of the soil to remove large pavement pieces is required for landfarming to minimize the potential of introducing pavement chips (cPAHs) into the soil during tilling operations. Treatability testing has been performed for both options to evaluate the effectiveness of treatment in AOC 44 and 52 soils as summarized in Section 1.4.3.

4.3.2 Implementability

Technical Feasibility. ISB is technically feasible for removing the hazardous organic compounds from the soils at AOCs 44 and 55. The soils at this site appear to be sufficiently permeable to permit the delivery of the mineral nutrients, moisture and oxygen necessary to promote biodegradation. However, nutrients would need to be applied and monitored so as to not impact either Grove Pond and its wetlands and/or the Grove Pond water supply wells and to avoid human health risks associated with nitrate/nitrite in groundwater, and ecological risks associated with nitrate and phosphate migrating to surface water. The bioventing process option is more technically complex and would require more engineering than the landfarming process option. However, landfarming would essentially remove the treatment area from operational use as parking lots or maintenance yards for the full remediation time period of 1 to 5 years and may need to be performed in stages to enable a portion of the yards to remain open. Construction of the bioventing system would require a much shorter period of disruption of the use of this site, estimated at 3 months. Odors are not expected to be a problem with either of the alternatives.

Administrative Feasibility. These process options may require compliance with air regulations and permitting, although volatile emissions, if any, are expected to be minimal as explained further in Section 7.5. The addition of water and mineral nutrients to the soil will require groundwater monitoring to ensure that no contamination is introduced into the groundwater due to remedial activities.

The MADEP Central Regional Office Water Supply Section has indicated that landfarming and bioventing are not recommended within a Zone II of a public water supply. The concerns include: high soil permeability, proximity to the Grove Pond Wells, mobilization of contaminants through nutrient addition, the time to complete degradation, and the difficulty biodegrading cPAHs. However, nutrients would be scientifically applied and monitored and are not expected to increase the solubility and migration of PAHs as described previously in Section 4.3 under "Nutrients".

Availability of Services and Materials. These remedial process options are relatively straightforward to implement and use widely available components. The availability of services and materials should not impede implementation of either process option.

4.3.3 Cost

Estimated costs for the two bioremediation process options are as follows:

Bioventing: $1,025,000 capital; $77,000/yr for 10 years

Landfarming: $560,000 capital; $271,500/yr for 5 years (assumes closing of the Maintenance Yards)

For a more detailed breakdown of costs, refer to Sections 5 and 6.

4.3.4 Process Option Selection

Both process options were retained for further evaluation for use in remediating soils at AOCs 44 and 52. Landfarming could potentially treat the top 2 feet of soil more rapidly but would disrupt current operations in the Maintenance Yards. Bioventing, although more expensive, would permit current use of the Maintenance Yards and more readily treat soils at greater depth.

4.4 EX-SITU PHYSICAL TREATMENT (ASPHALT BATCHING)

The two process options evaluated in this section are on-site and off-site asphalt batching. Mechanical screening, which is also a physical treatment process listed in Table 4-1, is retained for developing remedial alternatives because it is sufficiently different in performance from the asphalt batching process options. It is used only as a pretreatment process as described in Section 3.2.5.

Asphalt batching is a technology which entails recycling petroleum contaminated soil into a bituminous paving or road base product. There are two basic types of asphalt batching techniques evaluated in this FS; a hot mix asphalt process and a cold mix process. These general process techniques fall either within the on-site or off-site asphalt batching process options as described below. The hot mix asphalt process is performed off-site at a hot top plant. The contaminated soil is processed through the plant with uncontaminated aggregate to produce bituminous concrete or bituminous aggregate suitable for road base material, road shoulder material and other stabilizing applications. Most plant's licenses restrict the amount of contaminated soil to a small percentage (5 percent) of the total aggregate input. During the process most of the organic contaminants are destroyed or volatilized from the heat used in the mixing process. Volatilized contaminants are then destroyed as emissions in an after-burner or thermal oxidizer.

Cold mix processes are performed on-site or off-site and at ambient temperatures. The asphalt binder is an asphalt emulsion employing water and surfactants to soften the asphalt. Curing occurs upon evaporation of the water. In returning to its solid state, the asphalt acts to bind the soil and stone aggregate into a solid concrete-like material. In theory, the petroleum contaminants in the soil aggregate are immobilized during the curing process via physical and chemical processes. In this state the contaminants will not readily leach out and are presumed to have little or no potential exposure concerns via dermal, inhalation or ingestion pathways. The cold mix process entails excavating and processing the soil through a crusher or screen to produce a physically uniform (3 inch and less) material. The material is then blended with other aggregate (if required due to existing poor soil conditions) and the asphalt emulsion in a pugmill. The finished product is then used as the base or subbase material for roadway or parking lot construction. The material can be either spread into thin lifts and compacted into the base/subbase by roller, or stockpiled for later use as a stabilized aggregate material. The most economic approach (eliminating the need for backfill material) would be to place all the asphalt batched material back into the excavated area at AOCs 44 and 52. Reuse of this large quantity of pavement elsewhere on-base would be difficult.

4.4.1 Effectiveness

Long-term effectiveness. Both on-site and off-site batching can be effective at mitigating the risks associated with the soil contamination at AOCs 44 and 52. With on-site batching of the top two feet, organic contaminants are effectively immobilized minimizing the potential exposure concerns via dermal, or ingestion pathways. With off-site batching of the top two feet, soils are completely removed from the site and organic contaminants destroyed at a hot-mix plant. Inorganic contaminants are immobilized by the asphalt batching process. Based on the Supplemental Site Investigations and Data Gathering detailed in Section 1.0, bituminous paving contains cPAHs; thus on-site asphalt batching could potentially introduce more cPAHs to the site.

Short-term Effectiveness. Off-site batching creates a greater exposure to human health and the environment during remedial action implementation than on-site batching, largely due to the transportation of the soils off-site. The time taken from excavation to treatment is much shorter with on-site batching which minimizes contact time to potential receptors such as on-route communities and workers handling the soil.

Reduction of Toxicity, Mobility, or Volume through Treatment. Off-site batching that involves treatment at a hot mix plant reduces the overall volume of contaminated soil on-site and reduces the toxicity of the organics in the soil by thermal destruction at the hot mix plant. On-site batching performs two functions in reducing mobility of the contaminants at the site. Batching soil exceeding cleanup levels at the top 2 feet of the site achieves an irreversible reduction in mobility of all the contaminants driving the carcinogenic risk at AOCs 44 and 52. It also provides an impermeable surface barrier if placed over the surface of AOCs 44 and 52 thereby limiting potential migration of contaminants via precipitation infiltrating through to the groundwater and via surface water run-off to off-site locations. Off-site batching would require the additional installation of a cap to achieve the latter objective.

4.4.2 Implementability

Technical Feasibility. Both process options are technically feasible for removing or immobilizing hazardous organic compounds from the soils at AOCs 44 and 52. As with any asphalt product, restrictions apply regarding temperature and weather when applying on-site batched pavement. Typically, application should not occur if ambient temperatures are below 45 degrees Fahrenheit. Tilling, rolling and compaction operations should not be performed during periods of rainfall or immediately prior to a time of forecasted precipitation events. However the material can be stockpiled, covered or uncovered, depending on precipitation potential. Once set for an initial 72-hour curing period, the asphalt emulsion stabilized material can be utilized immediately or maintained in a stockpile for future use.

Off-site hot-mix plants in New England typically stop the production of pavement during the off-season (16 weeks). However, most plants will continue to accept petroleum contaminated soil into the winter months until their regulatory capacity limit is reached. Batch plants contacted for this FS claim that their process is designed such that there are no restrictions regarding when they can accept material.

Neither of the process options would prevent further remedial action should it be required in the future. On-site batching would make future excavation more difficult in the AOCs 44 and 52 soil (assuming that the batched material, estimated to be potentially 1 foot thick, would be placed back in the excavation) and would not be practical for future development other than for a parking lot.

Administrative Feasibility. Currently, batching plants in the Commonwealth of Massachusetts are not licensed to accept soil that has been contaminated by a known used waste oil source. Plants can usually accept soils that are contaminated with virgin petroleum oil which meets specified guidelines, and soils contaminated from an unknown source that meet specified analytical characteristics similar to a virgin petroleum oil. Although soils at AOCs 44 and 52 have contaminant concentrations which generally meet the latter criteria, the contaminant source is known to be a waste oil which currently excludes asphalt batching at most Massachusetts off-site facilities. The MADEP is currently working with off-site asphalt batch facilities to modify their existing permits so they can accept and process used waste oil contaminated soils. Until these permit modifications are made, used waste oil contaminated soils may only be transported for reuse or recycling to out-of-state facilities.

States such as Maine, that have a different classification procedure for waste oil, have some plants that will accept soils contaminated with waste oil, providing specified analytical characteristics are met. These plants are licensed as Class A recycling facilities. The same hot-mix licensing issues regarding waste oil contaminated soils also apply to the cold mix process performed off-site.

Availability of Services and Materials. These process options both use practices and materials common in the construction/paving industry. The availability of an off-site batch plant which will accept soil that is contaminated with a waste oil is currently limited to out-of-state locations.

4.4.3 Cost

For strictly comparison purposes, costs were based upon excavating and batching the top 2 feet across the site (38,400 tons) and hot spot areas (1,000 tons). Approximate capital costs for the two asphalt batching processes are shown below:

On-site Asphalt Batching (Cold Mix):	$2.6 Million
Off-site Asphalt Batching (Cold Mix):	$4 Million plus transportation costs

On-site cold mix asphalt batching costs are based on approximately $36 per ton treatment costs and are detailed in Section 5.0 and 6.0.

Off-site cold mix asphalt batching costs are based on an off-site treatment cost of $75 per ton ($2,880,000); approximately $81,000 for excavation; approximately $283,000 to backfill the site (bank run material); and a 25% contingency for unaccounted for details (as was applied for on-site batching).

4.4.4 Process Option Selection

Due to the higher cost and limited availability of an off-site batch plant licensed to handle AOCs 44 and 52 soils, only on-site cold mix asphalt batching has been retained for further evaluation.

4.5 THERMAL TREATMENT

The two process options retained for further evaluation are thermal desorption and incineration. Thermal desorption units have been included in the ROD for one or more operable units at approximately fourteen Superfund sites. Thermal desorption describes ex-situ processes that use either direct or indirect heat exchange to vaporize organic contaminants from soils. Thermal desorption systems are physical separation processes and are not specifically designed to provide organic decomposition. Thermal desorption is not incineration, since the decomposition of organic contaminants is not the desired result, although some decomposition may occur. The concentration of contaminants and the specific cleanup levels for the site will influence the technology's applicability for that site. Thermal desorption separates the contaminant from the solid medium to an off-gas stream where the vapors are either treated directly or condensed before treatment. Vapor or liquid phase treatment includes: carbon adsorption, catalytic or thermal oxidation, condensation, and/or chemical neutralization. The total volume of chemicals requiring subsequent treatment is typically small in comparison to the volume of contaminated medium at any given site. Thermal desorption may be viewed as a step in the sequence of remediating a site where isolating and concentrating the contaminants is useful. The technology must be used in concert with other treatment technologies.

Incineration technologies utilize high temperature oxidation under controlled conditions to destroy organic constituents in liquid gaseous and solid wastestreams. Various proven technologies suitable for on-site incineration are currently on the market. These major types of combustion chamber configuration are available: rotary kiln, infrared and fluidized bed. These units typically operate in the 1,600 to 2,400 degree F range, and average feed rates are approximately 25 to 200 tons per day. Air pollution control equipment is necessary to meet applicable emissions limits for incinerators.

4.5.1 Effectiveness

Long-Term Effectiveness. The thermal desorption technology described herein would be effective in separating TPHC, VOCs and SVOCs from contaminated soil. Bench-scale treatability studies would be required to determine what temperature would be needed to attain total cPAHs cleanup level and to estimate the quantity of oil, if any, that might be generated. Most inorganic constituents are not effectively removed by thermal desorption.

A destruction and removal efficiency greater than 99.9999 percent for hazardous organics in soils has been demonstrated for incineration. Because most of the contaminants are permanently destroyed, incineration significantly reduces the toxicity and mobility of organic contaminants. However, the mobility of heavy metals may increase after incineration.

Treated soil may be disposed back into the excavation providing soil does not exhibit characteristics of toxicity due to metal contaminant concentrations as determined by the TCLP.

Short Term Effectiveness. The potential effects on the community, workers, and the environment would be minimal with thermal desorption because all systems share the requirement for treatment of residuals and off-gas produced by the unit. Since the treated medium is typically dry, less than one percent moisture spraying and mixing with clean water is often used to suppress dust generation. The vaporized organic contaminants can be captured in the off-gas by passing it through a carbon adsorption bed or other treatment system. Emissions may also be destroyed by use of an off-gas combustion chamber (after burner) or a catalytic oxidation unit. When the off-gas from a thermal desorption unit is condensed, the resulting water stream may contain significant contamination depending on the boiling points and solubility of the contaminants, and may require further treatment (e.g., carbon adsorption). If the condensed water is relatively clean, it may be used to suppress dust from the treated medium. If carbon adsorption is used to remove contaminants from the off-gas or condensed water, spent carbon will be generated which is either returned to the supplier for reactivation/incineration or regenerated on-site. When off-gas is treated by a combustion process, compliance with incineration emission standards may be required. Demonstration of permit compliance through test burn trials may be advantageous, however, the incineration of exhaust gas would not leave residuals requiring further treatment. If incineration is used, the heat from the incineration process may be used in the thermal desorption process.

With the incineration process option, air quality impacts from incinerators can pose a potential risk to downwind receptors during remedial action. Potential adverse effects as a result of implementing incineration include: releases of low levels of products of incomplete combustion during process upsets, and releases of particulate matter containing metals. Air monitoring of particulates and organic compounds would have to be conducted to prevent exceedance of national and local air quality standards. Incineration systems do not pose significant safety hazards when operated by trained personnel in a properly controlled facility. Incineration systems are equipped with automatic feed shut-off controls in case of process upsets.

Reduction of Toxicity, Mobility, or Volume through Treatment. Incineration has demonstrated destruction and removal efficiency greater than 99.999 percent for hazardous organics in soil. Because most of the contaminants are permanently destroyed, incineration significantly reduces the toxicity and mobility of organic contaminants such as TPHC and cPAHs.

The thermal desorption unit does not destroy the contaminants but separates the organic contaminants from the soil to an off-gas stream. Although toxicity, mobility and volume of contaminants in the soil would be reduced, a residual off-gas waste stream is created which requires further treatment. Off-gases are either directly treated as a gas or condensed and treated as a liquid. It is anticipated that the contaminants at AOCs 44 and 52 may be treated in a thermal desorption unit with catalytic or thermal oxidation for off-gas treatment, which would destroy most of the contaminants. Large pieces of paving in the soil would probably need to be mechanically screened from the soil prior to soil treatment and disposed off-base.

4.5.3 Implementability

Technical Feasibility. Compliance with the technical requirements of air emission permits would be required for the thermal desorption process option. These requirements specify effluent quality criteria and monitoring requirements. Thermal desorption units are owned and operated by several independent service companies. These units may be mobile and brought to the site on over-the-road vehicles.

Incineration is technically feasible and proven for the destruction of organic contaminants over a wide range of concentrations. Incineration systems have been successfully demonstrated for soils contaminated with VOCs, cPAHs and TPHCs. The incineration technology has been used for remediation at numerous

Superfund sites. Mobile units capable of treating 75 tons of soil per day are currently available. Several commercial vendors and remediation companies market incineration equipment. Trial burns are required to demonstrate the ability of incinerators to achieve required standards. Compliance with the technical requirements of air emission permits also would be required for incineration.

4.5.4 Cost

Estimated costs for the two thermal technologies are as follows:

Thermal Desorption: $4.7 to $7.3 million
Incineration: $11.2 to $13.2 million

Costs include mobilization/demobilization and, for strictly cost comparison purposes, are for the treatment of approximately 40,000 tons of soil from AOCs 44 and 52. (Treatment of the top 2 feet of soil and hot spots). Costs also include a 25% contingency for undeveloped details.

Thermal desorption costs are based on a treatment cost of $90 to 140/ton ($3,816,000 to $5,836,000); approximately $81,000 for excavation; approximately $99,000 to backfill the site with treated soil; No cost was included for disposal of potential residual oil because the relatively low contaminant concentration would not produce residual oil with the process that uses thermal oxidation for off-gas treatment.

Incineration costs are based on a treatment cost of $250 to $300/ton ($10,000,000 to $12,000,000); $1,000,000 for mobilization; approximately $81,000 for excavation; approximately $99,000 to backfill the site with treated soil.

4.5.5 Process Option Selection

The thermal desorption technology option was retained because it can achieve the same environmental goals, in combination with ancillary off-gas processes, as incineration at a much lower cost.

TABLE 4-1
PROCESS OPTION EVALUATION
MAINTENANCE YARDS
FORT DEVENS, MASSACHUSETTS

RESPONSE ACTION / REMEDIAL TECHNOLOGY	PROCESS OPTION	RATIONALE
NO ACTION :		
NONE	NOT APPLICABLE	
LIMITED ACTION :		
ENVIRONMENTAL MONITORING	GROUNDWATER MONITORING	
INSTITUTIONAL CONTROL	LAND USE	
ACCESS CONTROL	FENCING AND SIGNS	
CONTAINMENT:		
CAPPING	ASPHALT	Both capping options are equally effective, however asphalt has a lower capital cost than concrete.
	CONCRETE (screened out)	
COLLECTION:		
EXCAVATION	BULLDOZER & BACKHOE	
IN-SITU TREATMENT:		
BIOLOGICAL	BIOVENTING	Landfarming may be more effective at treating the top 2 feet of soil but would entail greater disruption of current yard activities. Both process options are retained.
	LANDFARMING	

Process options that are screened out.

TABLE 4-1 (continued)
PROCESS OPTION EVALUATION
MAINTENANCE YARDS
FORT DEVENS, MASSACHUSETTS

RESPONSE ACTION / REMEDIAL TECHNOLOGY	PROCESS OPTION	RATIONALE
EX-SITU TREATMENT:		
BIOLOGICAL	COMPOSTING	
PHYSICAL	OFF-SITE ASPHALT BATCHING	Many off-site facilities are not licensed to treat soils contaminated with waste oil. Transportation costs and higher treatment costs make off-site asphalt batching less cost effective.
	ON-SITE ASPHALT BATCHING	
	SCREENING	
THERMAL	INCINERATION	Both treatment processes can potentially destroy organic contaminants. Thermal desorption units are more readily mobilized and have lower overall costs.
	THERMAL DESORPTION	
DISPOSAL:		
ON-BASE DISPOSAL	LANDFILL	
OFF-BASE DISPOSAL	LANDFILL	

Process options that are screened out.

5.0 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

Technologies and process options retained for further analysis are those that contain or actively remediate the soils at AOCs 44 and 52. These individual technologies and process options were combined to develop a range of remedial alternatives to meet the remedial action objectives stated in Section 2.1. Additionally, consideration was given to assembling alternatives that would reduce contaminants in subsurface soils (soils below 2 feet in depth) towards background levels.

5.1 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Remedial alternatives were developed by combining technologies and process options retained from Sections 3.0 and 4.0 (Tables 3-1 and 4-1). Table 5-1 presents the technologies assembled for each remedial alternative. Those technologies which are used in a given alternative are marked with an X. Alternatives are also broken down into two actions; those which may be undertaken on the Cannibalization Yard mogas spill and leaking UST soils (herein identified as "hot spot areas") listed in the "C" column and those which may be undertaken on the entire Maintenance Yards listed in the "M" column. For an example, Alternative 8 will entail groundwater monitoring, mechanically screening pavement pieces from the surface soils and in-situ landfarming for the entire Maintenance Yards; and excavating, spreading and landfarming of those soils associated with the hot spot areas. These alternatives are described in the following subsections and screened in Section 5.2. Table 5-2 through 5-12 summarize the advantages and disadvantages of the alternatives based on the criteria of effectiveness, implementability and cost.

For all alternatives requiring excavation, soils will be excavated, stockpiled, sampled and analyzed following an approved Excavated Soils Management Plan (ESMP) which will be written in accordance with the General Management Procedures for Excavated Waste Site Soils at Fort Devens (ABB-ES, 1994). The ESMP will contain the following elements, at a minimum:

- a brief description of the site and its history
- a discussion of the nature of soil contamination

- a summary of pre-excavation data
- an estimate of the volume of soil to be excavated
- a plan for interim soil disposition (e.g., stockpiling)
- a plan for post-excavation sampling and analysis
- a plan for final soil disposition (i.e., re-use/treatment/disposal).

Costs which were developed for the alternative screening were based on an assumption that the soil volume to be removed or treated in the hot spot areas equals approximately 700 cy or 1,000 tons of soil.

Costs for alternatives entailing excavating the top 2 feet of across the site were based on the assumption that approximately 50% of the soil excavated will exceed cleanup levels. This estimate was based on the belief that the highest concentration of cPAHs are in the top 1 foot of soil due to pavement and on SI data which indicates that surface soil samples from 11 of the 16 borings potentially exceed a 7 ppm total carcinogenic PAH cleanup level. A total of 6 of 16 surface soil boring samples are close to or exceed the 500 ppm TPHC cleanup level.

5.1.1 Alternative 1: No Action

The No Action Alternative includes sampling of groundwater monitoring wells and catch basins located within and downgradient of AOCs 44 and 52. The No Action Alternative does not involve remedial actions to control migration of contaminants or institutional controls to prevent exposure to contaminated soils within the Maintenance Yards but does include a "limited action" (groundwater monitoring). This "limited action" is permissible in accordance with CERCLA guidance under a No Action alternative.

Although there are no data indicating that off-site migration of contaminants is a problem, sampling of groundwater from six wells and stormwater/sediment from the two AOC 44 and 52 catch basins would be performed on a yearly basis for a five year period to monitor for any potential migration of contaminants. No action would be taken to remediate AOCs 44 and 52 soils. Alternative 1 is developed to provide a baseline for comparison with the other remedial alternatives.

5.1.2 Alternative 2: Fencing/Asphalt Batching Hot Spot Areas

This alternative combines a number of "limited action" technologies for AOCs 44 and 52 soils and a treatment technology. Preventing access by maintaining fencing around the site would minimize potential exposure pathways, thus mitigating future risk to public health. Deed and land use restrictions would act as an institutional control to ensure that the fence remained intact in the future and during resale of the property. Implementation of this deed restriction would require negotiation and agreement between several parties involved.

Excavation and asphalt batching soil which exceeds cleanup levels from the hot spot areas in the Cannibalization Yard would reduce the mobility of organic contaminants present in the highest concentrations at the site, thus affording a reduction in total mobile contaminants. Batched soil would be placed on the surface of part of the site. Sampling and analysis of groundwater within or downgradient of AOCs 44 and 52 would also be performed to monitor any adverse effects on the groundwater beneath the site. Sampling and analysis of stormwater and sediment from catch basins proximate to the site would be performed to monitor for off-site runoff of contaminants. This limited action alternative does not involve remedial actions to control migration of contaminants off-site, yet it does monitor for off-site migration.

5.1.3 Alternative 3: Capping Site/Asphalt Batch Hot Spot Areas

Alternative 3 entails excavating and asphalt batching soils exceeding cleanup levels from the hot spot areas, capping the entire site with asphalt pavement and groundwater monitoring. Capping with bituminous pavement would minimize potential exposure pathways, thus mitigate future risk to public health. Details of the cap construction are discussed in Section 4.1. Capping will increase the amount of runoff during rain events and will potentially transport any contaminants which might result from continued use of the yards to Cold Spring Brook (which would otherwise deposit in the soils at AOCs 44 and 52 without the cap). Therefore costs include expansion of the existing stormwater collection system which could entail installing up to 12 additional catch basins, 14 oil and grease traps, and additional 18-inch and 30-inch diameter piping. Additionally, investigations would be performed to determine what impacts the increased flow will have on the wetlands. Potentially, a retention basin and flow reducers will need to be incorporated into the design to minimize impacts on the wetlands.

Deed and land use restrictions would act as an institutional control to ensure that the cap remained intact in the future.

Excavation and asphalt batching hot spot areas in the Cannibalization Yard would reduce the mobility of organic contaminants present in the highest concentrations at the site, thus affording a reduction in total mobile contamination. Asphalt batched material from the hot spots can be used as capping material, decreasing capping material costs. Details of the asphalt batching technology are discussed in Section 4.4. Sampling and analysis of groundwater within and downgradient of AOCs 44 and 52 would also be performed to monitor the groundwater beneath the site.

5.1.4 Alternative 4: Capping Site/Bioventing Hot Spot Areas

Alternative 4 is similar to Alternative 3 except that the hot spot areas are treated in-situ with bioventing instead of excavating and asphalt batching the soil. Capping the entire site with asphalt pavement, deed and land use restrictions and groundwater monitoring would be as discussed in Alternative 3. Bioventing the hot spot areas in the Cannibalization Yard would reduce the volume of contaminants present in the highest concentrations at the site. Details of the bioventing technology are discussed in Section 4.3. Costs for this alternative include initial nutrient injection in the areas by tractor, and installation of approximately 8 bioventing wells to a 28 foot depth, with associated piping, blower, and humidifier. O&M, as well as process monitoring to ensure cleanup levels, are performed for a period of 10 years. The cap required to prevent short circuiting of air will be provided by the asphalt paving installed over the site. Costs for the cap also include expansion of the existing stormwater collection system as detailed in Alternative 3. Treatability studies have been conducted to evaluate the effectiveness in reducing cPAH and TPHC concentrations within AOCs 44 and 52 soils as summarized in Section 1.4.3.

5.1.5 Alternative 5: Asphalt Batching Site/Asphalt Batching Hot Spot Areas

Alternative 5 entails excavating the top two feet of soil across the Maintenance Yards and contaminated soils in the hot spot areas; placing excavated soils in piles at the site for sampling and analysis; asphalt batching soils which exceed site cleanup levels; and performing groundwater monitoring at AOCs 44 and 52. Soil with concentrations below the cleanup criteria will be placed back in the excavation area. Asphalt batching would immobilize the contaminants exceeding cleanup levels present in the top 2 feet, thus minimizing direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Additionally, potential of contaminant migration off-site is minimized. Costs include expansion of the existing stormwater collection system as required and discussed for capping; and excavating, sampling and analysis of the soil, batching, and putting the material back in place. A pavement wearing course placed over the batched material was not included in the cost as it reportedly would not be required by the MADEP (per discussion with MADEP during June 28, 1993 Draft FS Review Meeting) for this remedial action.

Excavation and asphalt batching hot spot areas in the Cannibalization Yard would reduce the mobility of organic contaminants present in the highest concentrations at the site.

5.1.6 Alternative 6: Asphalt Batching Site/Bioventing Hot Spot Areas

Alternative 6 is similar to Alternative 5 except that the hot spot areas would be treated in-situ with bioventing instead of excavating and asphalt batching. Bioventing details for the hot spots would be similar to those discussed in Alternative 4.

5.1.7 Alternative 7: Bioventing Site and Hot Spot Areas

Alternative 7 entails bioventing the entire site and the hot spot areas, and performing groundwater monitoring. Bioventing will reduce the contaminants present in the top 2 feet thus minimize direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Additionally, the concentrations of the contaminants of concern are reduced towards background levels in depths below two feet over the site area as well as in the hot spot areas. Because the bioventing system requires a cap to prevent short circuiting of air, the potential of contaminant migration off-site is immediately minimized upon construction of the cap. Details of the bioventing technology are discussed in Section 4.3. As summarized in Section 1.4.3 and detailed in the biological treatability report (ABB-ES, 1993b), bioventing may take twice as long for remediation as landfarming and composting, thus may not be an effective alternative.

Costs for this alternative include initial nutrient injection in the areas by tractor; installation of approximately 20 bioventing wells to a 28 foot depth, with associated piping, blower, and humidifier; operation and maintenance costs as well as process monitoring to ensure cleanup levels are obtained for a period of 5 years. To permit continued use of the site, the cap required to prevent short circuiting of air will be constructed of asphalt paving installed over the entire area of the site. Costs also include expansion of the existing stormwater collection system as required and discussed for capping. Soils excavated for installation of the stormwater collection system expansion and bioventing system will be spread out over the site for treatment by the bioventing system.

5.1.8 Alternative 8: Landfarming Site/Excavating and Landfarming Hot Spot Areas

Alternative 8 entails landfarming the entire site, excavating and landfarming the soil exceeding cleanup levels from the hot spot areas, and performing groundwater monitoring. As a pre-treatment process, surface soil in areas of the site containing bituminous pavement pieces will be mechanically screened to remove large sized fragments (see Section 3.2.5 regarding mechanical screening). Screened debris and pavement will be cleaned of soil and disposed off-site. It is anticipated that most pavement fragments are located within the top 6 inches of soil. Screening will be limited to only soil containing pavement. Screened soil will be spread for landfarming. Landfarming will reduce the contaminants present in the top 2 feet, thus minimize direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Additionally, the concentration of the contaminants of concern could be reduced towards background levels in depths below two feet over the site area by applying excess nutrients and water to the soil surface. As previously discussed in Section 1.4.3, treatability studies have been conducted to evaluate the effectiveness of landfarming in reducing cPAH and TPHC concentrations within AOCs 44 and 52 soils. Details of the landfarming technology are discussed in Section 4.3.

Costs for this alternative include purchasing a tractor for tilling and irrigating; mechanically screening the soil to remove the pavement and off-site disposal of this debris; excavation of hot spot areas and spreading this soil over the site to be landfarmed; initial nutrient injection in the soils by tractor; removal of the two catch basins within the Maintenance Yards and providing siltation fences and regrading as needed to minimize runoff; dust control and monitoring; and operation, maintenance and process monitoring of the remediation for an estimated seven years.

To enable the Maintenance Yards to be used in part during remediation, design would be based on treating 20 percent of the yards for up to five years while the other 80 percent remained functional as maintenance yards. After the Maintenance Yards close, the remaining area would be remediated requiring up to five more years. Assuming remediation starts in 1994 and the Maintenance Yards close in 1996, remediation would be expected to be complete by 2001.

5.1.9 Alternative 9: Treatment of Site and Hot Spot Area Soils at a Central Soil Treatment Facility

Alternative 9 entails excavating the top two feet of soil across the site and contaminated soils in the hot spot areas; placing excavated soils in piles at the site for sampling and analysis; transporting soils which exceed site cleanup levels to a central soil treatment facility on-base; and performing groundwater monitoring at AOCs 44 and 52. As a pre-treatment process, surface soil in areas of the site containing bituminous pavement pieces will be mechanically screened to remove large sized fragments as detailed in Section 5.1.8. Screened debris and pavement will be transported to the central soil treatment facility for crushing and asphalt batching or disposed of off-base. Details of this alternative are discussed below.

The top 2 feet of soil from approximately 20% of the yards (west end of the yards) will be excavated first. This phase of the remediation will serve as a pilot test for windrow composting treatment. Estimates of contaminated soil volumes will be confirmed and biodegradation rates will be better defined at this time. The remaining 80% of the Maintenance Yards will continue to be utilized by the Army and will not be remediated as part of Alternative 9 until the yards close in 1996. Following excavation of the top 2 feet from 20% of the yards, the hot spot areas will be excavated. Soils will be excavated, stockpiled, sampled and analyzed following an approved ESMP as detailed in Section 5.1.

Soil with TPHC concentrations exceeding 500 ppm or the risk-based cleanup criteria for total carcinogenic PAHs will be transported to the central soil treatment facility located on base. Soil with concentrations below the cleanup criteria will be placed back in the excavation area. The mechanically screened pavement material and debris will also be transported to the central soil treatment facility. Soils which are impractical to treat at the central soil treatment facility will be treated or disposed of at a licensed facility off-base

It is proposed that the facility, as described in the Siting Study Report (ABB-ES, 1994a) be designed with a variety of soil treatment methods in mind. The environmental regulators have, by policy, expressed a preference for re-use of the soil at Fort Devens as opposed to removal off-site for landfilling. Consequently, treatment methods used will predominantly result in re-use of soils in accordance with the approved General Management Procedures for Excavated Waste Site Soils at Fort Devens (ABB-ES, 1994). The two treatment methods proposed at the facility which would be likely used for treatment of AOCs 44 and 52 soils include:

Bioremediation by Windrow or Static Pile Composting. The concept of soil composting is to provide the proper environmental conditions for organic-degrading soil microorganisms present in the soil. Proper environmental conditions generally consist of providing oxygen, mineral nutrients, and adequate soil moisture, and controlling pH. Windrow composting consists of spreading and treating soil in long windrow piles. Oxygen is supplied to soil microorganisms by mechanical turning or mixing of the soil. An inert bulking agent may be added to soils in order to increase the soil permeability to air and moisture retention. Mineral nutrients, soil moisture and pH control are provided to soil microorganisms through the addition and mixing in of these amendments to the soil. The soil mixture is formed into windrows approximately 12 feet wide and 5 feet deep and extend the length of a lined treatment pad which has berms and runoff containment. The windrow composting operation consists of turning/mixing the soil windrow once per week using a horizontal auger for approximately 32 weeks per treatment season (mid-March through October). Appropriate soil moisture, mineral nutrient and pH concentrations would be maintained in the soil windrows during the treatment season.

The concept of static pile composting is the same as for windrowing except that soil is placed in piles and aerated with a fixed piping system that draws air through the soil instead of exposing the soil to the air by mechanical turning. Static piles may be more practical for soils when contaminants are more volatile. Emissions may be more readily controlled by covering the pile with plastic. Covering static piles is also useful for dust, and moisture control.

The majority of the soil from AOCs 44 and 52 is expected to be treated using the windrow composting method because of the non-volatile nature of the predominant contaminants.

Cold Mix Asphalt Batching. Cold mix asphalt batching, which is a technology which entails recycling petroleum contaminated soil into a bituminous paving or road base product, is described in Section 4.4.

Asphalt batching may be practical for treatment of soils at AOCs 44 and 52 containing extremely high concentrations of multi-ringed cPAHs and heavier molecular weight TPHC compounds such as those found in motor oils. Although these compounds are biodegradable, the need for large concentration reductions can result in uneconomically lengthy treatment times using windrow composting.

It may also be possible to crush the mechanically screened asphalt material and rocks hauled from AOCs 44 and 52. This material could then be used as an aggregate supplement for asphalt batching soils at the treatment facility.

Excavated soil which is unsuitable for treatment (if any) at the central soil treatment facility will be disposed of off-base at an approved treatment/disposal facility.

Alternative 9 will reduce the contaminants present in the top 2 feet and hot spot areas excavated. Soils with contaminants exceeding cleanup levels would be removed from the site when the Maintenance Yards close permitting immediate reuse of the site. This will meet the remedial objectives of minimizing direct contact/ingestion and inhalation of the soils having a carcinogenic risk. As discussed for bioventing and landfarming, treatability studies and available literature indicate that the TPHC and cPAHs contaminants in AOCs 44 and 52 soils are biodegradable.

Costs for this alternative include excavation of the top two feet of soil in the yards and hot spot areas; mechanically screening of soil to remove large pavement pieces; stockpiling the soil for sampling and analysis; hauling soil with contaminants exceeding cleanup concentrations to the treatment facility; initial addition of nutrients and bulking agents (if required); construction, operation, and maintenance of the facility for up to 4 years (assuming treatment of 2 batches) and asphalt batching an estimated 3,400 cubic yards of soil anticipated to otherwise have excessive bioremediation treatment time. Cost for backfilling the site is included.

5.1.10 Alternative 10: Thermal Desorption of Site and Hot Spot Areas

Alternative 10 entails excavating the top two feet of soil across the site and contaminated soils in the hot spot areas; placing excavated soils in piles at the site for sampling and analysis; treating soils which exceed site cleanup levels in a thermal desorption unit on-site; and performing groundwater monitoring at AOCs 44 and 52. As a pre-treatment process, surface soil in areas of the site containing bituminous pavement pieces will be mechanically screened to remove large sized fragments as detailed in Section 5.1.8. Screened debris and pavement will be transported off-site for disposal. Soils will be excavated, stockpiled, sampled and analyzed following an approved ESMP as detailed in Section 5.1.

The thermal desorption process option is discussed in detail in Section 4.5. Thermal desorption will reduce the contaminants present in the top 2 feet and hot spot areas excavated. This will meet the remedial objective of minimizing direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Since contaminant concentration is reduced, the potential for off-site migration of contaminants is also minimized.

Costs for this alternative include mobilization of a thermal desorption unit, excavation, sampling and analysis, treatment costs, backfilling and off-site disposal of pavement and other screened debris. No cost was included for disposal of potential residual oil because the relatively low contaminant concentration would not produce residual oil with the process that uses thermal oxidation for off-gas treatment. Water used for air pollution control may be sprayed onto the soil to be treated for dust control measures.

5.1.11 Alternative 11: Off-Site Disposal

Alternative 11 entails excavating the top two feet of soil across the site and contaminated soils in the hot spot areas; placing excavated soils in piles at the site for sampling and analysis; disposing of soils which exceed site cleanup levels in a permitted landfill; and performing groundwater monitoring at AOCs 44 and 52. Soils will be excavated, stockpiled, sampled and analyzed following an approved ESMP as detailed in Section 5.1.

Excavation and disposal will reduce the contaminants present in the top 2 feet and hot spot areas excavated. This will meet the remedial objectives of minimizing direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Since contaminant concentration is reduced, the potential for off-site migration of contaminants is also minimized.

Costs are for excavation, sampling and analysis, disposal and backfilling the site. MADEP does not typically consider the disposal of petroleum-contaminated soils in landfills to be a preferred alternative (MADEP Policy #WSC-400-89, 10.2.22). Furthermore, in-state landfills will only accept soils contaminated with used waste oil upon approval by the MADEP.

5.2 SCREENING OF REMEDIAL ALTERNATIVES

Remedial alternatives developed in Section 5.1 are screened based on effectiveness, implementability and cost. The objective of this screening step is to eliminate from further consideration alternatives that would be disadvantageous in these areas, while still preserving a range of options. For each alternative, a matrix was developed highlighting the alternative's advantages and disadvantages with respect to effectiveness, implementability, and cost criteria. Based on this matrix, a decision was made to either retain the alternative for detailed evaluation or eliminate the alternative from further consideration. The alternative screening process is presented in Tables 5-2 through 5-12.

5.3 SUMMARY OF REMEDIAL ALTERNATIVE SCREENING

Eleven remedial alternatives were initially developed and screened. The screening process included the comparison of similar remedial alternatives and the conclusion to eliminate less desirable alternatives. The screening of each alternative relative to effectiveness, implementability, and cost criteria is presented in Tables 5-2 through 5-12.

Remedial Alternatives 1, 2, 3, 5, 7, 8, and 9 were retained for further evaluation.

The No Action alternative was retained as a baseline for comparison to the other six remaining alternatives (see Table 5-2). Alternative 1 relies on groundwater and catch basin stormwater/sediment sampling and analysis to monitor for potential migration of contaminants off-site.

Alternative 2 incorporates access and institutional controls in the form of fencing and deed restrictions to minimize the public health risk. It also entails asphalt batching the known hot spot areas. Although the objectives to reduce off-site run-off and infiltration of contaminants are not directly met in Alternative 2, there is no data that indicates that these are problems if the site is not remediated. This alternative does monitor these objectives by including sampling and analysis of groundwater and stormwater/sediment. Alternative 2 was retained for detailed evaluation (see Table 5-3).

Alternative 3, which entails excavating and asphalt batching the hot spot areas, capping the entire site with asphalt pavement, and groundwater monitoring was retained since it addresses all the remedial objectives (see Table 5-4). However, as with Alternative 2, deed restrictions would be required.

Alternative 5, which also was retained, incorporates asphalt batching soil exceeding cleanup levels in the top two feet across the site and the hot spot areas, and monitoring of the groundwater (see Table 5-6). As with Alternative 3, all the objectives are met. However, with this alternative the health risk is minimized (at additional cost) by immobilizing the contaminants instead of by containment. Institutional controls would not be required.

Alternative 7 incorporates bioventing for in-situ treatment of AOCs 44 and 52 soils including the hot spot areas. It too meets all the remedial objectives;

however, the alternative may require a relatively long time (estimated to be 10 years) to be effective. However, since bioventing will potentially reduce contaminant concentrations at lower depths than the other alternatives at comparable cost, it was retained (see Table 5-8).

Alternative 8, involving landfarming, was retained because it can meet the remedial objectives with similar effectiveness as bioventing but at lower cost (see Table 5-9).

Alternative 9, involving excavation and treatment at an on-base central soil treatment facility, was retained because it removes contaminants in surface soils and hot spot areas from the site and treats the soils in a controlled treatment facility environment away from the Zone II of a public water supply. The facility provides the greatest flexibility in soil management and treatment, but also has a relatively high cost (see Table 5-10).

Alternatives 4 and 6 utilize bioventing of the hot spot areas instead of asphalt batching. These alternatives were eliminated since they did not offer any significant advantage over Alternatives 3 and 5, respectively; would take longer to implement; and were more expensive (see Tables 5-5 and 5-7).

Alternatives 10 and 11, entailing thermal desorption and off-site disposal, respectively, were eliminated because they too did not offer any significant advantage in effectiveness or implementability over the other alternatives to justify the relatively high costs (see Tables 5-11 and 5-12).

Remedial alternatives 1, 2, 3, 5, 7, 8 and 9 will be evaluated in Section 6.0 based on seven of the nine CERCLA criteria.

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TABLE 5-1
REMEDIAL ALTERNATIVE DEVELOPMENT
MAINTENANCE YARDS FEASIBILITY STUDY

RESPONSE ACTION/ TECHNOLOGY	ALTERNATIVE[a]																					
	1		2		3		4		5		6		7		8		9		10		11	
	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C
NO ACTION	X	X																				
LIMITED ACTION																						
Environmental Monitoring	X		X		X		X		X		X		X		X		X		X		X	
Access Controls (Fencing)			X																			
Institutional Controls (Deeds)			X		X		X															
CONTAINMENT																						
Asphalt Capping					X		X						X	X								
COLLECTION/REMOVAL																						
Excavation				X	X[b]	X	X[b]	X[c]	X	X	X	X[c]	X[c]	X[c]		X	X	X	X	X	X	X
IN-SITU TREATMENT																						
Bioventing								X				X	X	X								
Landfarming															X	X						
TREATMENT																						
Screening															X		X		X			
Composting																	X	X				
On-Site Asphalt Batching				X		X			X	X	X						X[e]	X[e]				
Thermal Desorption																			X	X		
DISPOSAL																						
On-Base																						
Off-Base Landfill															X[d]				X[d]		X	X

Alternative Description

(1) No Action - No Remedial Work; Only Environmental Monitoring
(2) Fencing/Asphalt Batch Hot Spot Areas
(3) Capping Site/Asphalt Batch Hot Spot Areas
(4) Capping Site/Bioventing Hot Spot Areas
(5) Asphalt Batch Site/Asphalt Batch Hot Spot Areas
(6) Asphalt Batch Site/Biovent Hot Spot Areas
(7) Bioventing Site and Hot Spot Areas
(8) Landfarming Site/Excavating and Landfarming Hot Spot Areas
(9) Treatment of Site & Hot Spot Areas at a Central Soil Treatment Facility
(10) Thermal Desorption of Site and Hot Spot Areas
(11) Excavate Site and Hot Spot Areas and Dispose Off-Site

[a] NOTE: C = Action taken on Cannibalization Yard Mogas and Leaking Underground Storage Tank Soils (Hot Spot Areas)
M = Action taken on entire Maintenance Yards
X = Indicates use of a Technology for the Alternative

[b] Excavation required for stormwater system expansion
[c] Excavation required for installing bioventing system
[d] Disposal of screened pavement and stone
[e] Batching performed at central treatment facility

TABLE 5-2
ALTERNATIVE 1: NO ACTION

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of groundwater monitoring.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• The objectives to reduce off-site runoff and infiltration of contaminants are not met, but this alternative does monitor these objectives.	• Would be easy to implement.	• No action is the least expensive alternative at this site (approximately $35,000/year for five years for environmental monitoring). • Existing wells are used so there will be no capital costs.
Disadvantages	Disadvantages	Disadvantages
• Would not reduce the toxicity, mobility, or volume of contaminants. • Would continue to exceed the USEPA acceptable risk range for human health risks. • Would not reduce the potential for off-site impacts, if any, due to contaminants in groundwater and surface water.	• May be more difficult to undertake future remedial actions if contaminants have migrated further from the source.	• Resale of property may be affected as a result of taking no action.

CONCLUSION: **The No-Action Alternative is retained as a baseline for comparing the remedial alternatives.**

TABLE 5-3
ALTERNATIVE 2: FENCING / ASPHALT BATCHING HOT SPOT AREAS

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating and asphalt batching the hot spot areas in the Cannibalization Yard, maintaining security fencing around the site and obtaining institutional controls to maintain the fence (i.e, deed restrictions) and groundwater monitoring and monitoring of stormwater/sediment from catch basins proximate to the site.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Excavation and asphalt batching hot spot areas would immobilize organic contaminants present in the highest concentrations at the site, thus reducing the concentration of total mobile contaminants. • Fencing would reduce potential exposure to contaminated soil, thus minimizing public health risks. • The objectives to reduce off-site runoff and infiltration of contaminants are not met, but this alternative does monitor these objectives.	• Easily implemented technologies. • Fencing already exists. • Asphalt batching on-site has been approved by the regulators for similar remedial efforts at Fort Devens.	• Relatively low capital costs (approximately $139,000 capital, $35,000/year operation and maintenance for five years for environmental monitoring, and $2,000/year for 30 years for fence maintenance).
Disadvantages	Disadvantages	Disadvantages
• Would not reduce the toxicity, mobility, or volume of contaminants outside hot spot areas. • Would not reduce the *potential* for off-site impacts, if any, due to contaminants in groundwater and surface water.	• May be more difficult to undertake future remedial actions if contaminants have migrated further from the source. • Would require negotiation and agreement between all parties involved in the deed restrictions.	• Deed restriction may affect resale of property. • Long term operation and maintenance.

CONCLUSION: **This alternative was retained for further evaluation because it minimizes public health risks, monitors compliance with off-site runoff of contaminants and groundwater infiltration of contaminants, reduces the concentration of contaminants in hot spot areas and capital costs are relatively low.**

TABLE 5-4
ALTERNATIVE 3: CAPPING SITE / ASPHALT BATCH HOT SPOT AREAS

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating and asphalt batching the hot spot areas in the Cannibalization Yard, capping the entire site with asphalt pavement, obtaining institutional controls to maintain the cap (i.e., deed restrictions) and groundwater monitoring.

Effectiveness	Implementability	Cost
Advantages • Excavation and asphalt batching hot spot areas would immobilize organic contaminants present in the highest concentrations at the site, thus reducing the concentration of total mobile contaminants. • Capping would reduce potential exposure to contaminated surface soil, thus minimizing public health risks. • Capping would reduce the potential for infiltration of contaminants into the groundwater and off-site runoff of contaminants (decrease mobility).	Advantages • Paving is easily implemented. A portion of the necessary paving material will be created as a result of asphalt batching of hot spot soil. • Asphalt batching on-site has been approved by the regulators for similar remedial efforts at Fort Devens. • Effectiveness of implementation would be nearly immediate.	Advantages • Costs are estimated to be low to moderate (approximately $946,000 capital; $19,000/year for 5 years for groundwater monitoring, and $14,000/year for 30 years for cap maintenance.)
Disadvantages • Would not reduce the toxicity, mobility, or volume of contaminants outside hot spot areas and thus would not alleviate the necessity for deed restrictions. • Asphalt pavement contains PAHs, thus more contaminants could be introduced to the Site.	Disadvantages • Would require negotiation and agreement between all parties involved in the deed restrictions. • Would need to upgrade site stormwater drainage system.	Disadvantages • Deed restrictions may affect resale of property.

CONCLUSION: **This alternative minimizes public health risk, reduces the concentration of contaminants in the hot spot areas, reduces off-site runoff of contaminants, minimizes infiltration of surface water through contaminated soils, monitors groundwater quality, and maintains a low to moderate cost and therefore, will be retained for further consideration.**

TABLE 5-5
ALTERNATIVE 4: CAPPING SITE / BIOVENTING HOT SPOT AREAS

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of bioventing the hot spot areas in the Cannibalization Yard, capping the entire site with asphalt pavement, obtaining institutional controls to maintain the cap (i.e., deed restrictions) and groundwater monitoring.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Bioventing hot spot areas reduces the concentration of site contaminants present in high concentrations. • Capping reduces potential exposure to surface soil, thus minimizing public health risks. • Capping reduces potential for infiltration of contaminants into the groundwater and off-site runoff of contaminants (decrease mobility).	• Paving is easily implemented.	• Costs estimated to be low to moderate (approximately \$906,000 capital; \$19,000/year for 5 years of groundwater monitoring, \$14,000/year for 30 years of cap maintenance, \$10,000/year for 5 years of bioventing operation and maintenance, and \$17,000/year for 5 years of process monitoring.
Disadvantages	Disadvantages	Disadvantages
• Would not reduce the toxicity, mobility, or volume of contaminants in media outside hot spot areas and thus would not alleviate the necessity for deed restrictions. • Treatability testing indicates bioventing may take up to twice as long to reduce TPHC concentrations than with landfarming and composting bioremedial technologies. • Asphalt pavement contains PAHs, thus more contaminants could be introduced to the Site.	• None of the paving material would be generated from the site. All pavement would have to be purchased and delivered. • Would require negotiation and agreement between all parties involved in the deed restrictions. • Effective implementation of bioventing will take 5 years (operation and maintenance involved). • Need to upgrade site stormwater drainage system.	• Deed restrictions may affect resale of property. • Future monitoring, operation and maintenance costs associated with bioventing would be incurred. • On-going remediation beyond time of base closure could impact resale of property.

CONCLUSION: **This alternative has been eliminated from further consideration because it does not better meet the remedial action objectives than Alternative 3 (Capping Site / Asphalt Batch Hot Spot Areas), has a similar cost, and takes substantially longer to implement effectively.**

TABLE 5-6
ALTERNATIVE 5: ASPHALT BATCH SITE / ASPHALT BATCH HOT SPOT AREAS

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating the entire site to a two-foot depth and hot spot areas, stockpiling/sampling/analyzing, asphalt batching soil which exceeds cleanup levels, putting the batched material back in place across the site, and groundwater monitoring.

Effectiveness	Implementability	Cost
<u>Advantages</u>	<u>Advantages</u>	<u>Advantages</u>
• Excavation and asphalt batching hot spot areas would immobilize the organic contaminants present in the highest concentrations at the site, thus reducing the total concentration of mobile contaminants. • Asphalt batching soil exceeding cleanup levels within the two-foot depth would form a cap which would immobilize the organic contaminants and reduce potential exposure to contaminated surface soils, thus minimizing public health risks. • The asphalt cap formed would reduce the potential for infiltration into the groundwater and off-site runoff of any remaining contaminants (decrease mobility).	• Asphalt batching easily implemented. • Asphalt batching on-site has been approved by regulators for similar remedial efforts at Fort Devens. • Effectiveness of implementation would be nearly immediate.	• No deed restriction may allow for easier resale of property.

TABLE 5-6
ALTERNATIVE 5: ASPHALT BATCH SITE / ASPHALT BATCH HOT SPOT AREAS
(Continued)

Disadvantages	Disadvantages	Disadvantages
• Does not reduce overall contamination at depths below 2 feet, outside hot spot areas. • Asphalt contains cPAHs, thus more contaminants could be introduced to the Site.	• Would need to upgrade site stormwater drainage system. • Creates a large volume of pavement which must either be placed back in the excavation (which creates future land use problems) or stockpiled and used elsewhere.	• Moderate cost (approximately \$1,668,000 capital and \$19,000/year for 5 years for groundwater monitoring).

CONCLUSION: **Although this alternative has a moderate cost, it has been retained for further consideration because it is implementable and does not require a deed restriction. It also meets all remedial action objectives; minimizes public health risk, reduces off-site run-off and infiltration of contaminants and also monitors groundwater quality.**

TABLE 5-7
ALTERNATIVE 6: ASPHALT BATCH SITE / BIOVENT HOT SPOT AREAS

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating the entire site to a two-foot depth, stockpiling/sampling/analyzing, asphalt batching soil which exceeds cleanup levels, putting the batched material back in place, bioventing the hot spot areas in the Cannibalization Yard and groundwater monitoring.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Bioventing hot spot areas would reduce the volume of contaminants present in the highest concentrations at the site, thus affording a great reduction of total contaminants. • Asphalt batching the entire site to a two-foot depth forms a cap which would immobilize organic contaminants and reduce potential exposure to contaminated surface soils, thus minimizing public health risks. • The asphalt cap would reduce the potential for infiltration into the groundwater and off-site runoff of any remaining contaminants (decrease mobility).	• Asphalt batching easily implemented. • Asphalt batching on-site has been approved by regulators for similar remedial efforts at Fort Devens.	• No deed restriction may allow for easier resale of property.
Disadvantages	Disadvantages	Disadvantages
• Treatability testing indicates bioventing may take up to twice as long to reduce TPHC concentrations than with landfarming and composting bioremedial technologies. • Does not reduce overall contamination at depths below 2 feet outside hot spot areas. • Asphalt contains cPAHs, thus more contaminants could be introduced to the Site.	• Would need to upgrade site stormwater drainage system. • Effective implementation of bioventing will take five years for reduction of TPHC (operation and maintenance involved).	• Moderate to high cost (approximately $1,595,000 capital, $19,000/year for 5 years for groundwater monitoring, $10,000/year for 5 years for Operation and Maintenance of the biovent system, and $17,000/year for 5 years for process monitoring).

CONCLUSION: **This alternative has been eliminated from further consideration because it does not better meet the remedial action objectives than Alternative 5 (Asphalt Batch Site / Asphalt Batch Hot Spot Areas), takes substantially longer to implement, and is slightly more costly.**

TABLE 5-8
ALTERNATIVE 7: BIOVENTING

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of bioventing the entire site and bioventing of hot spot areas in the Cannibalization Yard and groundwater monitoring. The bioventing system requires installation of a cap to minimize air short-circuiting.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Bioventing has the potential to reduce the toxicity, mobility, and volume of contamination outside the remediation design area because it inherently has a greater depth of influence. • Bioventing would reduce contaminant concentration and reduce potential exposure to contaminated surface soils, thus minimizing public health risk. • By decreasing contaminant concentration and by providing a cap as part of the treatment system the potential for infiltration of contaminants into the groundwater and off-site runoff will be reduced (decrease mobility).	• Less reduction of site functionality than with other bioremediation alternatives.	• Costs are estimated to be low to moderate (approximately $982,000 capital, $19,000/year for 5 years for groundwater monitoring, $22,000/year for 10 years for operation and maintenance of system, $36,000/year for 10 years for process monitoring). • No deed restriction may allow for easier resale of property.
Disadvantages	Disadvantages	Disadvantages
• Reductions in toxicity, mobility, and volume will not occur immediately, but will take several years (10) to reach remediation goals. • Treatability testing indicates bioventing may take up to twice as long to reduce TPHC concentrations than with landfarming and composting bioremedial technologies. • Asphalt pavement contains PAHs, thus more contaminants could be introduced.	• Would need to upgrade site stormwater drainage system. • Effective implementation of bioventing will take 10 years (operation and maintenance involved).	• Future monitoring, operation, and maintenance costs would be incurred. • On-going remediation beyond time of base closure would impact resale of property.

CONCLUSION: **Although this alternative requires a relatively long time (10 years) to be effective, it does maintain a low to moderate cost and does not require a deed restriction. It also meets all remedial action objectives (minimizes public health risk, reduces off-site runoff and infiltration of contaminants and also monitors groundwater quality). Therefore it has been retained for further consideration.**

TABLE 5-9
ALTERNATIVE 8: LANDFARMING

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of landfarming the entire site and excavating and landfarming the hot spot area soils in the Cannibalization yard and groundwater monitoring.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Landfarming would reduce contaminant concentration and reduce potential exposure to contaminated surface soil, thus minimizing public health risk. • By decreasing contaminant concentration, the potential for infiltration of contaminants into the groundwater and off-site runoff will be reduced over the duration of remediation (decrease mobility). • Has potential to reduce the toxicity, mobility, and volume of contamination outside design area.	• Landfarming is easy to implement. • Requires no unique equipment to implement, only common earthworking equipment.	• Costs are estimated to be low to moderate (approximately $545,000 capital [present worth], and about $150,000/year for 7 years for operation, maintenance, and monitoring). • No deed restriction may allow for easier resale of property.
Disadvantages	Disadvantages	Disadvantages
• Reductions in toxicity, mobility, and volume will not occur immediately, but will take several years (7) to reach remediation goals. • Does not reduce overall contamination at depths below two feet outside hot spot areas.	• Site functionality may be curtailed during implementation. • Effective implementation of landfarming will take 7 years (operation and maintenance involved). • Site is located in the Zone II aquifer area of influence. Potential for nutrients reaching groundwater exists.	• Future monitoring, operation, and maintenance costs would be incurred. • On-going remediation beyond time of base closure would impact resale of property.

CONCLUSION: **Although this alternative requires a relatively long time (7 years) to be effective, it does not require a deed restriction and meets all remedial action objectives (minimizes public health risk, reduces off-site runoff and infiltration of contaminants and also monitors groundwater quality). Therefore it has been retained for further consideration.**

TABLE 5-10
ALTERNATIVE 9:
TREATMENT OF SITE AND HOT SPOT AREA SOILS AT A CENTRAL SOIL TREATMENT FACILITY

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating the hot spot areas and the entire site to a depth of two-feet and treating soils exceeding cleanup levels at a central soil treatment facility; and groundwater monitoring.

Effectiveness	Implementability	Cost
<u>Advantages</u>	<u>Advantages</u>	<u>Advantages</u>
• Treatment at the facility would immediately reduce contaminant concentration (soil removed from site) and reduce potential exposure to contaminated surface soil, thus minimizing public health risk. • By decreasing contaminant concentration, the potential for infiltration of contaminants into the groundwater and off-site runoff will be reduced (decrease mobility).	• Composting and asphalt batching are easy to implement, and require only common earthwork practices. • Soils for AOCs 44 and 52 would be removed from the Zone II aquifer area of influence. • Although soil treatment will require extended time at a centralized facility, soil will be removed from the site upon yard closure thus allowing immediate sale of the property.	• No deed restriction may allow for easier resale of property.
<u>Disadvantages</u>	<u>Disadvantages</u>	<u>Disadvantages</u>
• Reductions in toxicity, mobility, and volume will not occur immediately in the soil at the facility but will take several years (estimated at 4 years) to reach remediation goals by composting. • Does not reduce overall contamination at depths below two feet outside hot spot areas.	• All soil intended for remediation will have to be excavated and moved to the central soil treatment facility. • Effective implementation of composting will take approximately 4 years (operation and maintenance involved). • Land area will be required for facility construction.	• Siting of the central soil treatment facility will be required. • Future monitoring, operation, and maintenance costs would be incurred. • Cost estimated to be high (approximately $2,661,000 capital and $204,000/year for 4 yrs.

CONCLUSION: **Although this alternative is expensive, soils would be removed from the Zone II aquifer area of influence for treatment. Treatment at the facility offers great flexibility in soil management and treatment. Therefore, Alternative 9 has been retained for future consideration.**

TABLE 5-11
ALTERNATIVE 10: THERMAL DESORPTION

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating the entire site to a depth of two-feet and the hot spot areas, stockpiling/sampling/analyzing, using the thermal desorption process on soils which exceed cleanup levels, putting the soil back in place after treatment and groundwater monitoring.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Excavation and asphalt batching hot spot areas would reduce the volume of contaminants present in the highest concentrations at the site. • Thermal Desorption will reduce contaminant concentration and reduce potential exposure to contaminated surface soil, thus minimizing public health risk. • By decreasing contaminant concentration, the potential for infiltration of contaminants into the groundwater and off-site runoff will be reduced (decrease mobility).	• Mobil units readily available.	• No deed restriction may allow for easier resale of property.
Disadvantages	Disadvantages	Disadvantages
• Does not reduce overall contamination at depths below two feet outside hot spot areas.	• Possible regulatory compliance issues related to air emissions.	• High Cost (approximately $4,370,000).

CONCLUSION: **Although this alternative meets the remedial action objectives, it has been eliminated from further consideration because of its relatively high cost to implement.**

TABLE 5-12
ALTERNATIVE 11: OFF-BASE LANDFILL

AOC's 44 and 52 Soils
Fort Devens, Massachusetts

This alternative consists of excavating the entire site to a depth of two-feet and excavating the hot spot area soils, stockpiling/sampling/analyzing and disposing of the soil which exceeds cleanup levels in an off-base landfill, and groundwater monitoring..

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• Excavation and off-base disposal of the soils in the hot spot areas would reduce the volume of contaminants present at the site. • Excavation and off-base disposal of the described soils would reduce contamination and reduce potential exposure to contaminated surface soils, thus minimizing public health risk. • By decreasing contaminant concentration, the potential for infiltration of contaminants into the groundwater and off-site runoff will be reduced (decrease mobility).	• Excavation process is simple.	• No deed restriction may allow for easier resale of property.
Disadvantages	Disadvantages	Disadvantages
• Does not reduce overall contamination at depths below two feet outside hot spot areas. • Liability for waste remains while in landfill.	• Necessity to transport in many trucks on highway. • Necessity to backfill site will clean soil.	• Very high cost (approximately $7,000,000).

CONCLUSION: Although this alternative meets the remedial action objectives, it has been eliminated from further consideration because of its high cost and liability issues.

6.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents the detailed analysis of the remedial alternatives for AOCs 44 and 52. This analysis presents the relevant information that allows decision-makers to select an alternative for remediating soil contaminated at the Maintenance Yards. The detailed analysis assesses each alternative which has been retained through the screening step in Section 5.0. Alternatives are evaluated with respect to seven of the nine evaluation criteria outlined in the NCP and shown in Table 6-1.

State and community acceptance criteria are not addressed in this FS at this time. Community acceptance is not generally addressed until public comments are solicited. State acceptance and community acceptance will be addressed following the public information meeting, public hearing, and public comment period.

6.1 ALTERNATIVE 1: NO ACTION

The No Action Alternative involves no remedial actions, but includes environmental monitoring. Alternative 1 was developed to comply with the NCP and to compare to other remedial action alternatives. This alternative does not meet the remedial action objectives because: it does not minimize the human health risks; does not reduce off-site runoff of contaminants; and it does not minimize infiltration of surface water through contaminated soils.

Environmental Monitoring. Although there is no data indicating that off-site migration of contaminants is a problem at this time, sampling of groundwater from six existing wells and stormwater/sediment from the two catch basins located in the Maintenance Yards would be performed yearly for a five year period to monitor for any potential migration of contaminants. Analytes tested would be those tested in the SI (ABB-ES, 1993) for AOCs 44 and 52.

6.1.1 Overall Protection of Human Health and the Environment

This alternative would provide no additional protection to human receptors over current conditions. Exposure to contaminated AOCs 44 and 52 surface soils for a working lifetime of 25 years, although unlikely, would result in risks exceeding the USEPA's target risk range.

6.1.2 Compliance with ARARs

Location-, action-, and chemical-specific ARARs for Alternative 1 are listed in Table 6-2.

The location-specific ARAR identified for this alternative regarding wetlands protection will not be met if sampling and analysis (to be performed as part of this alternative) indicates that contaminants from AOCs 44 and 52 are currently migrating off-site via the stormwater system. This alternative will not reduce potential off-site runoff of contaminants in surface water from AOCs 44 and 52 to the wetlands.

Action-specific ARARs associated with groundwater monitoring will be used in the development and implementation of the groundwater monitoring program.

Currently, there are no set maximum allowable residual levels for chemicals in soil under federal law. Therefore, chemical-specific ARARs for this site are driven by the risk-based numerical values and methodologies detailed in Section 1.4 and guidance from the MCP (310 CMR 40.00). The no action alternative would not comply with these risk-based values.

6.1.3 Long-Term Effectiveness and Permanence

This alternative is intended to provide a baseline for comparison to the other remedial alternatives, and does not meet the remedial objectives. The No Action alternative would not reduce human health risks posed by contaminants in the AOCs 44 and 52 soils. Health risk for a long-term worker exposed to the surface soil (to a depth of 2 feet) in AOCs 44 and 52 for a working lifetime of 25 years is estimated at 4E-3 to 7E-4 excess cancer risk.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Treatment processes would not be employed to address site contamination; however, there is no current evidence which supports that there is migration of contaminants off-site from AOCs 44 and 52.

6.1.5 Short-Term Effectiveness

This alternative would not involve any remedial activities that would endanger the community or the environment. Personnel conducting monitoring activities would need to follow a site specific health and safety plan (HASP).

6.1.6 Implementability

This alternative would be easy to implement and would not interfere with possible future remedial actions. Sampling and analytical services are widely available. Existing monitoring wells could be used. Since there would be no action taken, there would be no disruption to the Maintenance Yards activities.

6.1.7 Cost

The cost estimate for Alternative 1 is presented in Table 6-3. There are no capital costs associated with this alternative because it is assumed that existing wells would be sampled. O&M costs include labor, analytical, equipment, and expendable costs associated with periodic sampling and analyses of existing monitoring wells and catch basins annually for five years. A 25 percent contingency has been included to account for unforeseen conditions that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

6.2 ALTERNATIVE 2: FENCING/ASPHALT BATCHING HOT SPOT AREAS

This alternative combines several "limited action" technologies for AOCs 44 and 52 soils and a treatment technology. Although the remedial objectives to reduce the potential for off-site runoff and infiltration of contaminants are not met, there is no data that indicates that these are current problems at the site. Access and institutional controls would be implemented to reduce the potential for exposure of contaminants thereby reducing risk. Treatment of hot spot area soils would immobilize organic contaminants present in the highest concentrations at the site. Environmental monitoring would be employed to assess any migration of contaminants off-site.

Access and Institutional Controls. Preventing access by maintaining fencing around the site would minimize potential exposure pathways, thus mitigating future risk to public health. Deed and land use restrictions would act as institutional controls to ensure that the fence remained intact and that the land remained zoned as commercial/industrial in the future and after sale. Implementation of the deed restriction would require negotiation and agreement between several parties involved. When the property is sold, a notation could be included in the property deed.

Asphalt Batching Hot Spot Areas. Excavation and asphalt batching hot spot areas in the Cannibalization Yard would immobilize organic contaminants present in the highest concentrations at the site. The excavations would be backfilled with clean soil from off-site. Bituminous paving produced in the process would be applied to the surface of the site as an approximate 2 inch thick base course over half the site depending on the total quantity excavated. An air monitoring program would be developed to establish baseline air quality (prior to remediation) and to monitor for VOCs, PAHs and suspended particulates during excavation.

Environmental Monitoring. The objectives of environmental monitoring would be to evaluate if migration of contaminants off-site is occurring. Sampling and analysis of groundwater within or downgradient of AOCs 44 and 52 would be performed to monitor any adverse effects on the groundwater beneath the site. Sampling and analysis of stormwater and sediment from catch basins proximate to the site would be performed to monitor for off-site runoff of contaminants. For this evaluation, it was assumed that the monitoring program included in this alternative would be the same as for Alternative 1.

6.2.1 Overall Protection of Human Health and the Environment

This alternative would be protective of human health through access and institutional controls. Once the base is closed, worker exposure to contaminated soil would be prevented by fencing and deed and land use restrictions, thereby reducing risk.

6.2.2 Compliance with ARARs

Location-, action-, and chemical- specific ARARs for Alternative 2 are listed in Table 6-4.

Wetland nearby AOCs 44 and 52 may currently be impacted by surface water runoff via the storm water system. The location-specific ARAR identified for this alternative regarding wetlands protection will not be met if contaminants from AOCs 44 and 52 are currently migrating off-site via the stormwater system. This alternative will not reduce potential off-site runoff of contaminants in surface water from AOCs 44 and 52 to the wetlands. The remedy will be designed and constructed to minimize the potential of increased surface water flow (due to paved surfaces from asphalt batching) to the adjacent wetlands. Sampling and analysis will be performed on stormwater and sediment as a component of this alternative.

Action-specific ARARs identified for this alternative would be met. Excavation and asphalt batching would comply with state and federal ambient air quality standards by managing fugitive emissions and particulate matter through engineering controls during excavation and treatment. State regulations which apply to AOCs 44 and 52 regarding groundwater protection, and waste piles associated with hazardous wastes would be complied with during design and construction of this alternative. The asphalt batching vendor would be required to follow substantive requirements in the state recyclable material regulations.

Alternative 2 would not comply with chemical-specific risk-based values because the remediation would not reduce contaminant concentrations to these levels. However, remediation would limit exposure to these chemicals.

6.2.3 Long-Term Effectiveness and Permanence

This alternative would eliminate risks by preventing exposure but would require continual enforcement of access controls and deed and land use restrictions. Institutional controls are not by themselves sufficiently permanent and reliable to ensure effectiveness at AOCs 44 and 52. Environmental monitoring would provide data on the existence (if any) of contaminant migration off-site. Based on the Supplemental Site Investigation and Data Gathering detailed in Section 1.0, bituminous paving contains cPAHs; thus asphalt batching could potentially introduce more cPAHs to the site.

6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Treatment processes would be used only in the known hot spot areas of the site where contaminant concentrations are the highest. Asphalt batching would be used to potentially reduce the mobility of organic contaminants for an assumed 1,000 tons of soil. This alternative would not reduce the toxicity or volume of contaminants in the remainder of the site where soil is not asphalt batched. Mobility of contaminants would be minimized by the capping effect in those soils where the resultant batched bituminous paving material base course was placed.

6.2.5 Short-Term Effectiveness

This alternative would involve excavation of contaminated soils in the hot spot areas. These activities are not likely to endanger the community or the environment. Dust and emissions monitoring would be performed to ensure that workers and the public are not impacted during excavation. Excavating and asphalt batching the hot spots is anticipated to take approximately 3 weeks to complete. Personnel conducting remedial and monitoring activities would need to follow a site-specific HASP. Proper protective clothing and equipment and safe work practices would minimize the possibility of chemical exposure or injury.

6.2.6 Implementability

This alternative is relatively easy to implement and would not significantly interfere with possible future remedial actions. Excavation of the base course batched paving placed on the site might be required should additional intrusive remedial work be desired. Asphalt batching on-site has been approved by the regulators for similar remedial efforts at Fort Devens. Only a few restrictions with regard to temperature and weather pertain when applying on-site batched pavement as detailed in Section 4.4.

Security fencing currently exists at the site. Deed and land use restrictions would need to be applied upon sale of the property. Environmental monitoring also would be easy to implement as previously discussed in Alternative 1.

This alternative which entails asphalt batching the hot spots and applying the material on the surface of the site will require some short-term disruption of activities in the Maintenance Yards. There would probably need to be parking restrictions mostly in the Cannibalization Yard during excavation and batching (approximately 3 weeks) and movement of vehicles to unpaved areas of the yards when expanding the stormwater system and applying the paving material.

6.2.7 Cost

The cost estimate for Alternative 2 is presented in Table 6-5. Capital costs associated with this alternative include excavation, air monitoring, asphalt batching and analytical costs associated with the treatment of the hot spot soils. A volume of approximately 700 cy of soil was assumed for estimating purposes. Capital costs also include deed restrictions and anticipated site restoration including backfilling the holes with clean fill, reinstallation of fencing, and reapplying asphalt batched material to undermined portions of the road (if required) near the waste oil storage tank location and to the site surface. Depending on the quantity of asphalt material applied to the site, the stormwater collection system could require expansion.

O&M costs include labor, equipment, and expendable costs for periodically sampling groundwater and catch basins and associated analytical costs, as well as repairing the fence as needed. A 25 percent contingency has been included to account for unforeseen conditions that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

6.3 ALTERNATIVE 3: CAPPING SITE/ASPHALT BATCHING HOT SPOT AREAS

Alternative 3 entails excavating and asphalt batching the hot spot areas, capping the site with asphalt pavement and groundwater monitoring. Capping and utilization of deed restrictions would minimize potential exposure pathways, thus mitigating future risk to public health. The pavement surface also would reduce the potential for off-site runoff of contaminants. As with Alternative 2, asphalt batching the hot spot areas would reduce the volume of contaminants present in the highest concentrations at the site. Groundwater monitoring would be performed to verify that soils are not impacting the groundwater.

Capping Site. Details of the cap construction are discussed in Section 4.0. Capping will increase the amount of runoff during rain events and will potentially transport any contaminants which might result from continued use of the yards to Cold Spring Brook via catch basins (which would otherwise deposit in the soils at AOCs 44 and 52 without the cap). Capping requires expansion of the existing stormwater collection system which could entail installing up to 12 additional catch basins, 14 oil and grease traps, and additional 18- inch and 30-inch diameter piping. Additionally, investigations would need to performed to determine what impacts the increased flow will have on the wetlands. Potentially, a retention basin and flow reducers will need to be incorporated into the design to minimize impacts on the wetlands. A deed and land use restriction would act as an institutional control to ensure that the cap remained intact in the future and that property remained zoned for commercial/industrial use.

Asphalt Batching Hot Spot Areas. Excavation and asphalt batching hot spot areas in the Cannibalization Yard would immobilize organic contaminants present in the highest concentrations at the site, thus reducing the total concentration of mobile contaminants. The excavation would be backfilled with clean soil from off-site. Asphalt batched material from the hot spots would be used as capping material, decreasing the quantity of pavement required to be brought in from an off-site batch plant. Details of the asphalt batching technology are discussed in Section 4.4. An air monitoring program would be developed to establish baseline air quality (prior to remediation) and to monitor for VOCs, PAHs and suspended particulates during excavation.

Groundwater Monitoring. Sampling and analysis of groundwater within or downgradient of AOCs 44 and 52 also would be performed to verify that soil contaminants are not impacting the groundwater. Stormwater/sediment monitoring would not be required since AOCs 44 and 52 entire surface would be paved. Groundwater sampling would be as detailed in Alternative 1.

6.3.1 Overall Protection of Human Health and the Environment

This alternative would be protective of human health through capping and institutional controls. Worker exposure to contaminated soil would be prevented by capping the surface soils thereby reducing risk. Implementing this alternative would take approximately three months to complete. Deed and land use restrictions would be required to maintain the integrity of the cap.

6.3.2 Compliance with ARARs

Location-, action-, and chemical- specific ARARs for Alternative 3 are listed in Table 6-6.

The location-specific ARAR identified for this alternative regarding wetlands protection would be met. This alternative covers the site with pavement, thus reduces potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will be designed and constructed to manage the increased surface water flow (due to paved surfaces) in a manner that will minimize impact to the adjacent wetlands.

Action-specific ARARs identified for this alternative would be met. Excavation and asphalt batching would comply with state and federal ambient air quality standards by managing fugitive emissions and particulate matter through engineering controls during excavation and treatment. State regulations which apply to AOCs 44 and 52 regarding groundwater protection, waste piles, and closure activities associated with hazardous wastes would be complied with during design and construction of this alternative. The asphalt batching vendor would be required to follow substantive requirements in the state recyclable material regulations.

Alternative 3 would not comply with chemical-specific risk-based values because the remediation would not reduce contaminant concentrations to these levels. However, remediation would limit exposure to these chemicals.

6.3.3 Long-Term Effectiveness and Permanence

This alternative would eliminate risks by minimizing exposure, but would require continual enforcement of deed and land use restrictions to maintain the integrity of the cap system. Institutional controls are not by themselves sufficiently permanent and reliable to ensure effectiveness. Although the exposure to the risk is minimized in this alternative, the contaminants that create a carcinogenic risk at AOCs 44 and 52 would still be present below the cap. Groundwater monitoring would confirm the lack of or existence of contaminant migration off-site.
Based on the Supplemental Site Investigation and Data Gathering detailed in Section 1.0, bituminous paving contains cPAHs; thus capping could potentially

introduce more cPAHs to the site. Based on the Supplemental Site Investigations and Data Gathering detailed in Section 1.0, bituminous paving contains cPAHs; thus capping could potentially introduce more cPAHs to the site.

6.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Soil would be treated only in the known hot spot areas of the site where contaminant concentrations are the highest. Asphalt batching would be used to potentially reduce the mobility of organic contaminants for an assumed 1,000 tons of soil. This alternative would not reduce the toxicity or volume of contaminants in the remainder of the site where soil is not batched. Mobility of contaminants in the remainder of the site would be minimized by capping and institutional controls.

6.3.5 Short-Term Effectiveness

As with Alternative 2, this alternative would involve excavating contaminated soils in the hot spot areas. Applying the aggregate base, grading, and applying the bituminous base course and wearing course is anticipated to take at least 7 weeks. However, coordination with the stormwater system expansion and excavation/ asphalt batching of the hot spot areas is required. Overall excavating and asphalt batching the hot spots, and capping are anticipated to take approximately 3 months to complete. Installation of the cap will entail expansion of the stormwater collection system that will include installation of catch basins and storm drainage piping. Consequently, additional excavation work will be required for installation of these appurtenances. These activities are not likely to endanger the community or the environment. Dust and emissions monitoring would be performed to ensure that workers and the public are not impacted during excavation. Personnel conducting remedial and monitoring activities would need to follow a site-specific HASP. Proper protective clothing and equipment and safe work practices would minimize the possibility of chemical exposure or injury.

6.3.6 Implementability

This alternative is relatively easy to implement. Bituminous paving is a commonly used material in the construction industry. Asphalt batching on-site has been approved by the regulators for similar remedial efforts at Fort Devens. Only a few restrictions with regard to temperature and weather pertain to the batching technology when applying on-site batched pavement as detailed in Section 4.

Alternative 3 would not significantly interfere with possible future remedial actions. Excavation of the cap might be required should additional intrusive remedial work be desired. Deed restrictions would need to be applied upon sale of the property. Groundwater monitoring also would be easy to implement as previously discussed in Alternative 1.

This alternative would also require a short-term disruption of activities in the Maintenance Yards. Asphalt batching the hot spots and applying the material on the surface of the site will require parking restrictions, mostly in the Cannibalization Yard, during excavation and batching (approximately 3 months) and movement of vehicles when expanding the stormwater system and applying the paving material. All vehicles will ultimately be required to be moved at least back and forth within the yards to permit paving of the entire site.

6.3.7 Cost

The cost estimate for Alternative 3 is presented in Table 6-7.

Capital costs associated with this alternative include excavation, air monitoring, asphalt batching, analytical costs, and site restoration associated with the treatment of the hot spot soils as detailed more specifically in Alternative 2. Capital costs also include expansion of the existing stormwater collection system that could entail installing up to 12 additional catch basins and additional 18- and 30-inch diameter piping. The major components of the cap system include a 6-inch crushed gravel aggregate base course, base (binder) which includes the asphalt batched hot spot soils, and wearing paving courses that are detailed in Section 4.2. O&M costs include labor, equipment, and expendable costs associated with yearly groundwater sampling, and analytical costs for a 5-year period. It is assumed that the wearing course would be replaced every 10 years and a seal coat applied every 5 years for a 30-year maintenance period. A 25 percent contingency has been included to account for unforeseen conditions that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

6.4 ALTERNATIVE 5: ASPHALT BATCHING SITE/ASPHALT BATCHING HOT SPOT AREAS

Alternative 5 entails excavating the top two feet of soil across the site and contaminated soils in the hot spot areas; stockpiling the soil for sampling and analysis; asphalt batching the soil that exceeds cleanup levels; and performing groundwater monitoring.

Asphalt Batching. Asphalt batching would immobilize the contaminants exceeding cleanup levels in the top 2 feet thus minimize direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Excavation and asphalt batching hot spot areas in the Cannibalization Yard would immobilize contaminants present in the highest concentrations at the site, thus reducing the total concentration of mobile contaminants. Details of the asphalt batching technology are discussed in Section 4.4. Hot spot area excavations would be backfilled with clean material from off-site. Asphalt batched material would be placed in a layer (estimated to be up to 1 foot thick) on the surface of the site. This paved surface would require expanding the existing stormwater collection system as detailed in Alternative 3, including oil and grease traps and an investigation to determine what impacts the increased flow will have on the wetlands. An air monitoring program would be developed to establish baseline air quality (prior to remediation) and to monitor for VOCs, PAHs and suspended particulates during remediation.

Groundwater Monitoring. Sampling and analysis of groundwater within or downgradient of AOCs 44 and 52 also would be performed to monitor any adverse effects on the groundwater beneath the site as detailed in Alternative 1. Stormwater/sediment sampling would not be required since the entire site would be covered with asphalt batched material.

6.4.1 Overall Protection of Human Health and the Environment

Assuming long-term effectiveness and permanence is achieve, this alternative would be protective of human health. Asphalt batching achieves an irreversible reduction in mobility of the organic contaminants driving the carcinogenic risk at AOCs 44 and 52 immediately upon batching. Implementing this alternative would take approximately 4 months to complete. Since the contaminants are immobilized, no deed or land use restrictions are required.

6.4.2 Compliance with ARARs

Location-, action-, and chemical- specific ARARs for Alternative 5 are listed in Table 6-8.

The location-specific ARAR identified for this alternative regarding wetlands protection would be met. This alternative covers the site with pavement, thus reduces potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will be designed and constructed to manage the increased surface water flow (due to paved surfaces) in a manner that will minimize impact to the adjacent wetlands.

Action-specific ARARs identified for this alternative would be met. Excavation and asphalt batching would comply with state and federal ambient air quality standards by managing fugitive emissions and particulate matter through engineering controls during excavation and treatment. State regulations which apply to AOCs 44 and 52 regarding groundwater protection, waste piles, and closure activities associated with hazardous wastes would be complied with during design and construction of this alternative. The asphalt batching vendor would be required to follow substantive requirements in the state recyclable material regulations.

Alternative 5 would not comply with chemical-specific risk-based values, because remediation would not reduce contaminant concentrations to these levels. However, remediation would limit exposure to these chemicals.

6.4.3 Long-Term Effectiveness and Permanence

Asphalt batching would effectively mitigate the risks associated with the top 2 feet of soil at AOCs 44 and 52 through irreversible reduction in mobility. Residual risks would be reduced to within the USEPA Superfund target risk range of 1E-4 to 1E-6. In addition, contaminants from the hot spot areas would be immobilized from the batching operation, thereby eliminating potential migration of contaminants from these source soils. Groundwater monitoring would be used in Alternative 5 to assess contaminant migration off-site for 5 years following remediation.

Actual field or laboratory performance data on the effectiveness of batching is scarce due to the relative newness of the technology. However, asphalt batched soils have been evaluated by groundwater monitoring wells and laboratory tests for possible leaching of contaminants. A 4,000-ton stockpile of treated material was monitored for the MADEP for potential leaching to groundwater located only 3 feet bgs using wells. After 4 years there was still no adverse impact detected on the groundwater. Several TCLP tests conducted for TPHCs and PAHs also resulted in undetectable contaminant concentrations in TCLP extract (Knowlton, 1992). Based on the Supplemental Site Investigation and Data Gathering detailed in Section 1.0, bituminous paving material contains cPAHs; thus batching could potentially introduce more cPAHS to the site.

6.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Soil would be treated in the known hot spot areas of the site where contaminant concentrations are the highest and in the top 2 feet of soil at the site where there is a carcinogenic risk. Asphalt batching would be used to reduce the toxicity and mobility of organic contaminants for an assumed 1,000 tons of soil in the hot spot areas. The entire top 2 feet of the site will be excavated (38,400 tons of soil) of which 50% has been estimated, for cost estimating purposes, to exceed cleanup levels and require asphalt batching. Asphalt batching also provides an impermeable surface barrier, thereby limiting migration of contaminants via precipitation infiltrating through to the groundwater and via surface water run-off to off-site locations.

6.4.5 Short-Term Effectiveness

Alternative 5 would involve excavating potentially 29,000 cy of contaminated soils from the surface of the site and excavation of the hot spot areas. Excavating this amount of soil and asphalt batching soil exceeding cleanup criteria are anticipated to take approximately 2 months to complete. Batching and putting the material back in place also will entail expansion of the stormwater collection system that, as discussed in Alternative 3, will involve additional excavation for installation of catch basins, and storm drainage piping. These activities are not likely to endanger the community or the environment, providing adequate dust suppression methods are employed. Dust and emissions monitoring would be performed to ensure that workers and the public are not impacted during excavation. Personnel conducting remedial and monitoring activities would need to follow a site-specific HASP. Proper protective clothing and equipment and safe work practices would minimize the possibility of chemical exposure or injury.

6.4.6 Implementability

This alternative would entail handling and treating a large quantity of soil. However, the technology is relatively easy to implement. Numerous vendors exist. Mobile pugmill units are readily available. Placement of the asphalt batched material back in the site may interfere with possible future remedial actions due to its monolithic nature should additional intrusive remedial work be desired. Additionally, the asphalt batched soil cap (estimated to be up to 1 foot thick) is an impediment for a commercial/industrial setting in the future. The additional implementability details regarding regulator approval and weather restrictions discussed in Alternative 3 also apply to Alternative 5.

Alternative 5 is expected to create an even greater short-term disruption than alternatives discussed previously due to the volume of soil which would be potentially excavated, batched and reapplied back onto the site during an approximate 2 month period. Asphalt batching soils exceeding cleanup levels in the hot spot areas and 2 foot deep surface soils and applying the material on the surface of the site will require parking restrictions in the Cannibalization Yard as well as at proposed excavation areas throughout the site during excavation and batching. Vehicles also will need to be moved when expanding the stormwater system.

6.4.7 Cost

The cost estimate for Alternative 5 is presented in Table 6-9.

Capital costs for this alternative include expansion of the existing stormwater collection system as required and discussed for capping; excavating; air monitoring; sampling and analysis as required by the vendor; batching; and replacing the material on-site. A pavement wearing course placed over the batched material was not included in the cost as it would not be required by the regulators for this remedial action (see subsection 5.1.5)

O&M costs include labor, equipment, and expendable costs associated with annual groundwater sampling, and analytical costs for a 5 year period. A

25 percent contingency has been included to account for unforeseen conditions that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

6.5 ALTERNATIVE 7: BIOVENTING SITE AND HOT SPOT AREAS

Alternative 7 combines bioventing the entire site and the hot spot areas, and performing groundwater monitoring.

Bioventing will reduce the contaminants present in the top 2 feet thus minimizing direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Additionally, the concentration of the contaminants of concern are reduced towards background levels in depths below two feet over the site area and in the hot spot areas. Because the bioventing system requires a cap to prevent short-circuiting of air, the potential of contaminant migration off-site is immediately minimized upon construction of the cap.

Bioventing. Details of the bioventing technology are discussed in Section 4.3. This technology promotes ISB of the SVOCs and TPHC by delivering moisture and nutrients via wells and trenches, and oxygen via an SVE system with soil vapor return wells or conduits. Dissolved nutrients would be initially injected into the soil. The soil would be capped with pavement to prevent short-circuiting of air from the atmosphere to the withdrawal trenches and to ensure that the air flows through the contaminated soil depth.

This paved surface would require expanding the existing stormwater collection system as detailed in Alternative 3, including oil and grease traps and an investigation to determine what impacts the increased flow will have on the wetlands. An air monitoring program would be developed to establish baseline air quality (prior to remediation) and to monitor for VOCs, PAHs and suspended particulates during excavation for installation of the bioventing system and stormwater expansion. A long-term air quality monitoring program is not believed to be necessary because most of the gases extracted from the soil would be recycled through the soil for treatment by bioremediation.

Groundwater Monitoring. Sampling and analysis of groundwater within or downgradient of AOCs 44 and 52, as detailed in Alternative 1, also would be performed to monitor any adverse effects on the groundwater because of the contaminated soil and nutrient injection. Duration of monitoring would be for the treatment duration (estimated to be 10 years). Stormwater/sediment sampling would not be required since the entire site would be covered with a cap.

6.5.1 Overall Protection of Human Health and the Environment

This alternative would be protective of human health. Bioventing would promote destructive biodegradation of the hazardous organic compounds in the top 2 feet of the soil to within the USEPA Superfund target risk range of 1E-4 to 1E-6 within approximately 10 years. Additionally bioventing would potentially reduce the levels of contaminants in the soils beneath the two foot zone towards levels approaching background. The cap, which is required for the bioventing system to prevent short-circuiting of air flow through the soil, will immediately upon installation minimize exposure to the surface soil containing the contaminants driving the carcinogenic risk at AOCs 44 and 52.

6.5.2 Compliance with ARARs

Location-, action-, and chemical- specific ARARs for Alternative 7 are listed in Table 6-10.

The location-specific ARAR identified for this alternative regarding wetlands protection would be met because the wetlands would not be adversely affected by the remedial action. This alternative covers the site with pavement, thus reduces potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will be designed and constructed to manage the increased surface water flow (due to paved surfaces) in a manner that will minimize impact to the adjacent wetlands.

Action-specific ARARs identified for this alternative would be met. Excavation activities and bioventing would comply with state and federal ambient air quality standards by managing fugitive emissions and particulate matter through engineering controls during excavation and treatment. State regulations which apply to AOCs 44 and 52 regarding groundwater protection would be complied with during design and implementation of this alternative.

Alternative 7 would comply with the chemical-specific risk-based cleanup levels by promoting destructive biodegradation of the carcinogenic organic compounds in the top 2 feet of the soil and reducing the risk to within the USEPA Superfund target risk range of 1E-4 to 1E-6.

6.5.3 Long-Term Effectiveness and Permanence

Bioventing would effectively mitigate the risks associated with the top 2 feet of soil at AOCs 44 and 52 by reducing the carcinogenic contaminant concentrations. Residual risks would be expected to be reduced to within the USEPA Superfund target risk range of 1E-4 to 1E-6 within approximately 10 years (estimated). In addition, organic contaminants from the hot spot areas and in soils below the top 2 feet across the site would be destroyed by bioventing, thereby eliminating potential migration of contaminants from these source soils. Process monitoring, in the form of soil sampling and analysis, would need to be performed on a minimum yearly basis to track treatment performance.

Treatability studies have been conducted to determine the effectiveness of bioventing in reducing cPAH and TPHC concentrations within AOCs 44 and 52 soils. Tests included checking for the presence of toxic/inhibiting substances that would affect bacteria; the biodegradability of the target compounds; and soil permeability as it relates to oxygen and nutrient delivery. Based on the Biological Treatability Study Report (ABB-ES, 1993b), bioventing does not appear to be nearly as effective as landfarming or composting and, in fact, may not be an effective alternative. The estimated treatment period is 10 years to achieve a reduction in total cPAH concentration down to 7 mg/kg.

Based on the Supplemental Site Investigation and Data Gathering detailed in Section 1.0, bituminous paving material contains cPAHs; thus installing the pavement cap as needed for the bioventing system may introduce more cPAHs to the site.

Groundwater monitoring would be used in this alternative to assess contaminant migration off-site for 10 years during remediation.

6.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 7 will effectively reduce the toxicity, mobility and volume of the organic contaminants at AOCs 44 and 52. The biodegradation process will reduce the organic contaminant concentration by destruction of the compounds, thereby reducing the toxicity and volume of contaminants in the soils. Bioventing, unlike the previously discussed alternatives, also will reduce the levels of contaminants in the soils beneath the two-foot zone towards levels approaching background. Mobility of the contaminants via surface water infiltration and runoff is minimized immediately upon construction of the pavement cap which is installed to prevent short-circuiting of air through the soil.

6.5.5 Short-Term Effectiveness

Alternative 7 would involve excavating trenches for the bioventing system and stormwater system and drilling to install bioventing wells. Soil excavated from the trench work would be spread on the surface of the site and capped over for treatment by the bioventing system. These activities are not likely to endanger the community or the environment, providing adequate dust suppression methods are employed. Dust and emissions monitoring would be performed to ensure that workers and the public are not impacted during excavation. Personnel conducting remedial and monitoring activities would need to follow a site-specific HASP. Proper protective clothing and equipment and safe work practices would minimize the possibility of chemical exposure or injury.

Although it is anticipated that remediation will take up to 10 years to reduce the organic compounds in the top 2 feet of soil to meet cleanup objectives, risks would be immediately minimized upon construction of the bituminous pavement cap that would be placed atop the Maintenance Yards.

6.5.6 Implementability

Although the bioventing technology is relatively simple, this alternative would entail designing, constructing, operating and performance monitoring of a bioventing system. Numerous vendors exist who can design the system. Installation would require only basic construction techniques. O&M of the system would require no more than an average of one day per week activity to ensure proper operation. Performance monitoring would entail sampling and analysis of the soil for the remediation period (10 years) to ensure cleanup levels are achieved. Placement of the cap and construction of the bioventing system would not significantly interfere with possible future remedial actions should additional intrusive remedial work be desired.

Alternative 7 will create short-term disturbances of activities in the Maintenance Yards due to installing the bioventing system and stormwater piping and appurtenances, and paving the entire site. Implementation of this alternative would require parking restrictions and movement of vehicles when expanding the stormwater system and applying the paving material for an approximate 3-week period.

The initial injection of nutrients would need to be scientifically applied and monitored so as to not impact either Grove Pond and its wetlands or the Grove Pond water supply wells thereby avoiding human health risks associated with nitrate/nitrite in groundwater and ecological risks associated with nitrate and phosphate migrating to surface water. The MADEP Central Regional Office Water Supply Section has indicated that bioventing is not recommended within Zone II of a public water supply. The concerns that they have include: high soil permeability, proximity to the Grove Pond Wells, mobilization of contaminants through nutrient addition, the time to complete degradation, and the difficulty biodegrading cPAHs. However, nutrients would be scientifically applied and monitored and are not expected to increase the solubility and migration of cPAHs.

6.5.7 Cost

The cost estimate for Alternative 7 is presented in Table 6-11. Costs for this alternative include the designing of the system; initial nutrient injection in the areas by tractor; and installation of approximately 20 bioventing wells, with associated piping, blower, and humidifier. To permit continued use of the site, the cap required to prevent short-circuiting of air will be constructed of asphalt paving installed over the entire area of the site. Costs also include air monitoring and expansion of the existing stormwater collection system as required and discussed for capping. Soils excavated for installation of the stormwater collection system expansion and bioventing system will be spread out over the site for treatment by the bioventing system. O&M costs include labor, equipment, and expendable costs associated with operation and maintenance of the bioventing system, and process monitoring to ensure cleanup levels are obtained for a period of 10 years. Costs also include yearly groundwater sampling, and analytical costs for a 10 year period. A 25 percent contingency has been included to account for unforeseen conditions that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

6.6 ALTERNATIVE 8: LANDFARMING SITE/EXCAVATING AND LANDFARMING HOT SPOT AREAS

Alternative 8 entails landfarming the entire site and excavating and landfarming the hot spot areas, and performing groundwater monitoring. As a pre-treatment process, surface soil, in areas of the site containing bituminous pavement pieces, will be mechanically screened to remove large sized fragments as described in Section 5.1.8.

It is estimated that remediation of all the yards will take approximately 7 years. As described in Section 4.3, it is anticipated that biodegradation will require up to 5 years to reduce cPAH concentrations to the established cleanup level. As further explained in Section 5.1.8, design would entail first treating 20% of the yards while the other 80% remain functional as maintenance yards. After the Maintenance Yards close (assumed to be within 2 years after start of remediation of the 20% area), remediation of the remaining 80% would start, requiring up to five years for a total of 7 years for the entire site.

Landfarming will reduce the contaminants present in the top 2 feet, thus ultimately minimizing direct contact/ingestion and inhalation of the soils having a carcinogenic risk. Additionally, the concentration of the contaminants of concern are reduced towards background levels in depths below two feet over the site area by applying excess nutrients and water to the soil surface. The potential for migration of contaminants via surface water infiltration and runoff is minimized by contaminant concentration reduction. Groundwater sampling would be performed upon commencement of remediation and continue for 7 years.

Landfarming. Details of the landfarming technology are discussed in Section 4.3 This technology promotes ISB of the SVOCs and TPHC by delivering moisture and nutrients and air by tilling the soil. The Cannibalization Yard hot spot areas would be excavated and soil evenly spread over the area of the site to be tilled. The excavations would be backfilled with clean material from off-site. Dissolved nutrients would be initially injected into the soil. Tilling and nutrient injection would be performed by tractor. An air monitoring program would be developed to establish baseline air quality (prior to remediation) and to monitor for VOCs, PAHs and suspended particulates during excavation of the hot spots and tilling. It is expected that the air monitoring program could be reduced or terminated if initial monitoring shows that regulatory levels are not being exceeded.

Groundwater Monitoring. Sampling and analysis of groundwater would be performed as detailed in Alternative 1 to monitor for any adverse effects on the groundwater from the contaminated soil and landfarming operations for the duration of remediation (estimated to be 7 years). The two catch basins in the Maintenance Yards would be removed or filled and stormwater lines plugged, to minimize the potential for contaminated stormwater and sediment runoff.

6.6.1 Overall Protection of Human Health and the Environment

This alternative would be protective of human health. Landfarming would promote destructive biodegradation of the hazardous organic compounds in the top 2 feet of the soil to within the USEPA Superfund target risk range of 1E-4 to 1E-6. Although landfarming will aggressively treat the top 2 foot layer, by adding an excess of nutrients and water, landfarming would potentially reduce the levels of contaminants in the soils beneath the two-foot zone towards levels approaching background.

6.6.2 Compliance with ARARs

Location-, action-, and chemical- specific ARARs for Alternative 8 are listed in Table 6-12.

The location-specific ARAR identified for previous alternatives regarding wetlands protection is not applicable since as part of the landfarming operation, for Alternative 8, catch basins would be removed thus eliminating any flow to the wetlands.

Action-specific ARARs identified for this alternative would be met. Excavation and landfarming would comply with state and federal ambient air quality standards by managing fugitive emissions and particulate matter through engineering controls during excavation activities and treatment. State regulations which apply to AOCs 44 and 52 regarding groundwater protection, and land treatment units associated with hazardous wastes would be complied with during design and construction of this alternative.

Alternative 8 would comply with the chemical-specific risk-based cleanup levels by promoting destructive biodegradation of the carcinogenic organic compounds in the top 2 feet of the soil and reducing the risk to within the USEPA Superfund target risk range of 1E-4 to 1E-6.

6.6.3 Long-Term Effectiveness and Permanence

Landfarming would effectively mitigate the risks associated with the top 2 feet of soil at AOCs 44 and 52 by reducing the carcinogenic contaminant concentrations. Residual risks would be expected to be reduced to within the USEPA Superfund target risk range of 1E-4 to 1E-6 within 7 years. In addition, organic contaminants from the hot spot areas and in soils below the top 2 feet across the site would be destroyed by landfarming, thereby eliminating potential migration of contaminants from these source soils. Process monitoring in the form of soil sampling and analysis of the top 2 feet would need to be performed on a minimum yearly basis to track treatment performance to ensure cleanup levels are to be achieved.

Treatability testing and literature studies indicate that the TPHC and cPAH contaminants in AOCs 44 and 52 soils are biodegradable. Biodegradation of cPAHs in the soil is expected to occur slowly and was not observable within the laboratory treatment time of 69 days. (ABB-ES, 1993b) However, bioremediation treatment time data (see Appendix C) indicates that cPAHs (specifically benzo(a)pyrene, which is one of the more difficult cPAHs to biodegrade) has a half-life of approximately 11.5 months. Treatability testing also indicated that approximately 50% of the TPHC biodegraded within the first month followed by slower reduction of the more recalcitrant TPHC compounds. Bioremediation pilot-scale testing of the AOCs 44 and 52 soils is recommended as a design activity. Bioremediation of the first 20% of the Maintenance Yards will serve as this test. Results will be used to further refine the design for treatment of the remaining 80% of the yards.

Groundwater monitoring would be used in this alternative to assess contaminant migration off-site for 7 years upon commencement of remediation.

6.6.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 8 will effectively reduce the toxicity and volume of the organic contaminants at AOCs 44 and 52. Mechanical screening would be performed to first remove large sized pieces of pavement from the soil (anticipated to be within the top 6 inches of soil). This will minimize the possibility of introducing smaller sized chips of pavement (containing cPAHs) into the soil during the tilling of the soil which could adversely impact confirmation sampling results. The biodegradation process which follows will reduce the organic contaminant concentration by destroying the compounds, thereby reducing the toxicity and volume of contaminants in the soils. Landfarming also will potentially reduce the levels of contaminants in the soils beneath the two foot zone towards levels approaching background by the addition of excess nutrients. Mobility of any residual contaminants via surface water infiltration and runoff is not minimized. However, groundwater monitoring would be performed.

6.6.5 Short-Term Effectiveness

Alternative 8 would involve excavating approximately 1,000 tons of soil from the hot spot areas and spreading this soil over the site area that is to be landfarmed. Nutrients and water would be applied to the soil and soil tilled to approximately 18 inches in depth to mix and aerate the soil. These activities are not likely to endanger the community or the environment, providing soil is kept sufficiently moist during the tilling operation to minimize dust. Dust and emissions monitoring would be performed to ensure that workers and the public are not impacted during remediation. Personnel conducting remedial and monitoring activities would need to follow a site-specific HASP. Proper protective clothing and equipment and safe work practices would minimize the possibility of chemical exposure or injury.

Volatilization of contaminants is expected to be minimal since the contamination present at the Maintenance Yards contains only trace quantities of volatile compounds. The source of contamination is primarily crankcase oil (no volatiles) or asphalt. Compounds with molecular weight of naphthalene or greater are considered to be SVOCs and volatilization is minimal. PAHs that are present in the soil having two rings or less are expected to biodegrade within the first one to two weeks of remediation.

It is anticipated that remediation will take up to 7 years to reduce the organic compounds in the top 2 feet of soil to meet cleanup objectives.

6.6.6 Implementability

The landfarming technology is relatively simple, requiring tilling and adding nutrients and water by tractor. Mechanically screening the soil containing large pavement fragments prior to tilling is also a standard process used in the construction industry. Performance monitoring would entail sampling and analysis of the soil for the remediation period (7 years) to ensure cleanup levels are achieved. Landfarming would not interfere with possible future remedial actions should additional intrusive remedial work be desired.

Landfarming will require closure of approximately 20% of the Maintenance Yards upon commencement of remedial activities. The remaining 80% will be remediated upon closure of the Maintenance Yards.

Nutrients would need to be monitored so as to not impact either Grove Pond and its wetlands or the Grove Pond water supply wells. This would avoid human health risks associated with nitrate/nitrite in groundwater and ecological risks associated with nitrate and phosphate migrating to surface water. The MADEP Central Regional Office Water Supply Section has indicated that landfarming is not recommended within Zone II of a public water supply. The concerns that they have include: high soil permeability, proximity to the Grove Pond Wells, mobilization of contaminants through nutrient addition, the time to complete degradation, and the difficulty biodegrading cPAHs. However, nutrients would be scientifically applied and monitored and are not expected to increase the solubility and migration of cPAHs.

6.6.7 Cost

The cost estimate for Alternative 8 is presented in Table 6-13.

Capital costs for this alternative include purchasing a tractor for tilling and irrigating; screening of surficial soils to remove pieces of existing pavement, spraying or steam cleaning screened pavement and disposal of pavement in a demolition debris landfill; excavation of hot spot areas and spreading this soil over the site to be landfarmed; air monitoring; and initial nutrient injection in the soils by tractor.

O&M costs include labor, equipment, and expendable costs associated with operation, maintenance and process monitoring of the remediation for the seven year period. Costs also include annual groundwater sampling, and analytical costs for the duration of the remediation. A 25 percent contingency has been included to account for undeveloped design details that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

6.7 ALTERNATIVE 9: TREATMENT OF SITE AND HOT SPOT AREA SOILS AT A CENTRAL SOIL TREATMENT FACILITY

Alternative 9 entails excavating the top two feet of soil across the site and contaminated soils in the hot spot areas; utilizing the General Management Procedures for Excavated Waste Site Soils at Fort Devens (ABB-ES, 1994) for classifying, handling and reusing the excavated soils; hauling soil exceeding site cleanup levels to a central soil treatment facility at Fort Devens; and performing groundwater monitoring at AOCs 44 and 52. As a pre-treatment process, surface soil, in areas of the site containing bituminous pavement pieces, will be mechanically screened to remove large sized fragments as described in Section 5.1.9.

It is anticipated that remediation of AOCs 44 and 52 will take approximately 2 years. This assumes that excavation and backfill of 20% of the site will commence in the fall of 1994 and excavation and backfill of the remaining 80% of the site will be completed within a few months following closure of the Maintenance Yards in the summer of 1996. Estimated time for treatment of the soils at the central soil treatment facility is discussed under Section 6.7.7: Cost.

Removing soil with cPAHs exceeding the target cleanup concentration within the top two feet of soil mitigates the exposure risks associated with the surface soils at the site. In addition, the soil removed from the yards would be treated by composting to reduce contaminant concentrations or by asphalt batching which would immobilize the contaminants.

Central Soil Treatment Facility. Details of the central soil treatment facility and the proposed treatment methods employed are discussed in Section 5.1.9. This facility will use the composting technology which destroys SVOCs and TPHC by biodegradation. Biodegradation of these contaminants is enhanced by adding bulking agents, nutrients and moisture (as required), and mechanically aerating the soil in windrows. Fugitive dust from turning the windrows would be controlled by wetting the soil with water during dry periods. VOC emissions are not expected to be a problem for AOC 44 and 52 soils, but air quality monitoring would be conducted as described for Alternative 8. Additionally, asphalt batching at the facility or off-site disposal would be used for soil with excessively high contaminant concentrations which would otherwise require an impractical treatment time using bioremediation. Cutoff concentrations for utilizing asphalt batching and/or disposing offsite can be established once the 20% site remediation is underway.

Groundwater Monitoring. Sampling and analysis of groundwater at AOCs 44 and 52 would be performed to monitor for any adverse effects on the groundwater for a period of 5 years following commencement of site activities. The number of wells, frequency and analyses would be as described in Section 6.1 for Alternative 1.

6.7.1 Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment. Treating the soil at the Fort Devens central soil treatment facility would promote destructive biodegradation (by composting) of the hazardous organic compounds to within the USEPA target risk range of 1E-4 to 1E-6 or achieve an irreversible reduction in mobility (by asphalt batching) of the organic contaminants driving the carcinogenic risk.

6.7.2 Compliance with ARARs

Location-, action-, and chemical- specific ARARs for Alternative 9 are listed in Table 6-14.

The location-specific ARAR identified for this alternative regarding wetlands protection would be met. This alternative removes contaminated surface soils, thus reduces potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands.

Action-specific ARARs identified for this alternative would be met. Excavation, asphalt batching, and composting would comply with state and federal ambient air quality standards by managing fugitive emissions and particulate matter through engineering controls during excavation and treatment. State regulations which apply to AOCs 44 and 52 regarding groundwater protection, land treatment units, waste piles and closure activities associated with hazardous wastes would be complied with during design and construction of this alternative. The asphalt batching vendor and composting operations would follow the substantive requirements in the state recyclable material regulations.

This alternative also needs to be in compliance with the Massachusetts Hazardous Waste Rules, Location Standards for Facilities (310 CMR 30.700-30.707) regarding locating treatment facility operations on lands that are not overlaying an actual, planned, or potential public or private drinking water supply. The current site which has been selected is compliant with this criteria. If a groundwater recharge area does underlie a selected site, the site has to be relocated or a waiver, if appropriate, would have to be obtained under the State regulations. Details of the siting evaluation for the proposed facility are covered by the Siting Study Report (1994a).

Alternative 9 would comply with the chemical-specific risk-based cleanup levels. Compliance is achieved by physically removing soils containing carcinogenic organic compounds exceeding the cleanup concentration in the top 2 feet of the soil thereby mitigating the risk to within the USEPA Superfund target risk range of 1E-4 to 1E-6.

6.7.3 Long-Term Effectiveness and Permanence

Excavation of soils and treatment at a central soil treatment facility would effectively mitigate the risks associated with the hot spot areas and the top 2 feet of soil at AOCs 44 and 52 by removing the organic contaminants in excess of target cleanup levels. Residual risks at AOCs 44 and 52 would be expected to be within the USEPA Superfund target risk range of 1E-4 to 1E-6 within 2 years by removing soil from the site. Groundwater monitoring at AOCs 44 and 52 would be used in this alternative to monitor for any adverse effects on the groundwater for 5 years upon commencement of remediation. Process monitoring in the form of soil sampling and analysis would need to be performed to track treatment performance of composting at the central soil treatment facility.

Treatability testing and literature studies indicate that the TPHC and cPAH contaminants in AOCs 44 and 52 soils are biodegradable. Biodegradation of cPAHs in the soil is expected to occur slowly and was not observable within the laboratory treatment time of 69 days (ABB-ES, 1993b). However, bioremediation treatment time data (see Appendix C) indicates that cPAHs (specifically benzo(a)pyrene, which is one of the more difficult cPAHs to biodegrade) has a half-life of approximately 11.5 months. Treatability testing also indicated that approximately 50% of the TPHC biodegraded within the first month followed by slower reduction of the more recalcitrant TPHC compounds. Bioremediation pilot-scale testing of the AOCs 44 and 52 soils is recommended as a design activity. Bioremediation of the first 20% of the site will serve as this test. Results will be used to further refine the design for treatment of the remaining 80% of the site.

As detailed in Section 6.4.3, actual field or laboratory performance data on the long-term effectiveness of asphalt batching is scarce due to the relative newness of the technology. However, asphalt batched soils have been evaluated by groundwater monitoring wells and laboratory tests for possible leaching of contaminants with satisfactory results.

6.7.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 9 will effectively reduce the toxicity and volume of the organic contaminants at AOCs 44 and 52 by using composting. Mechanical screening would be performed first to remove the large sized pieces of pavement from the soil (anticipated to be within the to 6 inches of soil). This will minimize the possibility of introducing smaller sized chips of pavement (cPAHs) into the soil during windrowing which could adversely impact confirmation sampling results. The biodegradation process will reduce the organic contaminant concentration by destroying the compounds thereby reducing the toxicity and volume of contaminants in the soils. Any residual contaminants collected from stormwater runoff from the facility treatment area will be reapplied to the composted soil as moisture for the bioremediation process or for dust control. Screened asphalt pavement fragments and soils judged to be impractical for composting will be asphalt batched if practical. Asphalt batching will reduce the toxicity and mobility of the contaminants. Mobility of any residual contaminants below the top two feet via surface water infiltration is not minimized but is not likely. PAHs are very insoluble and not likely to migrate. Furthermore, groundwater sampling to date does not indicate that groundwater has been impacted by AOCs 44 and 52 operations. Groundwater monitoring would be performed to verify that there has not been any leaching of residual contaminants to the groundwater.

6.7.5 Short-term Effectiveness

Alternative 9 entails excavating approximately 1,000 tons of soil from the hot spot areas and 38,400 tons of surface soil; placing excavated soils in piles at the site for sampling and analysis; and transporting soils which exceed established cleanup criteria to the central soil treatment facility. At the facility, the soil will be placed in windrows. Nutrients and water will be applied and the soil mechanically turned to aerate the soil. As a supplement to composting, highly contaminated soil might be mixed with an asphalt emulsion in an asphalt batch plant located at the facility. These activities will not endanger the community or the environment, providing soil is kept sufficiently moist during excavation and the turning operation to minimize dust. Dust and emissions monitoring would be performed to ensure that workers and the public are not impacted during excavation and during soil handling operations. Increased truck traffic is expected over the route between AOCs 44 and 52 and the treatment site over the course of the remediation. Personnel conducting remedial and monitoring activities would need to follow a site-specific HASP. Proper protective clothing and equipment and safe work practices would minimize the possibility of chemical exposure or injury.

It is anticipated that removal of soil in the Maintenance Yards will take up to 2 years from start of excavation (assumed to be fall of 1994) to the end of excavation following closure of the Maintenance Yards (in summer of 1996). Estimated time for treatment of the soils at the central soil treatment facility is discussed under Section 6.7.7: Cost.

6.7.6 Implementability

Alternative 9 entails using simple removal and soils handling technologies at the site. These include excavation, screening, soil hauling to the central treatment facility and backfilling the excavations. Mechanically screening the soil containing large pavement fragments is a standard process used in the construction industry. The composting and asphalt batch technologies at the central soil treatment facility are relatively simple requiring turning and adding nutrients and water (composting) or asphalt emulsion and if needed, an aggregate additive (asphalt batching). Performance monitoring for composting would entail sampling and analysis of the soil for the remediation period to ensure cleanup levels are achieved. Monitoring of the groundwater at AOCs 44 and 52 would also entail sampling and analysis for a 5 year period. Excavation and treatment of soils at a central soil treatment facility would not interfere with possible future remedial actions at AOCs 44 and 52 should additional intrusive remedial work be required.

6.7.7 Cost

The cost estimate for Alternative 9 is presented in Table 6-15.

Capital costs for this alternative include excavating hot spot areas and surface soils; mechanically screening soils containing pavement; placing soil in piles for sampling and analysis; sampling and analytical costs; transporting excavated soils to the treatment facility; and construction of the treatment facility. The cost estimate assumes that the facility will be sized as detailed in the conceptual facility layout detailed in the Siting Study Report (ABB-ES, 1994a). It also assumes that approximately 20 percent of the soils may contain high concentrations of cPAHs and require asphalt batching. Composted soils would be treated in 2 batches, for up to a total of 4 years.

O&M costs include labor, equipment, and expendable costs associated with operation, maintenance and process monitoring of the remediation for the treatment period. Costs also include yearly groundwater sampling at AOCs 44 and 52, and analytical costs for a minimum five year period. A 25 percent contingency has been included to account for unforeseen conditions that could increase the estimated costs. This estimate is within the +50 to -30 percent range for FS cost estimates, and is based on current (1993) rates.

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TABLE 6-1
EVALUATION CRITERIA

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

THRESHOLD CRITERIA	
Overall Protection of Human Health and the Environment	Address whether or not a remedy provides adequate protection and describes how risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	Describes how the alternative complies with chemical-, location-, and action-specific ARARs, or other criteria, advisories, and guidance.
PRIMARY BALANCING CRITERIA	
Long-term Effectiveness and Permanence	Evaluates the effectiveness of alternatives in protecting human health and the environment after response objectives have been met, in terms of the magnitude of residual risk and the reliability of controls.
Reduction of Toxicity, Mobility, or Volume through Treatment	Evaluates the treatment technologies by the degree of expected reduction in toxicity, mobility, or volume of hazardous material. This criterion also evaluates the type and quantity of residuals remaining after treatment.
Short-term Effectiveness	Addresses any adverse impacts on human health and the environment that may be posed during the construction and implementation period, until the remedial action objectives have been achieved.

(Continued)

TABLE 6-1
EVALUATION CRITERIA

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Implementability	Assesses the ability to construct and operate the technology; the reliability of the technology; the ease of undertaking additional remedial actions; and the ability to monitor the effectiveness of the remedy. Administrative feasibility is addressed in terms of the ability to obtain approvals from other parties or agencies. This criterion also evaluates the availability of required resources such as equipment, facilities, specialists, and capacity.
Cost	Evaluates the capital, operation, and maintenance costs of each alternative, and provides an estimate of the total present worth cost of each alternative.
MODIFYING CRITERIA	
State Acceptance	Address whether, based on its review of the SI/FS and Proposed Plan, the State of Massachusetts concurs with, opposes, or has no comment on the alternatives or proposed remedial action.
Community Acceptance	Addresses whether the public concurs with the proposed remedial action. Community acceptance is typically evaluated based on comments received at public hearings and during the public comment period for the Proposed Plan.

TABLE 6-2
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 1: NO ACTION WITH ENVIRONMENTAL MONITORING

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
Federal Regulatory Requirements	Wetland	National Environmental Policy Act; [40 CFR Part 6]	Applicable	Requires that federal agencies minimize the degradation, loss, or destruction of wetlands, and preserve and enhance natural and beneficial values of wetlands under Executive Orders 11990 and 11988.	Wetlands adjacent to AOCs 44 & 52 may currently be impacted by surface runoff via the stormwater system. This alternative will not reduce potential off-site runoff of contaminants in surface water from AOCs 44 and 52 to the wetlands.
State Regulatory Authority	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and Listing of Hazardous Wastes [310 CMR 30.100]	Applicable	Waste oil is a listed as a hazardous waste under this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste Management Rules).	The wastes found at this site were determined not to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.
	Groundwater	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although cleanup of groundwater, if required, will be handled as a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	All	Minimum Standards for Analytical Data for Remedial Response Actions [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department as a result of the remedial response action conducted.	The groundwater monitoring program will be designed with consideration of this policy.

TABLE 6-3

COST ESTIMATE
ALTERNATIVE 1: NO ACTION

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs		
None	$0	$0
Total Capital Costs	$0	$0
Annual Operation and Maintenance Costs		
Environmental Monitoring		
Groundwater (assumed 6 wells)		
Labor	$6,000	
Analytical	$12,000	
Equipment, Expendables, etc.	$1,000	
	$19,000	$72,000[1]
Catch Basins (2)		
Labor	$ 3,000	
Analytical	$12,000	
Equipment, Expendables, etc.	$ 1,000	
	$16,000	$61,000[1]
Total Operation and Maintenance Cost	$35,000	$133,000[1]
TOTAL PRESENT WORTH COST		$133,000[1]

NOTE:
Costs include 25% contingency. Costs rounded to nearest $1,000.
[1] Present worth based on 10% interest rate and duration of 5 years.

TABLE 6-4
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 2: FENCING WITH ASPHALT BATCHING OF HOT-SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
Federal Regulatory Authority	Wetland	National Environmental Policy Act; [40 CFR Part 6]	Applicable	Requires that Federal agencies minimize the degradation, loss, or destruction of wetlands, and preserve and enhance natural and beneficial values of wetlands under Executive Orders 11990 and 11988.	Wetlands adjacent to AOCs 44 and 52 may currently be impacted by surface water runoff via the storm water system. This alternative will not reduce potential off-site runoff of contaminants in surface water from AOCs 44 and 52 to the wetlands. The remedy will be designed and constructed to minimize the potential of increased surface water flow from asphalt batched paved surfaces to adjacent wetlands.
State Regulatory Requirements	Air	Massachusetts Air Pollution Control Regulations; [310 CMR 6.00 - 7.00]	Applicable	Establishes the standards and requirements for air pollution control in the Commonwealth. Specifically, Section 6.04 provides ambient air quality criteria such as particulate matter standards which is pertinent to AOCs 44 and 52 activity. As a minimum, respirable particulate matter (PM_{10}) for treatment and excavation activities must be maintained at an annual mean arithmetic concentration of $50 \mu g/m^3$ and a maximum 24-hour concentration of $150 \mu g/m^3$. Section 7.02 provides emissions limitations from facilities and operations and requires BACT. Additionally, the Massachusetts toxic air pollutant (TAP) control program requirements will be considered in limiting fugitive emissions (VOCs) and total suspended particulates during treatment and excavation activities.	The emission limits for particulate matter and fugitive emissions will be managed through engineering controls during excavation and treatment activities.
	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and Listing of Hazardous Wastes [310 CMR 30.100]	Applicable	Waste oil is a listed as a hazardous waste under this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste Management Rules).	The wastes found at this site were determined not to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.

TABLE 6-4 (continued)
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 2: FENCING WITH ASPHALT BATCHING OF HOT-SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
State Regulatory Requirements	Soil	MHWMR Provisions for Recyclable Materials and for Waste Oil [310 CMR 30.200]	Applicable	This regulations contains procedural and substantive requirements for handling regulated recyclable materials. The substantive requirements include preventing and reporting releases to the environment, proper maintenance of treatment and control systems, and stockpiling and handling of regulated recyclable material.	Asphalt batching of soils would comply with the substantive requirements of this regulation.
	Soil	MHWMR - Waste Piles; [310 CMR 30.640 - 30.649]	Applicable	A waste pile facility must install a liner, provide a leachate collection system, provide a run-on/run-off control system, comply with the groundwater monitoring requirements, perform inspections, and close the facility properly.	These requirements will be addressed in the design of an area for stockpiling of wastes for on-site treatment.
	Ground-water	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although the cleanup of groundwater, if required, will be handled under a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	Soil	Management Procedures for Excavated Soils Contaminated with Virgin Petroleum Oils Policy [WSC-401-91]	To Be Considered	Guidance on storage, treatment, and disposal or reuse of excavated soil contaminated with virgin petroleum oils.	The requirements of this rule will be considered when designing and constructing this remedy.
	All	Minimum Standards for Analytical Data for Remedial Response Action [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department.	All sampling plans will consider the analytical methods provided in this policy.

TABLE 6-5

COST ESTIMATE
ALTERNATIVE 2: FENCING/ASPHALT BATCH HOT SPOTS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs		
Fencing (currently in place)	$0	$0
Deed Restrictions	$1,000	$1,000
Air Monitoring	$65,000	$65,000
Asphalt Batch Hot Spot Areas		
Pre-excavation Exploration	$13,000	
Excavation	$18,000	
Asphalt Batching	$83,000	
Analytical	$ 3,000	
Site Restoration	$ 21,000	
	$138,000	$138,000
Total Capital Costs	$204,000	$204,000
Annual Operation and Maintenance Costs		
Environmental Monitoring (See Table 6-3)	$35,000	$133,000[1]
Fence Maintenance	$2,000	$19,000[2]
Total Operation and Maintenance Cost	$37,000	$152,000
TOTAL PRESENT WORTH COST		$356,000

NOTE:
Costs include 25% contingency. Costs rounded to nearest $1,000.
[1] Present worth based on 10% interest rate and duration of 5 years.
[2] Present worth based on 10% interest rate and duration of 30 years.

TABLE 6-6
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 3: CAPPING/ASPHALT BATCHING OF HOT SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
Federal Regulatory Authority	Wetland	National Environmental *Policy Act*; [*40 CFR Part 6*]	Applicable	Requires that Federal agencies minimize the *degradation, loss, or destruction of wetlands*, and preserve and enhance natural and beneficial values of wetlands under Executive Orders 11990 and 11988.	Wetlands adjacent to AOCs 44 and 52 may currently be impacted by surface water runoff via the storm water system. This alternative caps the site, thus reducing potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will also be designed and constructed to manage the increased surface water flow from the paved surface in a manner that will minimize impact to the adjacent wetland.
State Regulatory Requirements	Air	Massachusetts Air Pollution Control Regulations; [310 CMR 6.00 - 7.00]	Relevant and Appropriate	Establishes the standards and requirements for air pollution control in the Commonwealth. Specifically, Section 6.04 provides ambient air quality criteria such as particulate matter standards which is pertinent to AOCs 44 and 52 activity. As a minimum, respirable particulate matter (PM_{10}) for treatment and excavation activities must be maintained at an annual mean arithmetic concentration of $50 \mu g/m^3$ and a maximum 24-hour concentration of 150 $\mu g/m^3$. Section 7.02 provides emissions limitations from facilities and operations and requires BACT. Additionally, the Massachusetts toxic air pollutant (TAP) control program requirements will be considered in limiting fugitive emissions (VOCs) and total suspended particulates during treatment and excavation activities.	The emissions limits for particulate matter and fugitive emissions will be managed through engineering controls during excavation and treatment activities.
	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and *Listing of Hazardous Wastes* [310 CMR 30.100]	Applicable	*Waste oil is a listed as a hazardous waste under* this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste *Management* Rules).	The wastes *found at this site were determined* not to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.

TABLE 6-6 (continued)
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 3: CAPPING/ASPHALT BATCHING OF HOT SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
State Regulatory Requirements	Soil	MHWMR Provisions for Recyclable Materials and for Waste Oil [310 CMR 30.200]	Relevant and Appropriate	This regulation contains procedural and substantive requirements for handling regulated recyclable materials. The substantive requirements include preventing and reporting releases to the environment, proper maintenance of treatment and control systems, and handling of regulated recyclable material.	Asphalt batching of soil on site will comply with the substantive requirements of this regulation.
	Soil	MHWMR - Closure; [30 CMR 30.580]	Relevant and Appropriate	Closure of a hazardous waste TSD facility must prevent post-closure escape of hazardous waste, hazardous waste constituents, leachate, contaminated run-off, and waste decomposition products to ground water, surface water, soil, or the atmosphere.	The design and construction of the remedy will comply with these closure requirements.
	Soil	MHWMR - Post Closure; [30 CMR 30.590]	Relevant and Appropriate	This rule establishes requirements for post-closure care and limitations on use of the property.	The design and construction of the remedy will comply with these post-closure requirements.
	Soil	MHWMR - Waste Piles; [310 CMR 30.640 - 30.649]	Relevant and Appropriate	A waste pile facility must install a liner, provide a leachate collection system, provide a run-on/run-off control system, comply with the groundwater monitoring requirements, perform inspections, and close the facility properly.	These requirements will be addressed in the design of an area for stockpiling of wastes for on-site treatment.
	Groundwater	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although the cleanup of groundwater, if required, will be handled under a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	Soil	Management Procedures for Excavated Soils Contaminated with Virgin Petroleum Oils Policy [WSC-401-91]	To Be Considered	Guidance on storage, treatment, and disposal or reuse of excavated soil contaminated with virgin petroleum oils. Soils treated off-site must be transported under a Bill of Lading to be exempt from management of as a hazardous waste.	The requirements of this rule will be considered when designing and constructing this remedy.
	All	Standards for Analytical Data for Remedial Response Action [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department.	All sampling plans will be designed with consideration of the analytical methods provided in this policy.

TABLE 6-7

COST ESTIMATE
ALTERNATIVE 3: CAPPING/ASPHALT BATCH HOT SPOTS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs		
Capping		
Raise Frames and Hydrants	$ 6,000	
Fence Modification	$ 17,000	
Grading	$ 33,000	
Paving	$606,000	
	$662,000	$662,000
Expansion of Stormwater Collection System		
Catch Basins	$ 27,000	
Trenching and Piping	$ 53,000	
Retention Basins/Flow Reducers	$ 13,000	
Oil and Grease Traps	$ 28,000	
Design for Wetlands Impact	$ 24,000	
	$145,000	$145,000
Deed Restrictions	$1,000	$1,000
Air Monitoring	$71,000	$71,000
Asphalt Batch Hot Spot Areas (See Table 6-5)	$138,000	$138,000
Total Capital Costs	$1,017,000	$1,017,000
Annual Operation and Maintenance Costs		
Groundwater Monitoring (See Table 6-3)	$ 19,000	$ 72,000[1]
Cap Maintenance	$ 14,000	$132,000[2]
Total Operation and Maintenance Cost	$33,000	$204,000
TOTAL PRESENT WORTH COST		$1,221,000

NOTE:
Costs include 25% contingency. Costs rounded to nearest $1,000.
[1] Present worth based on 10% interest rate and duration of 5 years.
[2] Present worth based on 10% interest rate and duration of 30 years.

TABLE 6-8
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 5: ASPHALT BATCHING SITE/ASPHALT BATCHING HOT SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
Federal Regulatory Authority	Wetland	National Environmental Policy Act; [40 CFR Part 6]	Applicable	Requires that Federal agencies minimize the degradation, loss, or destruction of wetlands, and preserve and enhance natural and beneficial values of wetlands under Executive Orders 11990 and 11988.	Wetlands adjacent to AOCs 44 and 52 may currently be impacted by surface water runoff via the storm water system. This alternative covers the site with pavement, thus reducing potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will also be designed and constructed to manage the increased flow from the paved surface in a manner that will minimize impact to adjacent wetlands.
State Regulatory Requirements	Air	Massachusetts Air Pollution Control Regulations; [310 CMR 6.00 - 7.00]	Applicable	Establishes the standards and requirements for air pollution control in the Commonwealth. Specifically, Section 6.04 provides ambient air quality criteria such as particulate matter standards which is pertinent to AOCs 44 and 52 activity. As a minimum, respirable particulate matter (PM_{10}) for treatment and excavation activities must be maintained at an annual mean arithmetic concentration of $50 \mu g/m^3$ and a maximum 24-hour concentration of $150 \mu g/m^3$. Section 7.02 provides emissions limitations from facilities and operations and requires BACT. Additionally, the Massachusetts toxic air pollutant (TAP) control program requirements will be considered in limiting fugitive emissions (VOCs) and total suspended particulates during treatment and excavation activities.	The emissions limits for particulate matter and fugitive emissions will be managed through engineering controls during excavation and treatment activities.
	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and Listing of Hazardous Wastes [310 CMR 30.100]	Applicable	Waste oil is a listed as a hazardous waste under this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste Management Rules).	The wastes found at this site were determined not to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.

TABLE 6-8 (continued)
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 5: ASPHALT BATCHING SITE/ASPHALT BATCHING HOT SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
State Regulatory Requirements	Soil	MHWMR Provisions for Recyclable Materials and for Waste Oil [310 CMR 30.200]	Applicable	This regulation contains procedural and substantive requirements for handling regulated recyclable materials. The substantive requirements include preventing and reporting releases to the environment, proper maintenance of treatment and control systems, and handling of regulated recyclable materials.	Asphalt batching of soil on site will comply with the substantive requirements of this regulation.
	Soil	MHWMR - Waste Piles; [310 CMR 30.640 - 30.649]	Applicable	A waste pile facility must install a liner, provide a leachate collection system, provide a run-on/run-off control system, comply with the groundwater monitoring requirements, perform inspections, and close the facility properly.	These requirements will be addressed in the design of an area for stockpiling of wastes for on-site treatment.
	Ground-water	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although cleanup of groundwater, if required, will be handled as a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	All	Standards for Analytical Data for Remedial Response Action [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department.	All sampling plans will be designed with consideration of the analytical methods provided in this policy.

TABLE 6-9

COST ESTIMATE
ALTERNATIVE 5: ASPHALT BATCH SITE/ASPHALT BATCH HOT SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs		
Asphalt Batch Site and Hot Spot Areas		
Excavation	$ 134,000	
Asphalt Batching	$1,072,000	
Analytical	$ 116,000	
Site Restoration	$ 129,000	
	$1,451,000	$1,451,000
Expansion of Stormwater Collection System (see Table 6-7)	$145,000	$145,000
Air Monitoring	$71,000	$71,000
Total Capital Costs	$1,667,000	$1,667,000
Annual Operation and Maintenance Costs		
Groundwater Monitoring (See Table 6-3)	$19,000	$72,000[1]
Total Operation and Maintenance Cost	$19,000	$72,000
TOTAL PRESENT WORTH COST		$1,739,000

NOTE:
Costs include 25% contingency. Costs rounded to nearest $1,000.
[1] Present worth based on 10% interest rate and duration of 5 years.

TABLE 6-10
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 7: BIOVENTING SITE AND HOT-SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
Federal Regulatory Authority	Wetland	National Environmental Policy Act; [40 CFR Part 6]	Applicable	Requires that Federal agencies minimize the degradation, loss, or destruction of wetlands, and preserve and enhance natural and beneficial values of wetlands under Executive Orders 11990 and 11988.	Wetlands adjacent to AOCs 44 and 52 may currently be impacted by surface water runoff via the storm water system. This alternative covers the site with pavement, thus reducing potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will also be designed and constructed to manage the increased flow from the paved surface in a manner that will *minimize impact to adjacent wetlands.*
State Regulatory Requirements	Air	Massachusetts Air Pollution Control Regulations; [310 CMR 6.00 - 7.00]	Applicable	Establishes the standards and requirements for air *pollution control in the Commonwealth.* Specifically, Section 6.04 provides ambient air quality criteria such as particulate matter standards which is pertinent to AOCs 44 and 52 activity. As a minimum, respirable particulate matter (PM_{10}) for treatment and excavation activities must be maintained at an annual mean arithmetic concentration of $50 \mu g/m^3$ and a maximum 24-hour concentration of $150 \mu g/m^3$. Section 7.02 provides emissions limitations from facilities and operations and requires BACT. Additionally, the Massachusetts toxic air pollutant (TAP) control program requirements will be considered in limiting fugitive emissions (VOCs) and total suspended particulates during treatment and excavation activities.	The emissions limits for particulate matter and *fugitive emissions will be managed through* engineering controls during excavation and treatment activities.
	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and Listing of Hazardous Wastes [310 CMR 30.100]	Applicable	Waste oil is a listed as a hazardous waste under this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste Management Rules).	The wastes found at this site were determined <u>not</u> to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.
	Ground-water	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although cleanup of groundwater, if required, will be handled as a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	All	Standards for Analytical Data for Remedial Response Action [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department.	All sampling plans will be designed with consideration of the analytical methods provided in this policy.

TABLE 6-11

COST ESTIMATE
ALTERNATIVE 7: BIOVENTING

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs		
Bioventing System Nutrient Injection Vapor Well and Piping Installation	 $110,000 $116,000 $226,000	 $226,000
Cap for System[1]	$522,000	$522,000
Expansion of Stormwater Collection System (see Table 6-7)	$145,000	$145,000
Air Monitoring	$71,000	$71,000
Engineering (10% of Capital Costs)	$89,000	$89,000
Total Capital Costs	$1,053,000	$1,053,000
Future Costs		
Confirmation Sampling	$43,000	$17,000[3]
Total Future Costs	$43,000	$17,000
Annual Operation and Maintenance Costs		
Groundwater Monitoring (See Table 6-3)	$19,000	$117,000[2]
Operation and Maintenance of Bioventing System (Labor and Electricity)	$22,000	$137,000[2]
Process Monitoring of Soil	$36,000	$224,000[2]
Total Operation and Maintenance Cost	$77,000	$478,000
TOTAL PRESENT WORTH COST		$1,548,000

NOTE:
Costs include 25% contingency. Costs rounded to nearest $1,000.
[1] See Table 6-7. Does not include 1.5-inch wearing course.
[2] Present worth based on 10% interest rate and duration of 10 years.
[3] Present worth based on 10% interest rate and future cost in 10 years.

TABLE 6-12
SYNOPSIS OF ACTION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 8: LANDFARMING SITE/EXCAVATING AND LANDFARMING HOT-SPOT AREAS

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	MEDIUM	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
State Regulatory Requirements	Air	Massachusetts Air Pollution Control Regulations; [310 CMR 6.00 - 7.00]	Applicable	Establishes the standards and requirements for air pollution control in the Commonwealth. Specifically, Section 6.04 provides ambient air quality criteria such as particulate matter standards which is pertinent to AOCs 44 and 52 activity. As a minimum, respirable particulate matter (PM_{10}) for treatment and excavation activities must be maintained at an annual mean arithmetic concentration of 50 $\mu g/m^3$ and a maximum 24-hour concentration of 150 $\mu g/m^3$. Section 7.02 provides emissions limitations from facilities and operations and requires BACT. Additionally, the Massachusetts toxic air pollutant (TAP) control program requirements will be considered in limiting fugitive emissions (VOCs) and total suspended particulates during treatment and excavation activities.	The emissions limits for particulate matter and fugitive emissions will be managed through engineering controls during excavation and treatment activities.
	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and Listing of Hazardous Wastes [310 CMR 30.100]	Applicable	Waste oil is a listed as a hazardous waste under this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste Management Rules).	The wastes found at this site were determined not to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.
	Soil	MHWMR - Land Treatment Units; [310 CMR 30.650 - 30.659]	Relevant and Appropriate	The treatment zone must consist of soils which meet the criteria for specified U.S.Department of Agriculture soil texture classes. The maximum depth of the treatment zone may be no more than 1.5 meters (5 feet) from the initial soil surface and at least four feet above the high probable groundwater level.	The substantive construction, monitoring, operational, and closure standards will be met in the design and construction of the land treatment remedy.
	Groundwater	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although groundwater will be cleaned up, if required, under a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	All	Standards for Analytical Data for Remedial Response Action [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department.	All sampling plans will be designed with consideration of the analytical methods provided in this policy.

TABLE 6-13

COST ESTIMATE
ALTERNATIVE 8: LANDFARMING

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs - 1994 (20% of Site)		
Prepare Hot Spots for Landfarming		
Excavation	$18,000	
Backfilling	$18,000	
	$36,000	$36,000
Remove Oversize Material and Pavement		
Excavate Top 6 Inches	$ 2,000	
Screen	$ 6,000	
Decontaminate and Dispose of Material	$50,000	
	$58,000	$58,000
Air Monitoring	$76,000	$76,000
Remove Old Fence and Install New Fence	$10,000	$10,000
Equipment		
Tractor	$175,000	
Irrigation System	$ 19,000	
	$194,000	$194,000
Initial Nutrient Addition	$36,000	$36,000
Capital Costs - 1996 (80% of Site)		
Remove Oversize Material and Pavement		
Excavate Top 6 Inches	$ 9,000	
Screen	$ 18,000	
Decontaminate and Dispose of Material	$190,000	
	$217,000	$179,000[1]
Fill Catch Basins	$3,000	$2,000[1]
Initial Nutrient Addition	$36,000	$30,000[1]
Total Capital Costs	$666,000	$621,000

(Continued)

TABLE 6-13

COST ESTIMATE
ALTERNATIVE 8: LANDFARMING

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Annual Operation and Maintenance Costs (20% of Site)		
Groundwater Monitoring (See Table 6-3)	$19,000	$ 92,000[2]
Operation and Maintenance (Labor, Nutrients, Equipment Maintenance)	$55,000	$208,000[3]
Process Monitoring of Soil	$ 9,000	$ 34,000[3]
Confirmation Sampling	$11,000	$ 42,000[3]
Annual Operation and Maintenance Costs (80% of Site)		
Operation and Maintenance (Labor, Nutrients, Equipment Maintenance)	$123,000	$385,000[4]
Process Monitoring of Soil	$ 35,000	$110,000[4]
Confirmation Sampling	$ 20,000	$ 61,000[4]
Total Operation and Maintenance Cost		$932,000
TOTAL PRESENT WORTH COST		$1,553,000

NOTE:
Costs include a 25% contingency. Costs rounded to nearest $1,000.
[1] Present worth based on a 10% interest rate and costs incurred in 2 years.
[2] Present worth based on 10% interest rate and duration of 7 years.
[3] Present worth based on 10% interest rate and duration of 5 years.
[4] Present worth based on 10% interest rate and duration of 5 years, beginning in 2 years.

TABLE 6-14
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 9: TREATMENT OF SITE AND HOT SPOT AREA SOILS AT A CENTRAL SOIL TREATMENT FACILITY

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	MEDIUM	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
Federal Regulatory Authority	Wetland	National Environmental Policy Act; [40 CFR Part 6]	Applicable	Requires that Federal agencies minimize the degradation, loss, or destruction of wetlands, and preserve and enhance natural and beneficial values of wetlands under Executive Orders 11990 and 11988.	Wetlands adjacent to AOCs 44 and 52 may currently be impacted by surface water runoff via the storm water system. This alternative covers the site with pavement, thus reducing potential off-site runoff of contaminants in surface water from AOCs 44 and 52 soils to the wetlands. The remedy will also be designed and constructed to manage the increased flow from the paved surface in a manner that will minimize impact to adjacent wetlands.
State Regulatory Requirements	Drinking Water Supply Recharge Area	Massachusetts Hazardous Waste Rules, Location Standards for Facilities; [310 CMR 30.700-30.707]	Applicable	No active portion of a new hazardous waste land treatment unit may be located on land overlying an actual, planned, or potential public or private drinking water supply.	The current site which has been selected does not overly an actual, planned, or potential public or private drinking water supply. If a groundwater recharge area does underlie a selected site, the site will have to be relocated or a waiver, if appropriate, will have to be obtained under state regulations.
	Air	Massachusetts Air Pollution Control Regulations; [310 CMR 6.00 - 7.00]	Applicable	Establishes the standards and requirements for air pollution control in the Commonwealth. Specifically, Section 6.04 provides ambient air quality criteria such as particulate matter standards which is pertinent to AOCs 44 and 52 activity. As a minimum, respirable particulate matter (PM_{10}) for treatment and excavation activities must be maintained at an annual mean arithmetic concentration of $50 \mu g/m^3$ and a maximum 24-hour concentration of $150 \mu g/m^3$. Section 7.02 provides emissions limitations from facilities and operations and requires BACT. Additionally, the Massachusetts toxic air pollutant (TAP) control program requirements will be considered in limiting fugitive emissions (VOCs) and total suspended particulates during treatment and excavation activities.	The emissions limits for particulate matter and fugitive emissions will be managed through engineering controls during excavation and treatment activities.
	Soil	Massachusetts Hazardous Waste Management Rules (MHWMR) Identification and Listing of Hazardous Wastes [310 CMR 30.100]	Applicable	Waste oil is a listed as a hazardous waste under this rule and is therefore subject to 310 CMR 30.000 (i.e., the Massachusetts Hazardous Waste Management Rules).	The wastes found at this site were determined not to be characteristic hazardous wastes; however, waste oil is a listed hazardous waste under this rule.
	Soil	MHWMR Provisions for Recyclable Materials and for Waste Oil [310 CMR 30.200]	Applicable	This regulation contains procedural and substantive requirements for handling regulated recyclable materials. The substantive requirements include preventing and reporting releases to the environment, proper maintenance of treatment and control systems, and handling of regulated recyclable materials.	Asphalt batching and composting of soil on site would comply with the substantive requirements of this regulation.

TABLE 6-14 (continued)
SYNOPSIS OF LOCATION-SPECIFIC FEDERAL AND STATE ARARS
ALTERNATIVE 9: TREATMENT OF SITE AND HOT SPOT AREA SOILS AT A CENTRAL SOIL TREATMENT FACILITY

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

AUTHORITY	MEDIUM	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN ARAR
State Regulatory Requirements	Soil	MHWMR - Closure; [30 CMR 30.580]	Applicable	Closure of a hazardous waste TSD facility must prevent post-closure escape of hazardous waste, hazardous waste constituents, leachate, contaminated run-off, and waste decomposition products to ground water, surface water, soil, or the atmosphere.	The soil treatment facility will be closed in compliance with these requirements.
	Soil	MHWMR - Post Closure; [30 CMR 30.590]	Applicable	This rule establishes requirements for post-closure care and limitations on use of the property.	The soil treatment facility will be maintained after closure in compliance with these requirements.
	Soil	MHWMR - Waste Piles; [310 CMR 30.640 - 30.649]	Applicable	A waste pile facility must install a liner, provide a leachate collection system, provide a run-on/run-off control system, comply with the groundwater monitoring requirements, perform inspections, and close the facility properly.	These requirements will be addressed in the design of an area for stockpiling of wastes for on-site treatment.
	Soil	MHWMR - Land Treatment Units; [310 CMR 30.650 - 30.659]	Applicable	The treatment zone must consist of soils which meet the criteria for specified U.S.Department of Agriculture soil texture classes. The maximum depth of the treatment zone may be no more than 1.5 meters (5 feet) from the initial soil surface and at least four feet above the high probable groundwater level.	The substantive construction, monitoring, operational, and closure standards will be met in the design and construction of the land treatment remedy.
	Ground-water	MHWMR Groundwater Protection; [310 CMR 30.660 - 30.679]	Relevant and Appropriate	Groundwater monitoring should be conducted during and following remedial actions. Concentration limits for the hazardous constituents are specified in 310 CMR 30.667.	Although cleanup of groundwater, if required, will be handled as a separate operable unit, groundwater monitoring will be conducted as a component of the remedy.
	Soil	Management Procedures for Excavated Soils Contaminated with Virgin Petroleum Oils Policy [WSC-401-91]	To Be Considered	Guidance on storage, treatment, and disposal or reuse of excavated soil contaminated with virgin petroleum oils.	The requirements of this guidance will be met for excavated soil contaminated with virgin petroleum oils.
	All	Standards for Analytical Data for Remedial Response Action [WSC-300-89]	To Be Considered	This policy describes the minimum standards for analytical data submitted to the Department.	All sampling plans will be designed with consideration of the analytical methods provided in this policy.

TABLE 6-15

COST ESTIMATE
ALTERNATIVE 9:
TREATMENT OF SITE AND HOT SPOT AREA SOILS
AT A CENTRAL SOIL TREATMENT FACILITY

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Capital Costs - Fall 1994/Spring 1995		
Treatment Facility:		
Treatment Area Construction (Compost and Asphalt Batch areas)	$609,000	
Stormwater Management/Irrigation	$335,000	
Site Work (Utilities, Roads, Bldg Demo)	$107,000	
Soil Turning & Air Monitoring Equipment	$278,000	
Monitoring Wells	$ 26,000	
	$1,355,000	$1,355,000
Nutrient/Amendment Addition	$ 10,000	$ 10,000
Site Preparation	$ 10,000	$ 10,000
Hot Spots & Surface Soil (20% of Yard) Excavations	$ 45,000	$ 45,000
Screen/Haul/Batch Pavement & Debris	$ 29,000	$ 29,000
Site Restoration	$ 72,000	$ 72,000
Load/Haul/Batch or Spread for Composting	$107,000	$107,000
Stockpile Sampling and Analysis	$ 24,000	$ 24,000
Air Monitoring (excluding equipment)	$ 80,000	$ 80,000
Capital Costs - 1996 (80% of Site)		
Site Preparation	$ 6,000	$ 5,000[1]
Excavation of Surface Soil (80%)	$ 72,000	$65,000[1]
Screen/Haul/Batch Pavement & Debris	$ 80,000	$73,000[1]
Site Restoration	$248,000	$225,000[1]
Load/Haul/Batch or Spread for Composting	$243,000	$221,000[1]

(Continued)

TABLE 6-15

COST ESTIMATE
ALTERNATIVE 9:
TREATMENT OF SITE AND HOT SPOT AREA SOILS
AT A CENTRAL SOIL TREATMENT FACILITY

AOCS 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

ITEM	COST	PRESENT WORTH
Stockpile Sampling and Analysis	$ 59,000	$54,000[1]
Engineering (10% of Capital Costs)	$243,000	$243,000
Siting and Permitting (5% of Capital Cost)	$121,000	$121,000
Total Capital Costs	$2,804,000	$2,739,000
Annual Operation and Maintenance Costs		
Groundwater Monitoring at AOCs 44 and 52	$ 19,000	$72,000[2]
Operation and Maintenance (Labor, Nutrients, Utilities, Equipment Maintenance)	$ 135,000	$428,000[3]
Process Monitoring of Soil	$ 12,000	$38,000[3]
Confirmation Sampling	$ 16,000	$51,000[3]
Groundwater Monitoring at Treatment Site	$ 22,000	$ 70,000[3]
Total Operation and Maintenance Cost	$204,000	$659,000
TOTAL PRESENT WORTH COST		$3,398,000

NOTE:
Costs include a 25% contingency. Costs rounded to nearest $1,000.
[1] Present worth based on a 10% interest rate and costs incurred in 1 year.
[2] Present worth based on 10% interest rate and duration of 5 years.
[3] Present worth based on 10% interest rate and duration of 4 years.

7.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The following paragraphs present a comparison of the seven remedial alternatives, (Alternatives 1, 2, 3, 5, 7, 8 and 9) highlighting the relative advantages and disadvantages of the alternatives with respect to the seven evaluation criteria. Table 7-1 presents a summary of results of the comparative analysis. The purpose of the comparative analysis is to aid decision-makers in selecting a remedy that meets the remedial objectives for the site as a whole.

7.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

This criterion is one that, according to CERCLA, must be met for a remedial alternative to be chosen as the final remedy for the site. While all the alternatives except for No Action provide some degree of protection, Alternative 9 provides the greatest degree of protection by removing hot spot area and surface soils from the site and irreversibly treating them by biodegrading organic contaminants and/or immobilizing contaminants by asphalt batching. Alternatives 7 and 8 would also irreversibly treat organic contaminants on site. Alternative 7 provides greater protection than Alternative 8 in the short term (i.e., during implementation) because a cap would be placed over the soils to reduce the possibility of exposure to soil contaminants during treatment. Maintenance operations in the yards could continue after the cap is in place. A disadvantage of Alternatives 8 and 9 relative to the other remedial alternatives is that while remediation of the hot spot areas and approximately 20 percent of the site could begin immediately, remediation of the remaining 80 percent of the site (which is currently fenced) would not begin until the summer of 1996 when operations in the Maintenance Yards cease.

Alternatives 5 and 3 would reduce risks by (1) reducing mobility of soil contaminants by asphalt batching and (2) limiting exposure to contaminants by capping. A disadvantage of capping relative to permanent treatment technologies is that it requires maintenance over the long term to remain effective. However, remedial action would be complete in a few months.

Alternative 2 relies primarily on fencing and institutional controls for protection of human health and the environment. While these controls may be effective while the Army occupies the site, enforcement of the land use restrictions may become more difficult when the property is sold. Because this alternative only treats the hot spot areas, risk would remain if the controls failed.

Alternative 1 provides no protection of human health and the environment. Risks in excess of USEPA's target risk range would remain.

7.2 COMPLIANCE WITH ARARs

CERCLA also requires that the selected alternative comply with ARARs or a waiver be obtained if the alternative does not comply. The location-specific ARAR identified for the AOCs 44 and 52 alternatives entails regulations that protect wetlands. Alternatives 1 and 2 will not reduce potential off-site runoff of contaminants in surface water from AOCs 44 and 52 to the wetlands. Alternatives 3, 5, 7, 8, and 9 all minimize the potential of off-site migration of contaminants via the stormwater system. Impacts to wetlands due to increased stormwater runoff from paved surfaces (Alternatives 2, 3, 5, and 7) would need to be considered during remediation and design of the stormwater collection system expansion. Additional location-specific ARARs for siting of hazardous waste treatment facilities would apply to the central soil treatment facility (Alternative 9). A location for the facility has not yet been finalized (siting is in process [ABB-ES, 1994a]); however, these ARARs would be considered in the site selection process.

Action-specific regulations for groundwater monitoring is an ARAR for all of the alternatives, including No Action, and would be met for all alternatives by instituting a groundwater monitoring program for each alternative. The Massachusetts Hazardous Waste Regulations contain ARARs for all remedial alternatives because of the nature of contamination at the site. Each alternative would comply with these regulations during the design and implementation of the remedial activity.

Federal and state air quality regulations would be met by all the alternatives. In particular, dust suppression would be required for alternatives involving excavation, tilling, or other activities that could generate dust.

Requirements specific to remedial actions such as soil recycling by asphalt batching, biological treatment, and land treatment would be met by the alternatives to which they apply.

Although there are no chemical-specific ARARs for establishing cleanup levels for soils at AOCs 44 and 52, a risk-based cleanup level for cPAHs has been developed. Only alternatives 7, 8 and 9 would reduce contaminant concentrations at the site to meet risk-based target levels. Alternatives 3 and 5, however, reduce risk by immobilizing soil contaminants.

7.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

This criterion evaluates the reliability of each alternative in protecting human health and the environment after the response objectives have been met, in terms of the magnitude of residual risk and the reliability of controls. All of the alternatives except for Alternative 1 reduce risks to levels within the USEPA's target risk range; however, only Alternatives 5, 7, 8, and 9 use treatment technologies to permanently and irreversibly immobilize or destroy cPAHs in the surface soils. Treatability testing (ABB-ES, 1993b) and literature studies (see Appendix C) indicate that the TPHC and cPAH contaminants in AOCs 44 and 52 soils are biodegradable. Biodegradation of cPAHs in the soil is expected to occur slowly.

Alternatives 2, 3, and 5 would not reduce the concentrations of organic contaminants, but would reduce risk by limiting exposure. Because Alternatives 2 and 3 require maintenance of the institutional controls and cap, respectively, over the long term to remain effective, they may not be as reliable as the treatment alternatives. However, remedial actions would be completed in a shorter timeframe than for the alternatives that involve bioremediation.

Based on the Supplemental Site Investigation and Data Gathering detailed in Section 1.0, bituminous paving material contains cPAHs; thus Alternatives 3, 5 and 7 that utilize bituminous paving as a part of the treatment process to remediate PAH contaminated soil, may potentially be introducing more cPAHs to the site.

Alternative 1 would not be effective over the long term because risks in excess of USEPA's target risk range would remain, and controls would not be implemented to mitigate the risk.

7.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion evaluates whether the alternatives meet the statutory preference for treatment under CERCLA. This criterion also evaluates whether the technology reduces the toxicity, mobility, or volume of contaminants and the type and quantity of residuals remaining after treatment. Alternatives 7, 8, and 9 utilize bioremediation treatment technologies which irreversibly reduce the toxicity, mobility, and volume of organic contaminants in hot spot areas and surface soils throughout the site. Alternatives 2, 3, and 5 also meet the statutory preference for treatment through asphalt batching, although alternatives 2 and 3 only include treating hot spot areas. Asphalt batching reduces the mobility of contaminants in soils. Alternative 1 does not meet the statutory preference for treatment.

Alternatives 7 and 8, which utilize biological treatment technologies on site, are not expected to have any residuals remaining after treatment. Alternative 9, which would occur off-site, would generate reusable soil as an end product of the composting process and some asphalt batched material from the batching process. The asphalt batched material could be used as paving material on-base and in construction of the central treatment facility. Asphalt batching (alternatives 2, 3, and 5) would produce asphalt, which would then be spread on site.

7.5 Short-Term Effectiveness

Potential adverse impacts to the surrounding community, workers, and environment will be considered during remedy selection. This criterion also considers the duration of the remedial alternative. Alternative 1 would have the least impact during implementation because it would not involve construction or operation. Alternative 7 would also have minimal impact on the community, workers, and environment because remediation would take place in-situ. However, increased stormwater runoff from the cap would need to be controlled to minimize impacts on the wetland which receives drainage from this area. Runoff control would also be an issue for Alternatives 3, 5, and 2 (to a lesser extent) which would place the impermeable asphalt batched material over the site.

Alternatives 2, 3, 5, 8, and 9 involve excavation and handling of contaminated soils. Adverse impacts from potential worker exposure would be mitigated by protective clothing and equipment and safe work practices. Fugitive dust would be controlled by application of water during remedial actions. Impacts from volatilization are not expected to be a problem with these alternatives. MADEP policy #WSC-400-89 regarding Management Procedures for Excavated Soils Contaminated with Virgin Petroleum Oils permits aeration at the site of generation for excavated soils containing less than 1800 ppm volatiles (volume/volume headspace concentration) during emergency response or short term measures without specific approval from the Division of Air Quality Control. The highest headspace concentration recorded during the excavation of the UST was 196 ppm (ATEC, 1992).

Completion of remedial actions would be essentially immediate for Alternatives 2, 3, and 5 because work on site could be accomplished within a few weeks or months. On-site remedial actions associated with Alternative 9 would be completed by the end of 1996, because by that time, the Maintenance Yards would no longer be in use and surface soils over the entire site could be excavated and soils exceeding cleanup levels could be taken off-site for treatment. Alternative 8 would take up to seven years to complete, because remediation would need to be phased (remediation of hot spots and 20 percent of the site to begin in 1994, and the remainder to begin in 1996) to accommodate the Maintenance Yards closure schedule. Although bioventing under Alternative 7 could begin in 1994 without major disruption to normal operations, remediation is expected to take 10 years to complete, because this type of bioremediation is not as aggressive as landfarming or composting.

7.6 IMPLEMENTABILITY

This criterion evaluates each alternative's ease of construction and operation; administrative feasibility; and availability of services, materials, equipment, and specialists that may required to construct and operate the technology. This criterion also considers the ease or difficulty of implementing further remedial actions at a later date, and the effect the remedial alternative would have on continued operations at the Maintenance Yards.

Alternative 1, which only includes groundwater monitoring, would be the easiest alternative to implement at the site, and would have the least impact on future remedial actions and Maintenance Yards activities. Similarly, Alternative 2 would be relatively easy to construct and would have minimal impact on activities at the site.

Alternatives 3 and 5 would be easy to construct because they involve paving the site, which is a common construction technology. Asphalt batching of petroleum-contaminated soils has been approved by the agencies for other sites at Fort Devens. However, these alternatives would disrupt the yards for several weeks during capping, stormwater collection system modification, and excavation. Also, if further action is warranted at a later date, the cap may need to be removed.

Alternative 9 involves excavation and transporting soil, which are common technologies. Composting technology has been used for treatment of sewage sludge and is also applicable to biodegradable contaminants in soil. Asphalt batching has also become a common treatment technology. This alternative would have minimal effect on future actions, and because implementation would be phased, impact to the Maintenance Yards activities would entail having to confine current operations to 80 percent of the yards until the Maintenance Yards close. An existing central soil treatment facility is not currently available; therefore, a facility will need to be sited and constructed for AOCs 44 and 52 soils. Construction of a facility with sufficient capacity to treat all of the soil at once would be difficult in terms of facility siting and other regulatory issues. Operation of the facility would be relatively simple and would not require skilled operators, but may require bioremediation specialists to monitor performance and troubleshoot on an as-needed basis.

Alternatives 7 and 8 would not be difficult to construct or operate but pose Zone II concerns. Nutrients for Alternatives 7 and 8 would need to be monitored so as to not impact either Grove Pond and its wetlands or the Grove Pond water supply wells. Stormwater collection system expansion would also be an issue for Alternative 7, because it would include capping the entire site. Because both alternatives entail remediation on-site, there would be some disruption of the Maintenance Yards operations.

7.7 COST

Capital, O&M, and present worth costs for each alternative were calculated within a range of accuracy of +50 percent to -30 percent. The alternatives with the lowest capital costs are those that include little remedial action, such as Alternatives 1, 2, and 3, and those that utilize in-situ treatment technologies (Alternatives 8 and 7). Alternatives 5 and 9, which involve excavation and treatment of soil, require the largest capital. O&M costs are computed on an annual basis, and are lowest for Alternative 5, which does not require long-term maintenance. O&M costs for Alternatives 1, 2, 3, and 5 include environmental monitoring for 5 years. Alternatives 7, 8, and 9 include operation of the treatment systems for the estimated duration of treatment and environmental monitoring.

Alternatives 1, 2 and 3 which have low capital costs, also have the lowest total present worth cost. Alternatives 7 and 8 have high present worth costs due to longer treatment durations; Alternative 5 has high costs due to treatment costs. Alternative 9 is the most expensive due to treatment facility construction and extended treatment duration. However, this alternative offers the greatest flexibility in soils management and treatment, and minimizes the quantity of soil requiring asphalt batching and associated problems with reuse of a large quantity of paving material.

7.8 COMPARATIVE ANALYSIS SUMMARY

Despite the higher costs of Alternatives 7, 8, and 9, these alternatives provide a greater degree of protection of human health and the environment by biodegrading soil contaminants and reducing concentrations to acceptable risk-based levels. The high cost of Alternative 5 is also offset by its effectiveness in immobilizing site contaminants. Although Alternatives 1, 2, and 3 could be implemented at relatively low cost, their effectiveness in risk reduction depends on limiting exposure to contaminants, which may not be reliable over the long term, when the property is sold.

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TABLE 7-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
OVERALL PROTECTION							
HUMAN HEALTH PROTECTION - *Direct Contact/Soil* Ingestion	No Risk Reduction	Risk Reduction Through Institutional Control and Fencing to Restrict Access. Hot Spot Area Contaminants Would Be Immobilized.	Barrier Layer (Cap) and Immobilization of Contaminants in Hot Spot Areas Reduces Risk	Immobilization of Contaminants Across Site and In Hot Spot Areas Reduces Risk	Remediation Through Bioventing Reduces Risk Over Time and Cap Reduces Risk during Implementation	Remediation Through Landfarming Reduces Risk Over Time	Excavation and Off-site Treatment Removes Soil Contamination from Site Treatment by Composting Reduces Risk over Time Asphalt Batching Immobilizes the Contaminants.
ENVIRONMENTAL PROTECTION	No Current Ecological Risk	No Current Ecological Risk	*No Current Ecological Risk*	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk	No Current Ecological Risk.
COMPLIANCE WITH ARARS							
CHEMICAL-SPECIFIC ARARS (Risk-based cleanup levels)	Does Not Reduce *Concentrations* to Risk-based Levels.	Does Not Reduce *Concentrations* to Risk-based Levels.	Does Not Reduce *Concentrations* to Risk-based Levels.	Does Not Reduce Concentrations to Risk-based Levels.	Would Meet Risk-based Target Levels.	Would Meet Risk-Based Target Levels.	Would Meet Risk-based Target Levels.
LOCATION-SPECIFIC ARARS	Does Not Reduce Potential *Off-site Run-off of* Contaminants to Wetlands.	Does Not Reduce Potential *Off-site Run-off of* Contaminants to Wetlands.	Reduces Potential Off-site Run-off of Contaminants to Wetlands and Will Manage Increased Surface Water Flow to Wetlands from Paved Surface.	Reduces Potential Off-site Run-off of Contaminants to Wetlands and Will Manage Increased Surface Water Flow to Wetlands from Paved Surface.	Reduces Potential Off-site Run-off of Contaminants to Wetlands and Will Manage Increased Surface Water Flow to Wetlands from Paved Surface.	Reduces Potential Off-site Run-off of Contaminants to Wetlands.	Reduces Potential Off-site Run-off of Contaminants to Wetlands. Facility Siting Would Comply with State Siting Regulations *Regarding Impacts to* Groundwater.
ACTION-SPECIFIC ARARS	Groundwater Monitoring Performed in Compliance with ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Waste Pile, and Recyclable Materials ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Waste Pile, Closure Actions and Recyclable Materials ARARs.	Would Comply with Air Quality, Groundwater Monitoring, Waste Pile, Closure Actions and Recyclable Materials ARARs.	Would Comply with Air Quality and Groundwater Monitoring ARARs.	Would Comply with Air *Quality, Groundwater* Monitoring, and Land Treatment Units ARARs.	Would Comply with Air *Quality, Groundwater* Monitoring, Land Treatment Units, Waste Piles, Closure Activities and Recyclable Material ARARs.

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TABLE 7-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

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LONG-TERM EFFECTIVENESS AND PERMANENCE							
MAGNITUDE OF RESIDUAL RISK							
- Direct Contact/Soil Ingestion	4E-3 to 7E-4 excess cancer risk.	Would Reduce Risk by *Limiting Exposure.*	Would Reduce Risk by Limiting Exposure.	Would Reduce Risk by Limiting Exposure.	Would Reduce Risk by Limiting Exposure and Reducing Contaminant Concentrations to Meet USEPA's Target Risk Range.	Would Reduce Risk by Reducing Contaminant Concentrations to Meet USEPA's Target Risk Range.	Would Reduce Risk by Removing Contaminated Soils Exceeding USEPA's Target Risk Range from the Site.
ADEQUACY AND RELIABILITY OF CONTROLS	No Controls Implemented	Institutional Controls Reliable if Enforced. Maintain Fence to Control Site Access.	Institutional Controls Reliable if Enforced. Maintain Cap to Control Exposure, Risk and Migration.	Asphalt Batching Proven to Immobilize Contaminants	Adequacy Determined by *Treatability Test and* Literature Studies.	Adequacy Determined by Treatability Test and Case Studies.	Adequacy of Composting Determined by Treatability Test and Case Studies. Asphalt Batching Proven to Immobilize Contaminants
REDUCTION IN TOXICITY, MOBILITY, OR VOLUME							
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME	None	Reduces Mobility of Contaminants in Hot Spot Area Soils.	Reduces Mobility of Contaminants in Hot Spot Soils and Soils Beneath Cap.	Reduces Mobility of Contaminants in Hot Spot Soils and Surface Soils across the Site.	Reduces the Toxicity, Mobility, and Volume of Organic Contaminants in Hot Spot Soils and Surface Soils across the Site.	Reduces the Toxicity, Mobility, and Volume of Organic Contaminants in Hot Spot Soils and Surface Soils across the Site.	Off-site Treatment Reduces Toxicity, Mobility and Volume of Soil Contaminants at Site by Removal.
IRREVERSIBLE TREATMENT	Not Applicable	Studies Have Shown That Contaminants Will Not Leach from Soils That Have Been Treated by Asphalt Batching.	Studies Have Shown That Contaminants Will Not Leach from Soils That Have Been Treated by *Asphalt Batching.*	Studies Have Shown *That* Contaminants Will Not Leach from Soils That Have Been Treated by Asphalt Batching.	*Biodegradation* Permanently Reduces Organic Contaminant Concentrations.	*Biodegradation Permanently* Reduces Organic Contaminant Concentrations.	Biodegradation Permanently Reduces Organic Contaminant Concentrations. Asphalt Batched Soils Will Not Leach Contaminants Based on Studies.

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TABLE 7-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
TYPE AND QUANTITY OF RESIDUALS REMAINING AFTER TREATMENT	Not Applicable	Asphalt Batched Material from Hot Spots Only.	Asphalt Batched Material from Hot Spots Only.	Asphalt Batched Material from Entire Site	None	None	Treated Soil and Asphalt Batched Material from Soil Not Readily Biodegradable.
STATUTORY PREFERENCE FOR TREATMENT	Not Met	Hot Spot Areas Would be Treated.	Hot Spot Areas Would Be Treated.	Entire Site Would Be Treated.	Entire Site Would Be Treated.	Entire Site Would Be Treated.	Entire Site Would Be Treated.
SHORT-TERM EFFEC-TIVENESS							
COMMUNITY PROTECTION	Risk to Community Minimized Through Monitoring	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Excavation.	Would Need to Control Dust during Tilling and Excavation.	Would Need to Control Dust during Excavation and Treatment.
WORKER PROTECTION	No Significant Risk to Workers Conducting Monitoring.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.	Protective Clothing and Safe Work Practices Would Reduce the Possibility of Exposure or Injury.
ENVIRONMENTAL IMPACTS		None	Modifications to stormwater collection system necessary.	Modifications to stormwater collection system necessary.	Modifications to stormwater collection system necessary.	None	None.
TIME UNTIL ACTION IS COMPLETE	Risk-based cleanup levels would not be met.	3 weeks for remediation of hot spots.	3 months for remediation of hot spots and capping entire site.	4 months for remediation of entire site.	Up to 10 years for remediation of entire site.	Up to 7 years for remediation of entire site.	Total of three months f[illegible] on-site activities (excavation of soil and backfilling site). Up t[illegible] years for biodegradation [illegible] contaminants for total [illegible]

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TABLE 7-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
IMPLEMENTABILITY							
ABILITY TO CONSTRUCT AND OPERATE	None required. Existing Wells Could Be Used For Monitoring.	Easy; Standard Construction Techniques. No Long-term Operation Required.	Easy; Standard Construction Technique. No Long-term Operation Required, but Cap Maintenance Required.	Easy; Standard Construction Technique. No Long-term Operation Required.	Cap And Well Construction Are Common Techniques. Basic Operation and Maintenance.	Standard Construction; Basic Operation and Maintenance	Standard Construction Technique; Basic Operation And Maintenance.
EASE OF DOING MORE ACTION IF NEEDED	Would Not Interfere With Future Actions.	Batched Pavement May Need To Be Removed If Future Actions Are Necessary.	Possibly Difficult Due to Cap over Site.	Possibly Difficult Due to Asphalt Batched Material over Site.	Possibly Difficult Due to Cap over Site.	Would Not Interfere with Future Actions.	Would Not Interfere with Future Actions.
ABILITY TO MONITOR EFFECTIVENESS	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater.	Effectiveness Would Be Monitored by Monitoring Groundwater, Soil Sampling, and Process Monitoring.	Effectiveness Would Be Monitored by Monitoring Groundwater and Soil.	Effectiveness Would Be Monitored by Process Monitoring.
ABILITY TO OBTAIN APPROVALS AND COORDINATE WITH OTHER AGENCIES	Coordination Required Among Property Owners, State and Local Agencies. Difficulties Anticipated Regarding Sale of Property.	Coordination Required Among Property Owners, State and Local Agencies. Difficulties Anticipated Regarding Sale of Property and Institutional Controls.	Coordination Required Among Property Owners, State and Local Agencies. Difficulties Anticipated Regarding Sale of Property and Institutional Controls.	Although No Institutional Controls are Needed, Placing a Pavement Cap over the Site Limits Future Land Use and is not Likely to be Favored by Land Developers.	Zone II Issues Likely to Limit Acceptance of this Alternative by Agencies.	Zone II Issues Likely to Limit Acceptance of this Alternative by Agencies.	Siting of the Facility Will Require Coordination with Property Owners, State and Local Agencies.
AVAILABILITY OF SERVICES AND CAPACITIES	Sampling and Analytical Services Are Widely Available.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Treatment and Disposal Capacity Not Required.	Sampling and Analytical Services Are Widely Available. Off-site Disposal of Screened Material Required.	Treatment Facility with Necessary Capacity Is Not Likely To Be Available Off site. Facility Will Need To Be Constructed Specifically for Fort Devens Soils.

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TABLE 7-1
COMPARATIVE ANALYSIS SUMMARY

AOCs 44 AND 52 SOILS
FORT DEVENS, MASSACHUSETTS

Assessment Factors	Alternative 1, No Action	Alternative 2, Fencing/Asphalt Batching Hot Spot Areas	Alternative 3, Capping Site/Asphalt Batching Hot Spot Areas	Alternative 5, Asphalt Batching Site and Hot Spot Areas	Alternative 7, Bioventing Site and Hot Spot Areas	Alternative 8, Landfarming Site and Hot Spot Areas	Alternative 9, Treatment of Site and Hot Spot Areas at a Central Soil Treatment Facility
AVAILABILITY OF EQUIPMENT, SPECIALISTS, AND MATERIALS	Available Locally.	Available Locally.	Available Locally.	Available Locally.	Bioremediation Specialists Are Available for Design and Operation of the System.	Bioremediation Specialists Are Available for Design and Operation of the System.	Asphalt Batching Vendors Available Locally; Bioremediation Specialists Are Available for Design and Operation of the Facility.
AVAILABILITY OF TECHNOLOGIES	Groundwater Monitoring Is Common Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology.	Groundwater Monitoring Is Common Technology. Paving Is a Common Construction Technology. Bioventing Has Been Used for Remediating Fuel-related Contamination in Soils at Other Locations.	Groundwater Monitoring Is Common Technology. Landfarming is a Simple Technology Used for Bioremediating Fuel Contamination in Soils.	Groundwater Monitoring and Paving are Common Technologies. Composting is a Common Technology for Remediating Biosolids from Municipal Waste Water Treatment and Remediating Fuel Contaminated Soils.
DISRUPTION TO YARD OPERATIONS	None	Temporary Disruption of Yard during Hot Spot Remediation.	Temporary Disruption of Yard during Hot Spot Remediation and Capping.	Disruption of Yard during 4-month Remediation Period.	Disruption of Yard during 3-week Construction Period. Yard Could Be Used during Remediation.	20% of Yard not Usable for Yard Operations Once Remediation Begins.	20% of Yard not Usable for Yard Operations Once Remediation Begins.
COST							
Capital Cost	$0	$204,000	$1,017,000	$1,667,000	$1,053,000	$621,000	$2,739,000
1st Year O&M	$35,000	$37,000	$33,000	$19,000	$77,000	$94,000	$204,000
Present Worth Cost	$133,000	$356,000	$1,221,000	$1,739,000	$1,548,000	$1,553,000	$3,398,000

Note: AOC = Area of Contamination
ARARs = Applicable or Relevant and Appropriate Requirements
O&M = Operation and Maintenance
USEPA = U.S. Environmental Protection Agency

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APPENDIX A

BASELINE RISK ASSESSMENT
RISK SPREADSHEETS

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TABLE A-1

CONS-A-1 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Average	mg/kg	
INGESTION RATE	IR	480	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm^2	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm^2/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	5	days/workweek	PRO.JUDGEMENT
EXPOSURE DURATION	ED	12	workweek(s)	PRO.JUDGEMENT
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	12	workweek(s)	USEPA, 1989a

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".
USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.
USEPA, 1989a. RAGs, Part A.
USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

INTAKE-INGESTION (HQ) = $\frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$

INTAKE-INGESTION (CANCER RISK) = $\frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$

INTAKE-DERMAL (HQ) = $\frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$

INTAKE-DERMAL (CANCER RISK) = $\frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$

For noncarcinogenic effects: AT = ED

TABLE A-1, continued

CONS-A-1 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	1.941	1	3.1E-08	0.02	4.3E-09	0.014	4.4E-10	6.0E-11	5.0E-10
Benzo(a)anthracene	0.2078	1	3.3E-09	0.2	4.6E-09	7.3	2.4E-08	3.4E-08	5.8E-08
Benzo(a)pyrene	2.241	1	3.6E-08	0.2	5.0E-08	7.3	2.6E-07	3.6E-07	6.3E-07
Benzo(b)fluoranthene	0.2318	1	3.7E-09	0.2	5.1E-09	7.3	2.7E-08	3.7E-08	6.5E-08
Benzo(k)fluoranthene	0.1658	1	2.7E-09	0.2	3.7E-09	7.3	1.9E-08	2.7E-08	4.6E-08
Carbazole	0.621	1	1.0E-08	1	6.9E-08	0.02	2.0E-10	1.4E-09	1.6E-09
Chrysene	0.02581	1	4.2E-10	0.2	5.7E-10	7.3	3.0E-09	4.2E-09	7.2E-09
Dibenz(a,h)anthracene	0.782	1	1.3E-08	0.09	7.8E-09	7.3	9.2E-08	5.7E-08	1.5E-07
Indeno(1,2,3-cd)pyrene	0.2001	1	3.2E-09	0.2	4.4E-09	7.3	2.4E-08	3.2E-08	5.6E-08
Arsenic	12.36	1	2.0E-07	0.03	4.1E-08	1.8	3.6E-07	7.4E-08	4.3E-07
Beryllium	0.514	1	8.3E-09	0.35	2.0E-08	4.3	3.6E-08	8.6E-08	1.2E-07
Lead	10.188	0.5	8.2E-08	NA		NA			
					SUMMARY CANCER RISK		8E-07	7E-07	2E-06

TABLE A-1, continued

CONS-A-1 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.000936	1	6.4E-09	0.2	8.8E-09	0.1	6.4E-08	8.8E-08	1.5E-07
Toluene	0.000441	1	3.0E-09	0.12	2.5E-09	2	1.5E-09	1.2E-09	2.8E-09
Xylenes	0.00129	1	8.8E-09	0.12	7.3E-09	4	2.2E-09	1.8E-09	4.0E-09
2-Methylnaphthalene	0.267	1	1.8E-06	0.1	1.3E-06	0.04	4.6E-05	3.1E-05	7.7E-05
Acenaphthene	0.235	1	1.6E-06	0.2	2.2E-06	0.6	2.7E-06	3.7E-06	6.4E-06
Acenaphthylene	0.297	0.91	1.9E-06	0.18	2.5E-06	0.04	4.6E-05	6.3E-05	1.1E-04
Anthracene	0.742	1	5.1E-06	0.29	1.0E-05	3	1.7E-06	3.4E-06	5.1E-06
Bis(2-ethylhexyl)phthalate	1.941	1	1.3E-05	0.02	1.8E-06	0.02	6.7E-04	9.1E-05	7.6E-04
Benzo(a)anthracene	2.078	0.91	1.3E-05	0.18	1.8E-05	0.04	3.2E-04	4.4E-04	7.6E-04
Bnezo(a)pyrene	2.241	0.91	1.4E-05	0.18	1.9E-05	0.04	3.5E-04	4.7E-04	8.2E-04
Benzo(b)fluoranthene	2.318	0.91	1.4E-05	0.18	2.0E-05	0.04	3.6E-04	4.9E-04	8.5E-04
Benzo(g,h,i)perylene	1.839	0.91	1.1E-05	0.18	1.6E-05	0.04	2.9E-04	3.9E-04	6.8E-04
Benzo(k)fluoranthene	1.658	0.91	1.0E-05	0.18	1.4E-05	0.04	2.6E-04	3.5E-04	6.1E-04
Carbazole	0.621	1	4.3E-06	1	2.9E-05	NA			
Chrysene	2.581	0.91	1.6E-05	0.18	2.2E-05	0.04	4.0E-04	5.5E-04	9.5E-04
Dibenz(a,h)anthracene	0.782	0.91	4.9E-06	0.08	2.9E-06	0.04	1.2E-04	7.4E-05	2.0E-04
Dibenzofuran	0.327	NA		NA		NA			
Fluoranthene	5.044	1	3.5E-05	0.2	4.7E-05	0.4	8.6E-05	1.2E-04	2.1E-04
Fluorene	0.564	1	3.9E-06	0.2	5.3E-06	0.4	9.7E-06	1.3E-05	2.3E-05
Indeno(1,2,3-cd)pyrene	2.001	0.91	1.2E-05	0.18	1.7E-05	0.04	3.1E-04	4.2E-04	7.4E-04
Naphthalene	0.554	1	3.8E-06	0.1	2.6E-06	0.04	9.5E-05	6.5E-05	1.6E-04
Phenanthrene	3.658	0.91	2.3E-05	0.18	3.1E-05	0.04	5.7E-04	7.7E-04	1.3E-03
Pyrene	3.405	1	2.3E-05	0.2	3.2E-05	0.3	7.8E-05	1.1E-04	1.8E-04
Arsenic	12.36	1	8.5E-05	0.03	1.7E-05	0.0003	2.8E-01	5.8E-02	3.4E-01
Barium	24.907	1	1.7E-04	0.35	4.1E-04	0.07	2.4E-03	5.9E-03	8.3E-03

TABLE A-1, continued

CONS-A-1 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	0.514	1	3.5E-06	0.35	8.5E-06	0.005	7.0E-04	1.7E-03	2.4E-03
Cadmium	0.635	1	4.4E-06	0.14	4.2E-06	0.001	4.4E-03	4.2E-03	8.5E-03
Chromium	17.192	1	1.2E-04	0.09	7.3E-05	0.02	5.9E-03	3.6E-03	9.5E-03
Copper	8.885	1	6.1E-05	0.35	1.5E-04	NA			
Iron	8547.391	1	5.9E-02	0.35	1.4E-01	NA			
Lead	10.189	0.5	3.5E-05	0.006	2.9E-06	NA			
Magnesium	2504.574	1	1.7E-02	0.35	4.1E-02	NA			
Manganese	154.293	1	1.1E-03	0.35	2.5E-03	0.1	1.1E-02	2.5E-02	3.6E-02
Nickel	15.299	1	1.0E-04	0.35	2.5E-04	0.02	5.2E-03	1.3E-02	1.8E-02
Potassium	1008.659	1	6.9E-03	0.35	1.7E-02	NA			
Sodium	155.042	1	1.1E-03	0.35	2.6E-03	NA			
Vanadium	10.942	1	7.5E-05	0.35	1.8E-04	0.007	1.1E-02	2.6E-02	3.6E-02
Zinc	26.532	1	1.8E-04	0.02	2.5E-05	0.3	6.1E-04	8.3E-05	6.9E-04
						SUMMARY HAZARD INDEX	0.33	0.14	0.47

TABLE A-2

CONS-A-2 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 - AVERAGE CONCENTRATIONS

FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Average	mg/kg	
INGESTION RATE	IR	480	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm²	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm²/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	5	days/workweek	PRO.JUDGEMENT
EXPOSURE DURATION	ED	12	workweek(s)	PRO.JUDGEMENT
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	12	workweek(s)	USEPA, 1989a

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.

USEPA, 1989a. RAGs, Part A.

USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION (HQ)} = \frac{\text{CS x IR x RAF x FI x CF x EF x ED}}{\text{BW x AT x 5 days/workweek}}$$

$$\text{INTAKE-INGESTION (CANCER RISK)} = \frac{\text{CS x IR x RAF x FI x CF x EF x ED}}{\text{BW x AT x 365 days/yr}}$$

$$\text{INTAKE-DERMAL (HQ)} = \frac{\text{CS x SA x SAF x RAF x CF x EF x ED}}{\text{BW x AT x 5 days/workweek}}$$

$$\text{INTAKE-DERMAL (CANCER RISK)} = \frac{\text{CS x SA x SAF x RAF x CF x EF x ED}}{\text{BW x AT x 365 days/yr}}$$

For noncarcinogenic effects: AT = ED

TABLE A-2, continued

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 - AVERAGE CONCENTRATIONS

FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	1.941	1	3.1E-08	0.02	4.3E-09	0.014	4.4E-10	6.0E-11	5.0E-10
Benzo(a)anthracene	2.078	1	3.3E-08	0.2	4.6E-08	7.3	2.4E-07	3.4E-07	5.8E-07
Benzo(a)pyrene	2.241	1	3.6E-08	0.2	5.0E-08	7.3	2.6E-07	3.6E-07	6.3E-07
Benzo(b)fluoranthene	2.318	1	3.7E-08	0.2	5.1E-08	7.3	2.7E-07	3.7E-07	6.5E-07
Benzo(k)fluoranthene	1.658	1	2.7E-08	0.2	3.7E-08	7.3	1.9E-07	2.7E-07	4.6E-07
Carbazole	0.621	1	1.0E-08	1	6.9E-08	0.02	2.0E-10	1.4E-09	1.6E-09
Chrysene	2.581	1	4.2E-08	0.2	5.7E-08	7.3	3.0E-07	4.2E-07	7.2E-07
Dibenz(a,h)anthracene	0.782	1	1.3E-08	0.09	7.8E-09	7.3	9.2E-08	5.7E-08	1.5E-07
Indeno(1,2,3-cd)pyrene	2.001	1	3.2E-08	0.2	4.4E-08	7.3	2.4E-07	3.2E-07	5.6E-07
Arsenic	12.36	1	2.0E-07	0.03	4.1E-08	1.8	3.6E-07	7.4E-08	4.3E-07
Beryllium	0.514	1	8.3E-09	0.35	2.0E-08	4.3	3.6E-08	8.6E-08	1.2E-07
Lead	10.188	0.5	8.2E-08	NA		NA			
					SUMMARY CANCER RISK		2E-06	2E-06	4E-06

TABLE A-2, continued

CONS-A-2	07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.000936	1	6.4E-09	0.2	8.8E-09	0.1	6.4E-08	8.8E-08	1.5E-07
Toluene	0.000441	1	3.0E-09	0.12	2.5E-09	2	1.5E-09	1.2E-09	2.8E-09
Xylenes	0.00129	1	8.8E-09	0.12	7.3E-09	4	2.2E-09	1.8E-09	4.0E-09
2-Methylnaphthalene	0.267	1	1.8E-06	0.1	1.3E-06	0.04	4.6E-05	3.1E-05	7.7E-05
Acenaphthene	0.235	1	1.6E-06	0.2	2.2E-06	0.6	2.7E-06	3.7E-06	6.4E-06
Acenaphthylene	0.297	0.91	1.9E-06	0.18	2.5E-06	0.04	4.6E-05	6.3E-05	1.1E-04
Anthracene	0.742	1	5.1E-06	0.29	1.0E-05	3	1.7E-06	3.4E-06	5.1E-06
Bis(2-ethylhexyl)phthalate	1.941	1	1.3E-05	0.02	1.8E-06	0.02	6.7E-04	9.1E-05	7.6E-04
Benzo(a)anthracene	2.078	0.91	1.3E-05	0.18	1.8E-05	0.04	3.2E-04	4.4E-04	7.6E-04
Bnezo(a)pyrene	2.241	0.91	1.4E-05	0.18	1.9E-05	0.04	3.5E-04	4.7E-04	8.2E-04
Benzo(b)fluoranthene	2.318	0.91	1.4E-05	0.18	2.0E-05	0.04	3.6E-04	4.9E-04	8.5E-04
Benzo(g,h,i)perylene	1.839	0.91	1.1E-05	0.18	1.6E-05	0.04	2.9E-04	3.9E-04	6.8E-04
Benzo(k)fluoranthene	1.658	0.91	1.0E-05	0.18	1.4E-05	0.04	2.6E-04	3.5E-04	6.1E-04
Carbazole	0.621	1	4.3E-06	1	2.9E-05	NA			
Chrysene	2.581	0.91	1.6E-05	0.18	2.2E-05	0.04	4.0E-04	5.5E-04	9.5E-04
Dibenz(a,h)anthracene	0.782	0.91	4.9E-06	0.08	2.9E-06	0.04	1.2E-04	7.4E-05	2.0E-04
Dibenzofuran	0.327	NA		NA		NA			
Fluoranthene	5.044	1	3.5E-05	0.2	4.7E-05	0.4	8.6E-05	1.2E-04	2.1E-04
Fluorene	0.564	1	3.9E-06	0.2	5.3E-06	0.4	9.7E-06	1.3E-05	2.3E-05
Indeno(1,2,3-cd)pyrene	2.001	0.91	1.2E-05	0.18	1.7E-05	0.04	3.1E-04	4.2E-04	7.4E-04
Naphthalene	0.554	1	3.8E-06	0.1	2.6E-06	0.04	9.5E-05	6.5E-05	1.6E-04
Phenanthrene	3.658	0.91	2.3E-05	0.18	3.1E-05	0.04	5.7E-04	7.7E-04	1.3E-03
Pyrene	3.405	1	2.3E-05	0.2	3.2E-05	0.3	7.8E-05	1.1E-04	1.8E-04
Arsenic	12.36	1	8.5E-05	0.03	1.7E-05	0.0003	2.8E-01	5.8E-02	3.4E-01
Barium	24.907	1	1.7E-04	0.35	4.1E-04	0.07	2.4E-03	5.9E-03	8.3E-03

TABLE A-2, continued

CONS-A-2	07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	0.514	1	3.5E-06	0.35	8.5E-06	0.005	7.0E-04	1.7E-03	2.4E-03
Cadmium	0.635	1	4.4E-06	0.14	4.2E-06	0.001	4.4E-03	4.2E-03	8.5E-03
Chromium	17.192	1	1.2E-04	0.09	7.3E-05	0.02	5.9E-03	3.6E-03	9.5E-03
Copper	8.885	1	6.1E-05	0.35	1.5E-04	NA			
Iron	8547.391	1	5.9E-02	0.35	1.4E-01	NA			
Lead	10.189	0.5	3.5E-05	0.006	2.9E-06	NA			
Magnesium	2504.574	1	1.7E-02	0.35	4.1E-02	NA			
Manganese	154.293	1	1.1E-03	0.35	2.5E-03	0.1	1.1E-02	2.5E-02	3.6E-02
Nickel	15.299	1	1.0E-04	0.35	2.5E-04	0.02	5.2E-03	1.3E-02	1.8E-02
Potassium	1008.659	1	6.9E-03	0.35	1.7E-02	NA			
Sodium	155.042	1	1.1E-03	0.35	2.6E-03	NA			
Vanadium	10.942	1	7.5E-05	0.35	1.8E-04	0.007	1.1E-02	2.6E-02	3.6E-02
Zinc	26.532	1	1.8E-04	0.02	2.5E-05	0.3	6.1E-04	8.3E-05	6.9E-04
SUMMARY HAZARD INDEX							0.33	0.14	0.47

TABLE A-3

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL – USEPA REGION IV TEF APPROACH FOR PAHS

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 – MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

CONS-A-3	09-Jun-93

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Maximum	mg/kg	
INGESTION RATE	IR	480	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm^2	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm^2/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	5	days/workweek	PRO.JUDGEMENT
EXPOSURE DURATION	ED	12	workweek(s)	PRO.JUDGEMENT
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	12	workweek(s)	USEPA, 1989a

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.

USEPA, 1989a. RAGs, Part A.

USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION (HQ)} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$$

$$\text{INTAKE-INGESTION (CANCER RISK)} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$$

$$\text{INTAKE-DERMAL (HQ)} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$$

$$\text{INTAKE-DERMAL (CANCER RISK)} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$$

For noncarcinogenic effects: AT = ED

TABLE A-3, continued

CONS-A-3 | 09-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	7.75	1	1.2E-07	0.02	1.7E-08	0.014	1.7E-09	2.4E-10	2.0E-09
Benzo(a)anthracene	2	1	3.2E-08	0.2	4.4E-08	7.3	2.4E-07	3.2E-07	5.6E-07
Benzo(a)pyrene	30	1	4.8E-07	0.2	6.6E-07	7.3	3.5E-06	4.8E-06	8.4E-06
Benzo(b)fluoranthene	3	1	4.8E-08	0.2	6.6E-08	7.3	3.5E-07	4.8E-07	8.4E-07
Benzo(k)fluoranthene	3	1	4.8E-08	0.2	6.6E-08	7.3	3.5E-07	4.8E-07	8.4E-07
Carbazole	20	1	3.2E-07	1	2.2E-06	0.02	6.4E-09	4.4E-08	5.1E-08
Chrysene	0.5	1	8.1E-09	0.2	1.1E-08	7.3	5.9E-08	8.1E-08	1.4E-07
Dibenz(a,h)anthracene	5	1	8.1E-08	0.09	5.0E-08	7.3	5.9E-07	3.6E-07	9.5E-07
Indeno(1,2,3-cd)pyrene	2	1	3.2E-08	0.2	4.4E-08	7.3	2.4E-07	3.2E-07	5.6E-07
Arsenic	29	1	4.7E-07	0.03	9.6E-08	1.8	8.4E-07	1.7E-07	1.0E-06
Beryllium	1.15	1	1.9E-08	0.35	4.4E-08	4.3	8.0E-08	1.9E-07	2.7E-07
Lead	53	0.5	4.3E-07	NA		NA			
						SUMMARY CANCER RISK	6E-06	7E-06	1E-05

TABLE A-3, continued

CONS-A-3	09-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.0049	1	3.4E-08	0.2	4.6E-08	0.1	3.4E-07	4.6E-07	8.0E-07
Toluene	0.0023	1	1.6E-08	0.12	1.3E-08	2	7.9E-09	6.5E-09	1.4E-08
Xylenes	0.022	1	1.5E-07	0.12	1.2E-07	4	3.8E-08	3.1E-08	6.9E-08
2-Methylnaphthalene	6	1	4.1E-05	0.1	2.8E-05	0.04	1.0E-03	7.1E-04	1.7E-03
Acenaphthene	6	1	4.1E-05	0.2	5.6E-05	0.6	6.9E-05	9.4E-05	1.6E-04
Acenaphthylene	4	0.91	2.5E-05	0.18	3.4E-05	0.04	6.2E-04	8.5E-04	1.5E-03
Anthracene	20	1	1.4E-04	0.29	2.7E-04	3	4.6E-05	9.1E-05	1.4E-04
Bis(2-ethylhexyl)phthalate	7.75	1	5.3E-05	0.02	7.3E-06	0.02	2.7E-03	3.6E-04	3.0E-03
Benzo(a)anthracene	20	0.91	1.2E-04	0.18	1.7E-04	0.04	3.1E-03	4.2E-03	7.4E-03
Bnezo(a)pyrene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Benzo(b)fluoranthene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Benzo(g,h,i)perylene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Benzo(k)fluoranthene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Carbazole	20	1	1.4E-04	1	9.4E-04	NA			
Chrysene	50	0.91	3.1E-04	0.18	4.2E-04	0.04	7.8E-03	1.1E-02	1.8E-02
Dibenz(a,h)anthracene	5	0.91	3.1E-05	0.08	1.9E-05	0.04	7.8E-04	4.7E-04	1.3E-03
Dibenzofuran	10	NA		NA		NA			
Fluoranthene	100	1	6.9E-04	0.2	9.4E-04	0.4	1.7E-03	2.4E-03	4.1E-03
Fluorene	20	1	1.4E-04	0.2	1.9E-04	0.4	3.4E-04	4.7E-04	8.1E-04
Indeno(1,2,3-cd)pyrene	20	0.91	1.2E-04	0.18	1.7E-04	0.04	3.1E-03	4.2E-03	7.4E-03
Naphthalene	20	1	1.4E-04	0.1	9.4E-05	0.04	3.4E-03	2.4E-03	5.8E-03
Phenanthrene	100	0.91	6.2E-04	0.18	8.5E-04	0.04	1.6E-02	2.1E-02	3.7E-02
Pyrene	60	1	4.1E-04	0.2	5.6E-04	0.3	1.4E-03	1.9E-03	3.3E-03
Arsenic	29	1	2.0E-04	0.03	4.1E-05	0.0003	6.6E-01	1.4E-01	8.0E-01
Barium	95.3	1	6.5E-04	0.35	1.6E-03	0.07	9.3E-03	2.2E-02	3.2E-02

TABLE A-3, continued

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DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	1.15	1	7.9E-06	0.35	1.9E-05	0.005	1.6E-03	3.8E-03	5.4E-03
Cadmium	8.85	1	6.1E-05	0.14	5.8E-05	0.001	6.1E-02	5.8E-02	1.2E-01
Chromium	58.7	1	4.0E-04	0.09	2.5E-04	0.02	2.0E-02	1.2E-02	3.3E-02
Copper	20.6	1	1.4E-04	0.35	3.4E-04	NA			
Iron	18900	1	1.3E-01	0.35	3.1E-01	NA			
Lead	53	0.5	1.8E-04	0.006	1.5E-05	NA			
Magnesium	9210	1	6.3E-02	0.35	1.5E-01	NA			
Manganese	313	1	2.1E-03	0.35	5.2E-03	0.1	2.1E-02	5.2E-02	7.3E-02
Nickel	41.8	1	2.9E-04	0.35	6.9E-04	0.02	1.4E-02	3.4E-02	4.9E-02
Potassium	4820	1	3.3E-02	0.35	7.9E-02	NA			
Sodium	316	1	2.2E-03	0.35	5.2E-03	NA			
Vanadium	34.9	1	2.4E-04	0.35	5.7E-04	0.007	3.4E-02	8.2E-02	1.2E-01
Zinc	92.9	1	6.4E-04	0.02	8.7E-05	0.3	2.1E-03	2.9E-04	2.4E-03
						SUMMARY HAZARD INDEX	0.89	0.47	1.36

CONS-A-4 | 07-Jun-93

TABLE A-4

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Maximum	mg/kg	
INGESTION RATE	IR	480	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm²	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm²/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	5	days/workweek	PRO.JUDGEMENT
EXPOSURE DURATION	ED	12	workweek(s)	PRO.JUDGEMENT
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	12	workweek(s)	USEPA, 1989a

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.

USEPA, 1989a. RAGs, Part A.

USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION (HQ)} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$$

$$\text{INTAKE-INGESTION (CANCER RISK)} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$$

$$\text{INTAKE-DERMAL (HQ)} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$$

$$\text{INTAKE-DERMAL (CANCER RISK)} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$$

For noncarcinogenic effects: AT = ED

TABLE A-4, continued

CONS-A-4 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL – USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 – MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	7.75	1	1.2E-07	0.02	1.7E-08	0.014	1.7E-09	2.4E-10	2.0E-09
Benzo(a)anthracene	20	1	3.2E-07	0.2	4.4E-07	7.3	2.4E-06	3.2E-06	5.6E-06
Benzo(a)pyrene	30	1	4.8E-07	0.2	6.6E-07	7.3	3.5E-06	4.8E-06	8.4E-06
Benzo(b)fluoranthene	30	1	4.8E-07	0.2	6.6E-07	7.3	3.5E-06	4.8E-06	8.4E-06
Benzo(k)fluoranthene	30	1	4.8E-07	0.2	6.6E-07	7.3	3.5E-06	4.8E-06	8.4E-06
Carbazole	20	1	3.2E-07	1	2.2E-06	0.02	6.4E-09	4.4E-08	5.1E-08
Chrysene	50	1	8.1E-07	0.2	1.1E-06	7.3	5.9E-06	8.1E-06	1.4E-05
Dibenz(a,h)anthracene	5	1	8.1E-08	0.09	5.0E-08	7.3	5.9E-07	3.6E-07	9.5E-07
Indeno(1,2,3-cd)pyrene	20	1	3.2E-07	0.2	4.4E-07	7.3	2.4E-06	3.2E-06	5.6E-06
Arsenic	29	1	4.7E-07	0.03	9.6E-08	1.8	8.4E-07	1.7E-07	1.0E-06
Beryllium	1.15	1	1.9E-08	0.35	4.4E-08	4.3	8.0E-08	1.9E-07	2.7E-07
Lead	53	0.5	4.3E-07	NA		NA			
					SUMMARY CANCER RISK		2E-05	3E-05	5E-05

TABLE A-4, *continued*

CONS-A-4 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.0049	1	3.4E-08	0.2	4.6E-08	0.1	3.4E-07	4.6E-07	8.0E-07
Toluene	0.0023	1	1.6E-08	0.12	1.3E-08	2	7.9E-09	6.5E-09	1.4E-08
Xylenes	0.022	1	1.5E-07	0.12	1.2E-07	4	3.8E-08	3.1E-08	6.9E-08
2-Methylnaphthalene	6	1	4.1E-05	0.1	2.8E-05	0.04	1.0E-03	7.1E-04	1.7E-03
Acenaphthene	6	1	4.1E-05	0.2	5.6E-05	0.6	6.9E-05	9.4E-05	1.6E-04
Acenaphthylene	4	0.91	2.5E-05	0.18	3.4E-05	0.04	6.2E-04	8.5E-04	1.5E-03
Anthracene	20	1	1.4E-04	0.29	2.7E-04	3	4.6E-05	9.1E-05	1.4E-04
Bis(2-ethylhexyl)phthalate	7.75	1	5.3E-05	0.02	7.3E-06	0.02	2.7E-03	3.6E-04	3.0E-03
Benzo(a)anthracene	20	0.91	1.2E-04	0.18	1.7E-04	0.04	3.1E-03	4.2E-03	7.4E-03
Bnezo(a)pyrene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Benzo(b)fluoranthene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Benzo(g,h,i)perylene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Benzo(k)fluoranthene	30	0.91	1.9E-04	0.18	2.5E-04	0.04	4.7E-03	6.4E-03	1.1E-02
Carbazole	20	1	1.4E-04	1	9.4E-04	NA			
Chrysene	50	0.91	3.1E-04	0.18	4.2E-04	0.04	7.8E-03	1.1E-02	1.8E-02
Dibenz(a,h)anthracene	5	0.91	3.1E-05	0.08	1.9E-05	0.04	7.8E-04	4.7E-04	1.3E-03
Dibenzofuran	10	NA		NA		NA			
Fluoranthene	100	1	6.9E-04	0.2	9.4E-04	0.4	1.7E-03	2.4E-03	4.1E-03
Fluorene	20	1	1.4E-04	0.2	1.9E-04	0.4	3.4E-04	4.7E-04	8.1E-04
Indeno(1,2,3-cd)pyrene	20	0.91	1.2E-04	0.18	1.7E-04	0.04	3.1E-03	4.2E-03	7.4E-03
Naphthalene	20	1	1.4E-04	0.1	9.4E-05	0.04	3.4E-03	2.4E-03	5.8E-03
Phenanthrene	100	0.91	6.2E-04	0.18	8.5E-04	0.04	1.6E-02	2.1E-02	3.7E-02
Pyrene	60	1	4.1E-04	0.2	5.6E-04	0.3	1.4E-03	1.9E-03	3.3E-03
Arsenic	29	1	2.0E-04	0.03	4.1E-05	0.0003	6.6E-01	1.4E-01	8.0E-01
Barium	95.3	1	6.5E-04	0.35	1.6E-03	0.07	9.3E-03	2.2E-02	3.2E-02

TABLE A-4, continued

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DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE AND SUBSURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	1.15	1	7.9E-06	0.35	1.9E-05	0.005	1.6E-03	3.8E-03	5.4E-03
Cadmium	8.85	1	6.1E-05	0.14	5.8E-05	0.001	6.1E-02	5.8E-02	1.2E-01
Chromium	58.7	1	4.0E-04	0.09	2.5E-04	0.02	2.0E-02	1.2E-02	3.3E-02
Copper	20.6	1	1.4E-04	0.35	3.4E-04	NA			
Iron	18900	1	1.3E-01	0.35	3.1E-01	NA			
Lead	53	0.5	1.8E-04	0.006	1.5E-05	NA			
Magnesium	9210	1	6.3E-02	0.35	1.5E-01	NA			
Manganese	313	1	2.1E-03	0.35	5.2E-03	0.1	2.1E-02	5.2E-02	7.3E-02
Nickel	41.8	1	2.9E-04	0.35	6.9E-04	0.02	1.4E-02	3.4E-02	4.9E-02
Potassium	4820	1	3.3E-02	0.35	7.9E-02	NA			
Sodium	316	1	2.2E-03	0.35	5.2E-03	NA			
Vanadium	34.9	1	2.4E-04	0.35	5.7E-04	0.007	3.4E-02	8.2E-02	1.2E-01
Zinc	92.9	1	6.4E-04	0.02	8.7E-05	0.3	2.1E-03	2.9E-04	2.4E-03
					SUMMARY HAZARD INDEX		0.89	0.47	1.36

TABLE A-5 | WORK-A-5 | 07-Jun-93

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Average	mg/kg	
INGESTION RATE	IR	50	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm^2	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm^2/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991
EXPOSURE DURATION	ED	25	years	USEPA, 1991
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	25	years	USEPA, 1991

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".
USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.
USEPA, 1989a. RAGs, Part A.
USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

$$\text{INTAKE-DERMAL} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

For noncarcinogenic effects: AT = ED

TABLE A-5, continued
DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL – USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 – AVERAGE CONCENTRATIONS
FORT DEVENS, MA

WORK-A-5	07-Jun-93

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.014			
Benzo(a)anthracene	0.574	1	1.0E-07	0.2	1.3E-06	7.3	7.3E-07	9.6E-06	1.0E-05
Benzo(a)pyrene	5.99	1	1.0E-06	0.2	1.4E-05	7.3	7.6E-06	1.0E-04	1.1E-04
Benzo(b)fluoranthene	0.609	1	1.1E-07	0.2	1.4E-06	7.3	7.8E-07	1.0E-05	1.1E-05
Benzo(k)fluoranthene	0.459	1	8.0E-08	0.2	1.1E-06	7.3	5.9E-07	7.7E-06	8.3E-06
Carbazole	1.79	1	3.1E-07	1	2.1E-05	0.02	6.3E-09	4.1E-07	4.2E-07
Chrysene	0.0717	1	1.3E-08	0.2	1.7E-07	7.3	9.1E-08	1.2E-06	1.3E-06
Dibenz(a,h)anthracene	1.64	1	2.9E-07	0.09	1.7E-06	7.3	2.1E-06	1.2E-05	1.4E-05
Indeno(1,2,3-cd)pyrene	0.503	1	8.8E-08	0.2	1.2E-06	7.3	6.4E-07	8.5E-06	9.1E-06
Arsenic	13.96	1	2.4E-06	0.03	4.8E-06	1.8	4.4E-06	8.7E-06	1.3E-05
Beryllium	0.71	1	1.2E-07	0.35	2.9E-06	4.3	5.3E-07	1.2E-05	1.3E-05
Lead	19.05	0.5	1.7E-06	NA		NA			
					SUMMARY CANCER RISK		2E-05	2E-04	2E-04

TABLE A-5, continued

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - AVERAGE CONCENTRATIONS

FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.0011	1	5.4E-10	0.2	7.1E-09	0.1	5.4E-09	7 1E-08	7.6E-08
Toluene	0.00055	1	2.7E-10	0.12	2.1E-09	0.2	1.3E-09	1.1E-08	1.2E-08
Xylenes	0.0025	1	1.2E-09	0.12	9.7E-09	2	6.1E-10	4.8E-09	5.4E-09
2-Methylnaphthalene	0.63	1	3.1E-07	0.1	2.0E-06	0.04	7.7E-06	5.1E-05	5.8E-05
Acenaphthene	0.6	1	2.9E-07	0.2	3.9E-06	0.06	4.9E-06	6.4E-05	6.9E-05
Acenaphthylene	0.78	0.91	3.5E-07	0.18	4.5E-06	0.04	8.7E-06	1.1E-04	1.2E-04
Anthracene	2.14	1	1.0E-06	0.29	2.0E-05	0.3	3.5E-06	6.7E-05	7.0E-05
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.02			
Benzo(a)anthracene	5.75	0.91	2.6E-06	0.18	3.3E-05	0.04	6.4E-05	8.3E-04	9.0E-04
Benzo(a)pyrene	5.99	0.91	2.7E-06	0.18	3.5E-05	0.04	6.7E-05	8.7E-04	9.4E-04
Benzo(b)fluoranthene	6.09	0.91	2.7E-06	0.18	3.5E-05	0.04	6.8E-05	8.8E-04	9.5E-04
Benzo(g,h,i)perylene	4.65	0.91	2.1E-06	0.18	2.7E-05	0.04	5.2E-05	6.7E-04	7.3E-04
Benzo(k)fluoranthene	4.59	0.91	2.0E-06	0.18	2.7E-05	0.04	5.1E-05	6.7E-04	7.2E-04
Carbazole	1.79	1	8.8E-07	1	5.8E-05	NA			
Chrysene	7.17	0.91	3.2E-06	0.18	4.2E-05	0.04	8.0E-05	1.0E-03	1.1E-03
Dibenz(a,h)anthracene	1.64	0.91	7.3E-07	0.08	4.2E-06	0.04	1.8E-05	1.1E-04	1.2E-04
Dibenzofuran	0.89	NA		NA		NA			
Fluoranthene	14.39	1	7.0E-06	0.2	9.3E-05	0.04	1.8E-04	2.3E-03	2.5E-03
Fluorene	1.63	1	8.0E-07	0.2	1.1E-05	0.04	2.0E-05	2.6E-04	2.8E-04
Indeno(1,2,3-cd)pyrene	5.03	0.91	2.2E-06	0.18	2.9E-05	0.04	5.6E-05	7.3E-04	7.9E-04
Naphthalene	1.57	1	7.7E-07	0.1	5.1E-06	0.04	1.9E-05	1.3E-04	1.5E-04
Phenanthrene	10.86	0.91	4.8E-06	0.18	6.3E-05	0.04	1.2E-04	1.6E-03	1.7E-03
Pyrene	9.74	1	4.8E-06	0.2	6.3E-05	0.03	1.6E-04	2.1E-03	2.3E-03
Arsenic	13.96	1	6.8E-06	0.03	1.4E-05	0.0003	2.3E-02	4.5E-02	6.8E-02
Barium	38.69	1	1.9E-05	0.35	4.4E-04	0.07	2.7E-04	6.2E-03	6.5E-03

TABLE A-5, continued
DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	0.71	1	3.5E-07	0.35	8.0E-06	0.005	6.9E-05	1.6E-03	1.7E-03
Cadmium	1.24	1	6.1E-07	0.14	5.6E-06	0.001	6.1E-04	5.6E-03	6.2E-03
Chromium	27.83	1	1.4E-05	0.09	8.1E-05	0.02	6.8E-04	4.0E-03	4.7E-03
Copper	11.11	1	5.4E-06	0.35	1.3E-04	NA			
Iron	11615	1	5.7E-03	0.35	1.3E-01	NA			
Lead	19.05	0.5	4.7E-06	0.006	3.7E-06	NA			
Magnesium	4205	1	2.1E-03	0.35	4.7E-02	NA			
Manganese	192	1	9.4E-05	0.35	2.2E-03	0.1	9.4E-04	2.2E-02	2.3E-02
Nickel	22.55	1	1.1E-05	0.35	2.5E-04	0.02	5.5E-04	1.3E-02	1.3E-02
Potassium	1695	1	8.3E-04	0.35	1.9E-02	NA			
Sodium	176	1	8.6E-05	0.35	2.0E-03	NA			
Vanadium	17.81	1	8.7E-06	0.35	2.0E-04	0.007	1.2E-03	2.9E-02	3.0E-02
Zinc	38.63	1	1.9E-05	0.02	2.5E-05	0.3	6.3E-05	8.3E-05	1.5E-04
SUMMARY HAZARD INDEX							0.03	0.14	0.16

WORK-A-6 | 07-Jun-93

TABLE A-6

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - AVERAGE CONCENTRATIONS

FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Average	mg/kg	
INGESTION RATE	IR	50	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm^2	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm^2/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991
EXPOSURE DURATION	ED	25	years	USEPA, 1991
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	25	years	USEPA, 1991

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.

USEPA, 1989a. RAGs, Part A.

USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365\ \text{days/year}}$$

$$\text{INTAKE-DERMAL} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365\ \text{days/year}}$$

For noncarcinogenic effects: AT = ED

TABLE A-6, continued

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DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - AVERAGE CONCENTRATIONS

FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.014			
Benzo(a)anthracene	5.74	1	1.0E-06	0.2	1.3E-05	7.3	7.3E-06	9.6E-05	1.0E-04
Benzo(a)pyrene	5.99	1	1.0E-06	0.2	1.4E-05	7.3	7.6E-06	1.0E-04	1.1E-04
Benzo(b)fluoranthene	6.09	1	1.1E-06	0.2	1.4E-05	7.3	7.8E-06	1.0E-04	1.1E-04
Benzo(k)fluoranthene	4.59	1	8.0E-07	0.2	1.1E-05	7.3	5.9E-06	7.7E-05	8.3E-05
Carbazole	1.79	1	3.1E-07	1	2.1E-05	0.02	6.3E-09	4.1E-07	4.2E-07
Chrysene	7.17	1	1.3E-06	0.2	1.7E-05	7.3	9.1E-06	1.2E-04	1.3E-04
Dibenz(a,h)anthracene	1.64	1	2.9E-07	0.09	1.7E-06	7.3	2.1E-06	1.2E-05	1.4E-05
Indeno(1,2,3-cd)pyrene	5.03	1	8.8E-07	0.2	1.2E-05	7.3	6.4E-06	8.5E-05	9.1E-05
Arsenic	13.96	1	2.4E-06	0.03	4.8E-06	1.8	4 4E-06	8.7E-06	1.3E-05
Beryllium	0.71	1	1.2E-07	0.35	2.9E-06	4.3	5.3E-07	1.2E-05	1.3E-05
Lead	19.05	0.5	1.7E-06	NA		NA			
						SUMMARY CANCER RISK	5E-05	6E-04	7E-04

TABLE A-6, continued
DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 - AVERAGE CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.0011	1	5.4E-10	0.2	7.1E-09	0.1	5.4E-09	7.1E-08	7.6E-08
Toluene	0.00055	1	2.7E-10	0.12	2.1E-09	0.2	1.3E-09	1.1E-08	1.2E-08
Xylenes	0.0025	1	1.2E-09	0.12	9.7E-09	2	6.1E-10	4.8E-09	5.4E-09
2-Methylnaphthalene	0.63	1	3.1E-07	0.1	2.0E-06	0.04	7.7E-06	5.1E-05	5.8E-05
Acenaphthene	0.6	1	2.9E-07	0.2	3.9E-06	0.06	4.9E-06	6.4E-05	6.9E-05
Acenaphthylene	0.78	0.91	3.5E-07	0.18	4.5E-06	0.04	8.7E-06	1.1E-04	1.2E-04
Anthracene	2.14	1	1.0E-06	0.29	2.0E-05	0.3	3.5E-06	6.7E-05	7.0E-05
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.02			
Benzo(a)anthracene	5.75	0.91	2.6E-06	0.18	3.3E-05	0.04	6.4E-05	8.3E-04	9.0E-04
Benzo(a)pyrene	5.99	0.91	2.7E-06	0.18	3.5E-05	0.04	6.7E-05	8.7E-04	9.4E-04
Benzo(b)fluoranthene	6.09	0.91	2.7E-06	0.18	3.5E-05	0.04	6.8E-05	8.8E-04	9.5E-04
Benzo(g,h,i)perylene	4.65	0.91	2.1E-06	0.18	2.7E-05	0.04	5.2E-05	6.7E-04	7.3E-04
Benzo(k)fluoranthene	4.59	0.91	2.0E-06	0.18	2.7E-05	0.04	5.1E-05	6.7E-04	7.2E-04
Carbazole	1.79	1	8.8E-07	1	5.8E-05	NA			
Chrysene	7.17	0.91	3.2E-06	0.18	4.2E-05	0.04	8.0E-05	1.0E-03	1.1E-03
Dibenz(a,h)anthracene	1.64	0.91	7.3E-07	0.08	4.2E-06	0.04	1.8E-05	1.1E-04	1.2E-04
Dibenzofuran	0.89	NA		NA		NA			
Fluoranthene	14.39	1	7.0E-06	0.2	9.3E-05	0.04	1.8E-04	2.3E-03	2.5E-03
Fluorene	1.63	1	8.0E-07	0.2	1.1E-05	0.04	2.0E-05	2.6E-04	2.8E-04
Indeno(1,2,3-cd)pyrene	5.03	0.91	2.2E-06	0.18	2.9E-05	0.04	5.6E-05	7.3E-04	7.9E-04
Naphthalene	1.57	1	7.7E-07	0.1	5.1E-06	0.04	1.9E-05	1.3E-04	1.5E-04
Phenanthrene	10.86	0.91	4.8E-06	0.18	6.3E-05	0.04	1.2E-04	1.6E-03	1.7E-03
Pyrene	9.74	1	4.8E-06	0.2	6.3E-05	0.03	1.6E-04	2.1E-03	2.3E-03
Arsenic	13.96	1	6.8E-06	0.03	1.4E-05	0.0003	2.3E-02	4.5E-02	6.8E-02
Barium	38.69	1	1.9E-05	0.35	4.4E-04	0.07	2.7E-04	6.2E-03	6.5E-03

TABLE A-6, continued

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - AVERAGE CONCENTRATIONS

FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	0.71	1	3.5E-07	0.35	8.0E-06	0.005	6.9E-05	1.6E-03	1.7E-03
Cadmium	1.24	1	6.1E-07	0.14	5.6E-06	0.001	6.1E-04	5.6E-03	6.2E-03
Chromium	27.83	1	1.4E-05	0.09	8.1E-05	0.02	6 8E-04	4.0E-03	4.7E-03
Copper	11.11	1	5.4E-06	0.35	1.3E-04	NA			
Iron	11615	1	5.7E-03	0.35	1.3E-01	NA			
Lead	19.05	0.5	4.7E-06	0.006	3.7E-06	NA			
Magnesium	4205	1	2.1E-03	0.35	4.7E-02	NA			
Manganese	192	1	9.4E-05	0.35	2.2E-03	0.1	9.4E-04	2.2E-02	2.3E-02
Nickel	22.55	1	1.1E-05	0.35	2.5E-04	0.02	5.5E-04	1.3E-02	1.3E-02
Potassium	1695	1	8.3E-04	0.35	1.9E-02	NA			
Sodium	176	1	8.6E-05	0.35	2.0E-03	NA			
Vanadium	17.81	1	8.7E-06	0.35	2.0E-04	0.007	1.2E-03	2.9E-02	3.0E-02
Zinc	38.63	1	1.9E-05	0.02	2.5E-05	0.3	6.3E-05	8.3E-05	1.5E-04
						SUMMARY HAZARD INDEX	0.03	0.14	0.16

TABLE A-7

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

WORK-A-7	07-Jun-93

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Maximum	mg/kg	
INGESTION RATE	IR	50	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm^2	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm^2/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991
EXPOSURE DURATION	ED	25	years	USEPA, 1991
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	25	years	USEPA, 1991

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.

USEPA, 1989a. RAGs, Part A.

USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

$$\text{INTAKE-DERMAL} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

For noncarcinogenic effects: AT = ED

TABLE A-7, continued

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DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.014			
Benzo(a)anthracene	4	1	7.0E-07	0.2	9.2E-06	7.3	5.1E-06	6.7E-05	7.2E-05
Benzo(a)pyrene	30	1	5.2E-06	0.2	6.9E-05	7.3	3.8E-05	5.0E-04	5.4E-04
Benzo(b)fluoranthene	3	1	5.2E-07	0.2	6.9E-06	7.3	3.8E-06	5.0E-05	5.4E-05
Benzo(k)fluoranthene	3	1	5.2E-07	0.2	6.9E-06	7.3	3.8E-06	5.0E-05	5.4E-05
Carbazole	20	1	3.5E-06	1	2.3E-04	0.02	7.0E-08	4.6E-06	4.7E-06
Chrysene	0.5	1	8.7E-08	0.2	1.2E-06	7.3	6.4E-07	8.4E-06	9.0E-06
Dibenz(a,h)anthracene	5	1	8.7E-07	0.09	5.2E-06	7.3	6.4E-06	3.8E-05	4.4E-05
Indeno(1,2,3-cd)pyrene	2	1	3.5E-07	0.2	4.6E-06	7.3	2.6E-06	3.4E-05	3.6E-05
Arsenic	29	1	5.1E-06	0.03	1.0E-05	1.8	9.1E-06	1.8E-05	2.7E-05
Beryllium	1.15	1	2.0E-07	0.35	4.6E-06	4.3	8.6E-07	2.0E-05	2.1E-05
Lead	73	0.5	6.4E-06	NA		NA			
					SUMMARY CANCER RISK		7E-05	8E-04	9E-04

TABLE A-7, continued

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

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NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.0049	1	2.4E-09	0.2	3.2E-08	0.1	2.4E-08	3.2E-07	3.4E-07
Toluene	0.0023	1	1.1E-09	0.12	8.9E-09	0.2	5.6E-09	4.4E-08	5.0E-08
Xylenes	0.022	1	1.1E-08	0.12	8.5E-08	2	5.4E-09	4.3E-08	4.8E-08
2-Methylnaphthalene	6	1	2.9E-06	0.1	1.9E-05	0.04	7.3E-05	4.8E-04	5.6E-04
Acenaphthene	6	1	2.9E-06	0.2	3.9E-05	0.06	4.9E-05	6.4E-04	6.9E-04
Acenaphthylene	4	0.91	1.8E-06	0.18	2.3E-05	0.04	4.5E-05	5.8E-04	6.2E-04
Anthracene	20	1	9.8E-06	0.29	1.9E-04	0.3	3.3E-05	6.2E-04	6.6E-04
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.02			
Benzo(a)anthracene	40	0.91	1.8E-05	0.18	2.3E-04	0.04	4.5E-04	5.8E-03	6.2E-03
Bnezo(a)pyrene	30	0.91	1.3E-05	0.18	1.7E-04	0.04	3 3E-04	4.4E-03	4.7E-03
Benzo(b)fluoranthene	30	0.91	1.3E-05	0.18	1.7E-04	0.04	3.3E-04	4.4E-03	4.7E-03
Benzo(g,h,i)perylene	20	0.91	8.9E-06	0.18	1.2E-04	0.04	2.2E-04	2.9E-03	3.1E-03
Benzo(k)fluoranthene	30	0.91	1.3E-05	0.18	1.7E-04	0.04	3.3E-04	4.4E-03	4.7E-03
Carbazole	20	1	9.8E-06	1	6.4E-04	NA			
Chrysene	50	0.91	2.2E-05	0.18	2.9E-04	0.04	5.6E-04	7.3E-03	7.8E-03
Dibenz(a,h)anthracene	5	0.91	2.2E-06	0.08	1.3E-05	0.04	5.6E-05	3.2E-04	3.8E-04
Dibenzofuran	10	NA		NA		NA			
Fluoranthene	100	1	4.9E-05	0.2	6.4E-04	0.04	1.2E-03	1.6E-02	1.7E-02
Fluorene	20	1	9.8E-06	0.2	1.3E-04	0.04	2.4E-04	3.2E-03	3.5E-03
Indeno(1,2,3-cd)pyrene	20	0.91	8.9E-06	0.18	1.2E-04	0.04	2.2E-04	2.9E-03	3.1E-03
Naphthalene	20	1	9.8E-06	0.1	6.4E-05	0.04	2.4E-04	1.6E-03	1.9E-03
Phenanthrene	100	0.91	4.5E-05	0.18	5.8E-04	0.04	1.1E-03	1.5E-02	1.6E-02
Pyrene	60	1	2.9E-05	0.2	3.9E-04	0.03	9.8E-04	1.3E-02	1.4E-02
Arsenic	29	1	1.4E-05	0.03	2.8E-05	0.0003	4.7E-02	9.3E-02	1.4E-01
Barium	95.3	1	4.7E-05	0.35	1.1E-03	0.07	6.7E-04	1.5E-02	1.6E-02

TABLE A-7, continued

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DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION IV TEF APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	1.15	1	5.6E-07	0.35	1.3E-05	0.005	1.1E-04	2.6E-03	2.7E-03
Cadmium	8.85	1	4.3E-06	0.14	4.0E-05	0.001	4.3E-03	4.0E-02	4.4E-02
Chromium	58.7	1	2.9E-05	0.09	1.7E-04	0.02	1.4E-03	8.5E-03	1.0E-02
Copper	20.6	1	1.0E-05	0.35	2.3E-04	NA			
Iron	18900	1	9.2E-03	0.35	2.1E-01	NA			
Lead	73	0.5	1.8E-05	0.006	1.4E-05	NA			
Magnesium	9210	1	4.5E-03	0.35	1.0E-01	NA			
Manganese	313	1	1.5E-04	0.35	3.5E-03	0.1	1.5E-03	3.5E-02	3.7E-02
Nickel	41.8	1	2.0E-05	0.35	4.7E-04	0.02	1.0E-03	2.4E-02	2.5E-02
Potassium	4820	1	2.4E-03	0.35	5.4E-02	NA			
Sodium	316	1	1.5E-04	0.35	3.6E-03	NA			
Vanadium	34.9	1	1.7E-05	0.35	3.9E-04	0.007	2.4E-03	5.6E-02	5.9E-02
Zinc	92.9	1	4.5E-05	0.02	6.0E-05	0.3	1.5E-04	2.0E-04	3.5E-04
						SUMMARY HAZARD INDEX	0.07	0.36	0.42

WORK-A-8 | 07-Jun-93

TABLE A-8

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION SOIL	CS	Maximum	mg/kg	
INGESTION RATE	IR	50	mg/day	USEPA, 1991
FRACTION INGESTED	FI	100%		
SOIL ADHERENCE FACTOR	SAF	1	mg/cm^2	USEPA, 1992
SURFACE AREA EXPOSED	SA	3,295	cm^2/day	USEPA, 1989b (1)
CONVERSION FACTOR	CF	0.000001	kg/mg	
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991
EXPOSURE DURATION	ED	25	years	USEPA, 1991
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
NONCANCER	AT	25	years	USEPA, 1991

USEPA, 1991. "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors".

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim report, EPA/600/8-91/011B, January 1992.

USEPA, 1989a. RAGs, Part A.

USEPA, 1989b. Exposure Factors Handbook.

(1) Arms and Hands

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

INTAKE = (INTAKE-INGESTION) + (INTAKE-DERMAL)

$$\text{INTAKE-INGESTION} = \frac{CS \times IR \times RAF \times FI \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

$$\text{INTAKE-DERMAL} = \frac{CS \times SA \times SAF \times RAF \times CF \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

For noncarcinogenic effects: AT = ED

TABLE A-8, continued
DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL – USEPA REGION I B(a)P APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 – MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK INGESTION	CANCER RISK DERMAL	TOTAL CANCER RISK
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.014			
Benzo(a)anthracene	40	1	7.0E-06	0.2	9.2E-05	7.3	5.1E-05	6.7E-04	7.2E-04
Benzo(a)pyrene	30	1	5.2E-06	0.2	6.9E-05	7.3	3.8E-05	5.0E-04	5.4E-04
Benzo(b)fluoranthene	30	1	5.2E-06	0.2	6.9E-05	7.3	3.8E-05	5.0E-04	5.4E-04
Benzo(k)fluoranthene	30	1	5.2E-06	0.2	6.9E-05	7.3	3.8E-05	5.0E-04	5.4E-04
Carbazole	20	1	3.5E-06	1	2.3E-04	0.02	7.0E-08	4.6E-06	4.7E-06
Chrysene	50	1	8.7E-06	0.2	1.2E-04	7.3	6.4E-05	8.4E-04	9.0E-04
Dibenz(a,h)anthracene	5	1	8.7E-07	0.09	5.2E-06	7.3	6.4E-06	3.8E-05	4.4E-05
Indeno(1,2,3-cd)pyrene	20	1	3.5E-06	0.2	4.6E-05	7.3	2.6E-05	3.4E-04	3.6E-04
Arsenic	29	1	5.1E-06	0.03	1.0E-05	1.8	9.1E-06	1.8E-05	2.7E-05
Beryllium	1.15	1	2.0E-07	0.35	4.6E-06	4.3	8.6E-07	2.0E-05	2.1E-05
Lead	73	0.5	6.4E-06	NA		NA			
					SUMMARY CANCER RISK		3E-04	3E-03	4E-03

TABLE A-8, continued

DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS

RECEPTOR: WORKER

AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS

FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Ethylbenzene	0.0049	1	2.4E-09	0.2	3.2E-08	0.1	2.4E-08	3.2E-07	3.4E-07
Toluene	0.0023	1	1.1E-09	0.12	8.9E-09	0.2	5.6E-09	4.4E-08	5.0E-08
Xylenes	0.022	1	1.1E-08	0.12	8.5E-08	2	5.4E-09	4.3E-08	4.8E-08
2-Methylnaphthalene	6	1	2.9E-06	0.1	1.9E-05	0.04	7 3E-05	4.8E-04	5.6E-04
Acenaphthene	6	1	2.9E-06	0.2	3.9E-05	0.06	4.9E-05	6.4E-04	6.9E-04
Acenaphthylene	4	0.91	1.8E-06	0.18	2.3E-05	0.04	4.5E-05	5.8E-04	6.2E-04
Anthracene	20	1	9.8E-06	0.29	1.9E-04	0.3	3.3E-05	6.2E-04	6.6E-04
Bis(2-ethylhexyl)phthalate	ND	1		0.02		0.02			
Benzo(a)anthracene	40	0.91	1.8E-05	0.18	2.3E-04	0.04	4.5E-04	5.8E-03	6.2E-03
Bnezo(a)pyrene	30	0.91	1.3E-05	0.18	1.7E-04	0.04	3.3E-04	4.4E-03	4.7E-03
Benzo(b)fluoranthene	30	0.91	1.3E-05	0.18	1.7E-04	0.04	3.3E-04	4.4E-03	4.7E-03
Benzo(g,h,i)perylene	20	0.91	8.9E-06	0.18	1.2E-04	0.04	2.2E-04	2.9E-03	3.1E-03
Benzo(k)fluoranthene	30	0.91	1.3E-05	0.18	1.7E-04	0.04	3.3E-04	4.4E-03	4.7E-03
Carbazole	20	1	9.8E-06	1	6.4E-04	NA			
Chrysene	50	0.91	2.2E-05	0.18	2.9E-04	0.04	5.6E-04	7.3E-03	7.8E-03
Dibenz(a,h)anthracene	5	0.91	2.2E-06	0.08	1.3E-05	0.04	5.6E-05	3.2E-04	3.8E-04
Dibenzofuran	10	NA		NA		NA			
Fluoranthene	100	1	4.9E-05	0.2	6.4E-04	0.04	1.2E-03	1.6E-02	1.7E-02
Fluorene	20	1	9.8E-06	0.2	1.3E-04	0.04	2.4E-04	3.2E-03	3.5E-03
Indeno(1,2,3-cd)pyrene	20	0.91	8.9E-06	0.18	1.2E-04	0.04	2.2E-04	2.9E-03	3.1E-03
Naphthalene	20	1	9.8E-06	0.1	6.4E-05	0.04	2.4E-04	1.6E-03	1.9E-03
Phenanthrene	100	0.91	4.5E-05	0.18	5.8E-04	0.04	1.1E-03	1.5E-02	1.6E-02
Pyrene	60	1	2.9E-05	0.2	3.9E-04	0.03	9.8E-04	1.3E-02	1.4E-02
Arsenic	29	1	1.4E-05	0.03	2.8E-05	0.0003	4.7E-02	9.3E-02	1.4E-01
Barium	95.3	1	4.7E-05	0.35	1.1E-03	0.07	6.7E-04	1.5E-02	1.6E-02

TABLE A-8, continued

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DIRECT CONTACT WITH AND INCIDENTAL INGESTION OF SURFACE SOIL - USEPA REGION I B(a)P APPROACH FOR PAHS
RECEPTOR: WORKER
AOCs 44 AND 52 - MAXIMUM CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	SOIL CONCENTRATION (mg/kg)	INGESTION RAF	INTAKE INGESTION (mg/kg-day)	DERMAL RAF	INTAKE DERMAL (mg/kg-day)	REFERENCE DOSE (mg/kg-day)	HAZARD QUOTIENT INGESTION	HAZARD QUOTIENT DERMAL	TOTAL HAZARD QUOTIENT
Beryllium	1.15	1	5.6E-07	0.35	1.3E-05	0.005	1.1E-04	2.6E-03	2.7E-03
Cadmium	8.85	1	4.3E-06	0.14	4.0E-05	0.001	4.3E-03	4.0E-02	4.4E-02
Chromium	58.7	1	2.9E-05	0.09	1.7E-04	0.02	1.4E-03	8.5E-03	1.0E-02
Copper	20.6	1	1.0E-05	0.35	2.3E-04	NA			
Iron	18900	1	9.2E-03	0.35	2.1E-01	NA			
Lead	73	0.5	1.8E-05	0.006	1.4E-05	NA			
Magnesium	9210	1	4.5E-03	0.35	1.0E-01	NA			
Manganese	313	1	1.5E-04	0.35	3.5E-03	0.1	1.5E-03	3.5E-02	3.7E-02
Nickel	41.8	1	2.0E-05	0.35	4.7E-04	0.02	1.0E-03	2.4E-02	2.5E-02
Potassium	4820	1	2.4E-03	0.35	5.4E-02	NA			
Sodium	316	1	1.5E-04	0.35	3.6E-03	NA			
Vanadium	34.9	1	1.7E-05	0.35	3.9E-04	0.007	2.4E-03	5.6E-02	5.9E-02
Zinc	92.9	1	4.5E-05	0.02	6.0E-05	0.3	1.5E-04	2.0E-04	3.5E-04
SUMMARY HAZARD INDEX							0.07	0.36	0.42

TABLE A-9

SUMMARY OF BASELINE RISK ESTIMATES

for AOCs 44 and 52
Fort Devens, Masschusetts

EXPOSURE SCENARIO	**EXCESS LIFETIME CANCER RISKS**				**NONCANCER HAZARD INDICES**	
	USEPA Region I B(a)P Approach		USEPA Region IV TEF Approach			
	Average EPC[1]	Max EPC	Average EPC	Max EPC	Average EPC	Max EPC
Construction Worker[2]	4E-6	5E-5	2E-6	1E-5	0.5	1
Long-Term Worker[3]	7E-4	4E-3	2E-4	9E-4	0.2	0.4

[1] EPC = Exposure Point Concentration

[2] Exposed through direct contact and incidental ingestion of surface an subsurface soil 5 days per week for a 3 month period.

[3] Exposed through direct contact and incidental ingestion of surface soil 250 days/year for 25 years

TABLE A-10
SOIL CONTAMINANT RELEASE ANALYSIS - FUGITIVE DUST
BASED ON NATIONAL AMBIENT AIR QUALITY STANDARD (NAAQS)
FOR RESPIRABLE PARTICLES (PM10) (1)

AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

CONTAMINANT	SOIL CONCENTRATION (mg/kg)	FUGITIVE DUST NAAQS (ug/m^3)	FUGITIVE DUST CONCENTRATION (2) (mg/m^3)
Carcinogens			
Bis(2-ethylhexyl)phthalate	1.941	50	9.71E-08
Benzo(a)anthracene	2.078	50	1.04E-07
Benzo(a)pyrene	2.241	50	1.12E-07
Benzo(b)fluoranthene	2.318	50	1.16E-07
Benzo(k)fluoranthene	1.658	50	8.29E-08
Carbazole	0.621	50	3.11E-08
Chrysene	2.581	50	1.29E-07
Dibenz(a,h)anthracene	0.782	50	3.91E-08
Indeno(1,2,3-cd)pyrene	2.001	50	1.00E-07
Arsenic	12.36	50	6.18E-07
Beryllium	0.514	50	2.57E-08
Lead	10.188	50	5.09E-07
Cadmium	0.635	50	3.18E-08
Chromium VI (3)	1.719	50	8.60E-08
Nickel	15.299	50	7.65E-07
Noncarcinogens			
Ethylbenzene	0.000936	50	4.68E-11
Toluene	0.000441	50	2.21E-11
Xylenes	0.00129	50	6.45E-11
2-Methylnaphthalene	0.267	50	1.34E-08
Acenaphthene	0.235	50	1.18E-08
Acenaphthylene	0.297	50	1.49E-08
Anthracene	0.742	50	3.71E-08
Benzo(g,h,i)perylene	1.839	50	9.20E-08
Dibenzofuran	0.327	50	1.64E-08
Fluoranthene	5.044	50	2.52E-07
Fluorene	0.564	50	2.82E-08
Naphthalene	0.554	50	2.77E-08
Phenanthrene	3.658	50	1.83E-07
Pyrene	3.405	50	1.70E-07
Barium	24.907	50	1.25E-06
Copper	8.885	50	4.44E-07
Chromium III (3)	15.473	50	7.74E-07
Iron	8547.391	50	4.27E-04

TABLE A-10

SOIL CONTAMINANT RELEASE ANALYSIS - FUGITIVE DUST

BASED ON NATIONAL AMBIENT AIR QUALITY STANDARD (NAAQS)

FOR RESPIRABLE PARTICLES (PM10) (1)

AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS

FORT DEVENS, MA

CONTAMINANT	SOIL CONCENTRATION (mg/kg)	FUGITIVE DUST NAAQS (ug/m^3)	FUGITIVE DUST CONCENTRATION (2) (mg/m^3)
Magnesium	2504.574	50	1.25E-04
Manganese	154.293	50	7.71E-06
Potassium	1008.659	50	5.04E-05
Sodium	155.042	50	7.75E-06
Vanadium	10.942	50	5.47E-07
Zinc	26.532	50	1.33E-06

(1) The National Ambient Air Quality Standard for respirable particulates (PM10) is 50 ug/m^3 (annual arithmetic mean concentration)

(2) Fugitive Dust Concentration (mg/m^3) = [Soil Concentration (mg/kg) x NAAQS for Fugitive Dust (mg/m^3)]/1 x 10^9 ug/kg

(3) The total chromium concentration (17.192 mg/kg) was divided into 90% chromium III and 10% chromium VI (a carcinogen via inhalation).

DUST-NAQ.WK1

DST-FTD1 | 03-Aug-93

TABLE A-11
INHALATION EXPOSURE TO DUST- NAAQS OF 50 UG/M^3 (PM10)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION AIR	CA		mg/m^3	Modeled
INHALATION RATE	IR	2.5	m^3/hour	USEPA, 1991a
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE TIME	ET	8	hours/day	USEPA, 1991a
EXPOSURE FREQUENCY	EF	5	days/workweek	PRO. JUDGEMENT
EXPOSURE DURATION	ED	12	weeks	PRO. JUDGEMENT
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
	AT	12	weeks	USEPA, 1989a*

USEPA, 1991a. " STANDARD DEFAULT EXPOSURE FACTORS"
USEPA, 1989a RISK ASSESSMENT GUIDANCE FOR SUPERFUND, PART A.

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day)^-1

$$\text{INTAKE} = \frac{CA \times IR \times RAF \times ET \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

$$\text{INTAKE} = \frac{CA \times IR \times RAF \times ET \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$$

Note:
*For noncarcinogenic effects: AT = ED

TABLE A-11, continued
INHALATION EXPOSURE TO DUST- NAAQS OF 50 UG/M^3 (PM10)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	AIR CONC. (mg/m³)	INHALATION RAF	INTAKE (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK
Bis(2-ethylhexyl)phthalate	9.71E-08	1	6.5E-11	1.40E-02	9.1E-13
Benzo(a)anthracene	1.04E-07	1	7.0E-11	6.10E+00	4.3E-10
Benzo(a)pyrene	1.12E-07	1	7.5E-11	6.10E+00	4.6E-10
Benzo(b)fluoranthene	1.16E-07	1	7.8E-11	6.10E+00	4.7E-10
Benzo(k)fluoranthene	8.29E-08	1	5.6E-11	6.10E+00	3.4E-10
Carbazole	3.11E-08	1	2.1E-11	2.00E-02	4.2E-13
Chrysene	1.29E-07	1	8.7E-11	6.10E+00	5.3E-10
Dibenz(a,h)anthracene	3.91E-08	1	2.6E-11	6.10E+00	1.6E-10
Indeno(1,2,3-cd)pyrene	1.00E-07	1	6.7E-11	6.10E+00	4.1E-10
Arsenic	6.18E-07	1	4.1E-10	5.00E+01	2.1E-08
Beryllium	2.57E-08	1	1.7E-11	8.40E+00	1.4E-10
Cadmium	3.18E-08	1	2.1E-11	6.10E+00	1.3E-10
Chromium VI	8.60E-08	1	5.8E-11	4.10E+01	2.4E-09
Nickel	7.65E-07	1	5.1E-10	8.40E-01	4.3E-10
Lead	5.09E-07	1	3.4E-10	NA	
			SUMMARY CANCER RISK		3E-08

TABLE A-11, continued
INHALATION EXPOSURE TO DUST- NAAQS OF 50 UG/M^3 (PM10)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	AIR CONC. (mg/m³)	INHALATION RAF	INTAKE (mg/kg-day)	SUBCHRONIC REFERENCE DOSE (mg/kg-day)	SUBCHRONIC HAZARD QUOTIENT
Bis(2-ethylhexyl)phthalate	9.71E-08	1	2.8E-08	0.02	1.4E-06
Benzo(a)anthracene	1.04E-07	1	3.0E-08	0.04	7.4E-07
Benzo(a)pyrene	1.12E-07	1	3.2E-08	0.04	8.0E-07
Benzo(b)fluoranthene	1.16E-07	1	3.3E-08	0.04	8.3E-07
Benzo(k)fluoranthene	8.29E-08	1	2.4E-08	0.04	5.9E-07
Carbazole	3.11E-08	1	8.9E-09	ND	
Chrysene	1.29E-07	1	3.7E-08	0.04	9.2E-07
Dibenz(a,h)anthracene	3.91E-08	1	1.1E-08	0.04	2.8E-07
Indeno(1,2,3-cd)pyrene	1.00E-07	1	2.9E-08	0.04	7.1E-07
Arsenic	6.18E-07	1	1.8E-07	0.0003	5.9E-04
Beryllium	2.57E-08	1	7.3E-09	0.005	1.5E-06
Lead	5.09E-07	1	1.5E-07	ND	
Ethylbenzene	4.68E-11	1	1.3E-11	0.29	4.6E-11
Toluene	2.21E-11	1	6.3E-12	0.11	5.7E-11
Xylenes	6.45E-11	1	1.8E-11	0.086	2.1E-10
2-Methylnaphthalene	1.34E-08	1	3.8E-09	0.04	9.5E-08
Acenaphthene	1.18E-08	1	3.4E-09	0.6	5.6E-09
Acenaphthylene	1.49E-08	1	4.2E-09	0.04	1.1E-07
Anthracene	3.71E-08	1	1.1E-08	3	3.5E-09
Benzo(g,h,i)perylene	9.20E-08	1	2.6E-08	0.04	6.6E-07
Dibenzofuran	1.64E-08	1	4.7E-09	ND	
Fluoranthene	2.52E-07	1	7.2E-08	0.4	1.8E-07
Fluorene	2.82E-08	1	8.1E-09	0.4	2.0E-08
Naphthalene	2.77E-08	1	7.9E-09	0.04	2.0E-07
Phenanthrene	1.83E-07	1	5.2E-08	0.04	1.3E-06
Pyrene	1.70E-07	1	4.9E-08	0.3	1.6E-07

TABLE A-11, continued
INHALATION EXPOSURE TO DUST- NAAQS OF 50 UG/M^3 (PM10)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	AIR CONC. (mg/m³)	INHALATION RAF	INTAKE (mg/kg-day)	SUBCHRONIC REFERENCE DOSE (mg/kg-day)	SUBCHRONIC HAZARD QUOTIENT
Barium	1.25E-06	1	3.6E-07	0.001	3.6E-04
Cadmium	3.18E-08	1	9.1E-09	0.001	9.1E-06
Chromium VI	8.60E-08	1	2.5E-08	0.0000057	4.3E-03
Chromium III	7.74E-07	1	2.2E-07	0.0000057	3.9E-02
Copper	4.44E-07	1	1.3E-07	ND	
Iron	4.27E-04	1	1.2E-04	ND	
Magnesium	1.25E-04	1	3.6E-05	ND	
Manganese	7.71E-06	1	2.2E-06	0.14	1.6E-05
Nickel	7.65E-07	1	2.2E-07	0.02	1.1E-05
Potassium	5.04E-05	1	1.4E-05	ND	
Sodium	7.75E-06	1	2.2E-06	ND	
Vanadium	5.47E-07	1	1.6E-07	0.007	2.2E-05
Zinc	1.33E-06	1	3.8E-07	0.3	1.3E-06
			SUMMARY HAZARD INDEX		4E-02

TABLE A-12

SOIL CONTAMINANT RELEASE ANALYSIS - FUGITIVE DUST

BASED ON NATIONAL AMBIENT AIR QUALITY STANDARD (NAAQS)

FOR TOTAL RESPIRABLE PARTICLES - 24 HOUR MAXIMUM/ONCE PER YEAR (1)

AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS

FORT DEVENS, MA

CONTAMINANT	SOIL CONCENTRATION (mg/kg)	FUGITIVE DUST NAAQS (ug/m^3)	FUGITIVE DUST CONCENTRATION (2) (mg/m^3)
Carcinogens			
Bis(2-ethylhexyl)phthalate	1.941	150	2.91E-07
Benzo(a)anthracene	2.078	150	3.12E-07
Benzo(a)pyrene	2.241	150	3.36E-07
Benzo(b)fluoranthene	2.318	150	3.48E-07
Benzo(k)fluoranthene	1.658	150	2.49E-07
Carbazole	0.621	150	9.32E-08
Chrysene	2.581	150	3.87E-07
Dibenz(a,h)anthracene	0.782	150	1.17E-07
Indeno(1,2,3-cd)pyrene	2.001	150	3.00E-07
Arsenic	12.36	150	1.85E-06
Beryllium	0.514	150	7.71E-08
Lead	10.188	150	1.53E-06
Cadmium	0.635	150	9.53E-08
Chromium VI (3)	1.719	150	2.58E-07
Nickel	15.299	150	2.29E-06
Noncarcinogens			
Ethylbenzene	0.000936	150	1.40E-10
Toluene	0.000441	150	6.62E-11
Xylenes	0.00129	150	1.94E-10
2-Methylnaphthalene	0.267	150	4.01E-08
Acenaphthene	0.235	150	3.53E-08
Acenaphthylene	0.297	150	4.46E-08
Anthracene	0.742	150	1.11E-07
Benzo(g,h,i)perylene	1.839	150	2.76E-07
Dibenzofuran	0.327	150	4.91E-08
Fluoranthene	5.044	150	7.57E-07
Fluorene	0.564	150	8.46E-08
Naphthalene	0.554	150	8.31E-08
Phenanthrene	3.658	150	5.49E-07
Pyrene	3.405	150	5.11E-07
Barium	24.907	150	3.74E-06
Copper	8.885	150	1.33E-06
Chromium III (3)	15.473	150	2.32E-06
Iron	8547.391	150	1.28E-03

DST-NAQT.WK1

TABLE A-12

SOIL CONTAMINANT RELEASE ANALYSIS - FUGITIVE DUST

BASED ON NATIONAL AMBIENT AIR QUALITY STANDARD (NAAQS)

FOR TOTAL RESPIRABLE PARTICLES - 24 HOUR MAXIMUM/ONCE PER YEAR (1)

AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS

FORT DEVENS, MA

CONTAMINANT	SOIL CONCENTRATION (mg/kg)	FUGITIVE DUST NAAQS (ug/m^3)	FUGITIVE DUST CONCENTRATION (2) (mg/m^3)
Magnesium	2504.574	150	3.76E-04
Manganese	154.293	150	2.31E-05
Potassium	1008.659	150	1.51E-04
Sodium	155.042	150	2.33E-05
Vanadium	10.942	150	1.64E-06
Zinc	26.532	150	3.98E-06

(1) The National Ambient Air Quality Standard for the concentration of total respirable particulates (PM10) in a 24-hour period not to be exceeded more than once per year is 150 ug/m^3

(2) Fugitive Dust Concentration (mg/m^3) = [Soil Concentration (mg/kg) x NAAQS for Fugitive Dust (mg/m^3)]/1 x 10^9 ug/kg

(3) The total chromium concentration (17.192 mg/kg) was divided into 90% chromium III and 10% chromium VI (a carcinogen via inhalation).

TABLE A-13 | DST-FTD3 | 03-Aug-93

INHALATION EXPOSURE TO DUST- NAAQS OF 150 UG/M^3 (24 HOUR MAXIMUM - NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

EXPOSURE PARAMETERS

PARAMETER	SYMBOL	VALUE	UNITS	SOURCE
CONCENTRATION AIR	CA		mg/m^3	Modeled
INHALATION RATE	IR	2.5	m^3/hour	USEPA, 1991a
BODY WEIGHT	BW	70	kg	USEPA, 1989a
EXPOSURE TIME	ET	8	hours/day	USEPA, 1991a
EXPOSURE FREQUENCY	EF	5	days/workweek	PRO. JUDGEMENT
EXPOSURE DURATION	ED	12	weeks	PRO. JUDGEMENT
AVERAGING TIME				
CANCER	AT	70	years	USEPA, 1989a
	AT	12	weeks	USEPA, 1989a *

USEPA, 1991a. " STANDARD DEFAULT EXPOSURE FACTORS"
USEPA, 1989a RISK ASSESSMENT GUIDANCE FOR SUPERFUND, PART A.

EQUATIONS

CANCER RISK = INTAKE (mg/kg-day) x CANCER SLOPE FACTOR (mg/kg-day) ^ -1

$$\text{INTAKE} = \frac{CA \times IR \times RAF \times ET \times EF \times ED}{BW \times AT \times 365 \text{ days/year}}$$

HAZARD QUOTIENT = INTAKE (mg/kg-day) / REFERENCE DOSE (mg/kg-day)

$$\text{INTAKE} = \frac{CA \times IR \times RAF \times ET \times EF \times ED}{BW \times AT \times 5 \text{ days/workweek}}$$

Note:
*For noncarcinogenic effects: AT = ED

TABLE A-13, continued

DST-FTD3 | 03-Aug-93

INHALATION EXPOSURE TO DUST- NAAQS OF 150 UG/M^3 (24 HOUR MAXIMUM - NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	AIR CONC. (mg/m^3)	INHALATION RAF	INTAKE (mg/kg-day)	CANCER SLOPE FACTOR (mg/kg-day)^-1	CANCER RISK
Bis(2-ethylhexyl)phthalate	2.91E-07	1	2.0E-10	1.40E-02	2.7E-12
Benzo(a)anthracene	3.12E-07	1	2.1E-10	6.10E+00	1.3E-09
Benzo(a)pyrene	3.36E-07	1	2.3E-10	6.10E+00	1.4E-09
Benzo(b)fluoranthene	3.48E-07	1	2.3E-10	6.10E+00	1.4E-09
Benzo(k)fluoranthene	2.49E-07	1	1.7E-10	6.10E+00	1.0E-09
Carbazole	9.32E-08	1	6.3E-11	2.00E-02	1.3E-12
Chrysene	3.87E-07	1	2.6E-10	6.10E+00	1.6E-09
Dibenz(a,h)anthracene	1.17E-07	1	7.9E-11	6.10E+00	4.8E-10
Indeno(1,2,3-cd)pyrene	3.00E-07	1	2.0E-10	6.10E+00	1.2E-09
Arsenic	1.85E-06	1	1.2E-09	5.00E+01	6.2E-08
Beryllium	7.71E-08	1	5.2E-11	8.40E+00	4.3E-10
Cadmium	9.53E-08	1	6.4E-11	6.10E+00	3.9E-10
Chromium VI	2.58E-07	1	1.7E-10	4.10E+01	7.1E-09
Nickel	2.29E-06	1	1.5E-09	8.40E-01	1.3E-09
Lead	1.53E-06	1	1.0E-09	NA	
				SUMMARY CANCER RISK	8E-08

TABLE A-13, continued

DST-FTD3 | 03-Aug-93

INHALATION EXPOSURE TO DUST- NAAQS OF 150 UG/M^3 (24 HOUR MAXIMUM - NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR)
RECEPTOR: CONSTRUCTION WORKER
AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS
FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	AIR CONC. (mg/m³)	INHALATION RAF	INTAKE (mg/kg-day)	SUBCHRONIC REFERENCE DOSE (mg/kg-day)	SUBCHRONIC HAZARD QUOTIENT
Bis(2-ethylhexyl)phthalate	2.91E-07	1	8.3E-08	0.02	4.2E-06
Benzo(a)anthracene	3.12E-07	1	8.9E-08	0.04	2.2E-06
Benzo(a)pyrene	3.36E-07	1	9.6E-08	0.04	2.4E-06
Benzo(b)fluoranthene	3.48E-07	1	9.9E-08	0.04	2.5E-06
Benzo(k)fluoranthene	2.49E-07	1	7.1E-08	0.04	1.8E-06
Carbazole	9.32E-08	1	2.7E-08	ND	
Chrysene	3.87E-07	1	1.1E-07	0.04	2.8E-06
Dibenz(a,h)anthracene	1.17E-07	1	3.3E-08	0.04	8.4E-07
Indeno(1,2,3-cd)pyrene	3.00E-07	1	8.6E-08	0.04	2.1E-06
Arsenic	1.85E-06	1	5.3E-07	0.0003	1.8E-03
Beryllium	7.71E-08	1	2.2E-08	0.005	4.4E-06
Lead	1.53E-06	1	4.4E-07	ND	
Ethylbenzene	1.40E-10	1	4.0E-11	0.29	1.4E-10
Toluene	6.62E-11	1	1.9E-11	0.11	1.7E-10
Xylenes	1.94E-10	1	5.5E-11	0.086	6.4E-10
2-Methylnaphthalene	4.01E-08	1	1.1E-08	0.04	2.9E-07
Acenaphthene	3.53E-08	1	1.0E-08	0.6	1.7E-08
Acenaphthylene	4.46E-08	1	1.3E-08	0.04	3.2E-07
Anthracene	1.11E-07	1	3.2E-08	3	1.1E-08
Benzo(g,h,i)perylene	2.76E-07	1	7.9E-08	0.04	2.0E-06
Dibenzofuran	4.91E-08	1	1.4E-08	ND	
Fluoranthene	7.57E-07	1	2.2E-07	0.4	5.4E-07
Fluorene	8.46E-08	1	2.4E-08	0.4	6.0E-08
Naphthalene	8.31E-08	1	2.4E-08	0.04	5.9E-07
Phenanthrene	5.49E-07	1	1.6E-07	0.04	3.9E-06
Pyrene	5.11E-07	1	1.5E-07	0.3	4.9E-07

TABLE A-13, continued

INHALATION EXPOSURE TO DUST- NAAQS OF 150 UG/M^3 (24 HOUR MAXIMUM - NOT TO BE E

RECEPTOR: CONSTRUCTION WORKER

AOCs 44 AND 52 - AVERAGE SOIL CONCENTRATIONS

FORT DEVENS, MA

NONCARCINOGENIC EFFECTS

COMPOUND	AIR CONC. (mg/m³)	INHALATION RAF	INTAKE (mg/kg-day)	SUBCHRONIC REFERENCE DOSE (mg/kg-day)	SUBCHRONIC HAZARD QUOTIENT
Barium	3.74E-06	1	1.1E-06	0.001	1.1E-03
Cadmium	9.53E-08	1	2.7E-08	0.001	2.7E-05
Chromium VI	2.58E-07	1	7.4E-08	0.0000057	1.3E-02
Chromium III	2.32E-06	1	6.6E-07	0.0000057	1.2E-01
Copper	1.33E-06	1	3.8E-07	ND	
Iron	1.28E-03	1	3.7E-04	ND	
Magnesium	3.76E-04	1	1.1E-04	ND	
Manganese	2.31E-05	1	6.6E-06	0.14	4.7E-05
Nickel	2.29E-06	1	6.5E-07	0.02	3.3E-05
Potassium	1.51E-04	1	4.3E-05	ND	
Sodium	2.33E-05	1	6.7E-06	ND	
Vanadium	1.64E-06	1	4.7E-07	0.007	6.7E-05
Zinc	3.98E-06	1	1.1E-06	0.3	3.8E-06
			SUMMARY HAZARD INDEX		1E-01

TABLE A-14

USEPA Interim[1] Region IV TEFs for Carcinogenic PAHs

Compound	TEF
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

[1] From Interim Region IV guidance dated February 10, 1992.

APPENDIX B

TARGET LEVEL EQUATION, TARGET LEVEL SPREADSHEETS, AND TARGET LEVEL SUMMARY

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APPENDIX B

TARGET LEVEL EQUATION

$$\frac{TargetLevels}{mg/kg} = \frac{TR \times AT \times 365\ days/year}{SF_o \times 10^{-6}\ kg/mg \times EF \times \left[\dfrac{IR \times ED \times RAF}{BW} + \dfrac{SA \times AF \times ED \times RAF}{BW}\right]}$$

Where:

PARAMETERS	DEFINITION (units)	VALUE
TR	target excess individual lifetime cancer risk (unitless)	10^{-5}
SF_o	oral cancer slope factor $(mg/kg - day)^{-1}$	see below
AT	averaging time (yr)	70 yrs
EF	exposure frequency (days/yr)	250
IR	soil ingestion rate (mg/day)	50
ED	exposure duration (yrs)	25
RAF	relative absorption factor (unitless)	see below
SA	exposed surface area (cm^2/day)	3295
AF	soil to skin adherence factor (mg/cm^2)	1
BW	body weight (kg)	70

Toxicity Constants

COMPOUND	TOXIC EQUIVALENCY FACTOR [1]	RAF [2]	
		ORAL	DERMAL
Benzo(a)anthracene	0.1	1	0.2
Benzo(a)pyrene	1.0[3]	1	0.2
Benzo(b) fluoranthene	0.1	1	0.2
Dibenz(a,h)anthracene	1.0	1	0.09
Indeno(1,2,3,-cd)pyrene	0.1	1	0.2
Benzo(k)fluoranthene	0.1	1	0.2
Chrysene	0.01	1	0.2

[1] USEPA Interim Region IV Guidance (dated 2/10/92)
[2] MADEP Documentation for the Risk Assessment Short Form
[3] CSF of 7.3 $(mg/kg/\ day)^{-1}$

TABLE B-1

SURFACE SOIL TARGET LEVELS - USEPA REGION IV TEF APPROACH FOR PAHS (METHOD A)

SITE WORKER

AOCs 44 AND 52

FORT DEVENS, MA

TARGET CANCER RISK	1.0E-04
TARGET HAZARD INDEX	1.0

EXPOSURE PARAMETERS

PARAMETER	VARIABLE	VALUE ADULT	UNITS	SOURCE	
INGESTION RATE	IR	50	mg soil/day	USEPA, 1991	
SKIN SURFACE AREA EXPOSED	SA	3295	cm^2 skin/day	USEPA, 1989b	
SOIL ADHERENCE FACTOR	AF	1	mg/cm^2	USEPA, 1989b	
FRACTION INTAKE FROM SITE	F	100%	assumption		
BODY WEIGHT	BW	70	kg	USEPA, 1989a	
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991	
EXPOSURE DURATION	ED	25	year	USEPA, 1991	
AVERAGING TIME	AT	70	years	USEPA, 1989a	

USEPA, 1991. "STANDARD DEFAULT EXPOSURE FACTORS"

USEPA, 1989a RISK ASSESSMENT GUIDANCE FOR SUPERFUND

USEPA, 1989b EXPOSURE FACTORS HANDBOOK

TABLE B-1, continued
SURFACE SOIL TARGET LEVELS - USEPA REGION IV TEF APPROACH FOR PAHS (METHOD A)
SITE WORKER
AOCs 44 AND 52
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	TARGET RISK	CANCER SLOPE FACTOR (mg/kg-d)^-1	TARGET INTAKE (mg/kg-d)	ORAL RAF	DERMAL RAF	HIF (kg-soil/kg-d)	TARGET LEVEL (mg/kg)
Benzo(a)anthracene	2.0E-05	0.73	2.7E-05	1	0.2	2.5E-06	1.1E+01
Benzo(a)pyrene	2.0E-05	7.3	2.7E-06	1	0.2	2.5E-06	1.1E+00
Benzo(b)fluoranthene	2.0E-05	0.73	2.7E-05	1	0.2	2.5E-06	1.1E+01
Dibenz(a,h)anthracene	2.0E-05	7.3	2.7E-06	1	0.09	1.2E-06	2.3E+00
Indeno(1,2,3-cd)pyrene	2.0E-05	0.73	2.7E-05	1	0.2	2.5E-06	1.1E+01

3.7E+01

TABLE B-2
SURFACE SOIL TARGET LEVELS - USEPA REGION I B(a)P APPROACH FOR PAHS (METHOD B)
SITE WORKER
AOCs 44 AND 52
FORT DEVENS, MA

TARGET CANCER RISK	1.0E-04
TARGET HAZARD INDEX	1.0

EXPOSURE PARAMETERS

PARAMETER	VARIABLE	VALUE ADULT	UNITS	SOURCE	
INGESTION RATE	IR	50	mg soil/day	USEPA, 1991	
SKIN SURFACE AREA EXPOSED	SA	3295	cm^2 skin/day	USEPA, 1989b	
SOIL ADHERENCE FACTOR	AF	1	mg/cm^2	USEPA, 1989b	
FRACTION INTAKE FROM SITE	F	100%	assumption		
BODY WEIGHT	BW	70	kg	USEPA, 1989a	
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991	
EXPOSURE DURATION	ED	25	year	USEPA, 1991	
AVERAGING TIME	AT	70	years	USEPA, 1989a	

USEPA, 1991. "STANDARD DEFAULT EXPOSURE FACTORS"
USEPA, 1989a RISK ASSESSMENT GUIDANCE FOR SUPERFUND
USEPA, 1989b EXPOSURE FACTORS HANDBOOK

TABLE B-2, continued

SURFACE SOIL TARGET LEVELS - USEPA REGION I B(a)P APPROACH FOR PAHS (METHOD B)

SITE WORKER

AOCs 44 AND 52

FORT DEVENS, MA

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CARCINOGENIC EFFECTS

COMPOUND	TARGET RISK	CANCER SLOPE FACTOR (mg/kg-d)^-1	TARGET INTAKE (mg/kg-d)	ORAL RAF	DERMAL RAF	HIF (kg-soil/kg-d)	TARGET LEVEL (mg/kg)
Benzo(a)anthracene	1.43E-05	7.3	2.0E-06	1	0.2	2.5E-06	7.9E-01
Benzo(a)pyrene	1.43E-05	7.3	2.0E-06	1	0.2	2.5E-06	7.9E-01
Benzo(b)fluoranthene	1.43E-05	7.3	2.0E-06	1	0.2	2.5E-06	7.9E-01
Dibenz(a,h)anthracene	1.43E-05	7.3	2.0E-06	1	0.09	1.2E-06	1.6E+00
Indeno(1,2,3-cd)pyrene	1.43E-05	7.3	2.0E-06	1	0.2	2.5E-06	7.9E-01
Benzo(k)fluoranthene	1.43E-05	7.3	2.0E-06	1	0.2	2.5E-06	7.9E-01
Chrysene	1.43E-05	7.3	2.0E-06	1	0.2	2.5E-06	7.9E-01
							6.4E+00

TABLE B-3

SURFACE SOIL TARGET LEVELS - USEPA REGION IV TEF APPROACH FOR PAHS (METHOD C)

SITE WORKER

AOCs 44 AND 52

FORT DEVENS, MA

TARGET CANCER RISK	1.0E-04
TARGET HAZARD INDEX	1.0

EXPOSURE PARAMETERS

PARAMETER	VARIABLE	VALUE ADULT	UNITS	SOURCE	
INGESTION RATE	IR	50	mg soil/day	USEPA, 1991	
SKIN SURFACE AREA EXPOSED	SA	3295	cm^2 skin/day	USEPA, 1989b	
SOIL ADHERENCE FACTOR	AF	1	mg/cm^2	USEPA, 1989b	
FRACTION INTAKE FROM SITE	F	100%	assumption		
BODY WEIGHT	BW	70	kg	USEPA, 1989a	
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991	
EXPOSURE DURATION	ED	25	year	USEPA, 1991	
AVERAGING TIME	AT	70	years	USEPA, 1989a	

USEPA, 1991. "STANDARD DEFAULT EXPOSURE FACTORS"

USEPA, 1989a RISK ASSESSMENT GUIDANCE FOR SUPERFUND

USEPA, 1989b EXPOSURE FACTORS HANDBOOK

TABLE B-3, continued
SURFACE SOIL TARGET LEVELS - USEPA REGION IV TEF APPROACH FOR PAHS (METHOD C)
SITE WORKER
AOCs 44 AND 52
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	TARGET RISK	CANCER SLOPE FACTOR (mg/kg-d)^-1	TARGET INTAKE (mg/kg-d)	ORAL RAF	DERMAL RAF	HIF (kg-soil/kg-d)	TARGET LEVEL (mg/kg)
Benzo(a)anthracene	6.2E-06	0.73	8.5E-06	1	0.2	2.5E-06	3.4E+00
Benzo(a)pyrene	6.9E-05	7.3	9.5E-06	1	0.2	2.5E-06	3.8E+00
Benzo(b)fluoranthene	6.9E-06	0.73	9.5E-06	1	0.2	2.5E-06	3.8E+00
Dibenz(a,h)anthracene	8.8E-06	7.3	1.2E-06	1	0.09	1.2E-06	1.0E+00
Indeno(1,2,3-cd)pyrene	5.7E-06	0.73	7.8E-06	1	0.2	2.5E-06	3.2E+00
Benzo(k)fluoranthene	5.2E-06	0.73	7.1E-06	1	0.2	2.5E-06	2.9E+00
Chrysene	8.1E-07	0.073	1.1E-05	1	0.2	2.5E-06	4.5E+00
							2.3E+01

TABLE B-4
SURFACE SOIL TARGET LEVELS (METHOD D)
SITE WORKER
AOCs 44 AND 52
FORT DEVENS, MA

TARGET CANCER RISK	1.0E-04
TARGET HAZARD INDEX	1.0

EXPOSURE PARAMETERS

PARAMETER	VARIABLE	VALUE ADULT	UNITS	SOURCE	
INGESTION RATE	IR	50	mg soil/day	USEPA, 1991	
SKIN SURFACE AREA EXPOSED	SA	3295	cm^2 skin/day	USEPA, 1989b	
SOIL ADHERENCE FACTOR	AF	1	mg/cm^2	USEPA, 1989b	
FRACTION INTAKE FROM SITE	F	100%	assumption		
BODY WEIGHT	BW	70	kg	USEPA, 1989a	
EXPOSURE FREQUENCY	EF	250	days/year	USEPA, 1991	
EXPOSURE DURATION	ED	25	year	USEPA, 1991	
AVERAGING TIME	AT	70	years	USEPA, 1989a	

USEPA, 1991. "STANDARD DEFAULT EXPOSURE FACTORS"

USEPA, 1989a RISK ASSESSMENT GUIDANCE FOR SUPERFUND

USEPA, 1989b EXPOSURE FACTORS HANDBOOK

TABLE B-4, continued
SURFACE SOIL TARGET LEVELS (METHOD D)
SITE WORKER
AOCs 44 AND 52
FORT DEVENS, MA

CARCINOGENIC EFFECTS

COMPOUND	TARGET RISK	CANCER SLOPE FACTOR (mg/kg-d)^-1	TARGET INTAKE (mg/kg-d)	ORAL RAF	DERMAL RAF	HIF (kg-soil/kg-d)	TARGET LEVEL (mg/kg)
Benzo(a)pyrene	1.0E-04	7.3	1.4E-05	1	0.2	2.5E-06	5.5E+00

TABLE B-5

TARGET LEVEL SUMMARY[1]

Total Carcinogenic PAHs

TARGET RISK[3]	METHOD[2]			
	A	B	C	D
1.0E-04	37	6.4	23	5.5
1.0E-06	0.37	0.07	0.23	0.06

(1) All target level units are average concentrations in mg/kg.

(2) Method A = 5 most significant carcinogenic PAHs; TEF approach; Target Risks for each contaminant are equal.

Method B = All 7 carcinogenic PAHs; Benzo(a)pyrene potency for all PAHs; Target Risks for each contaminant are equal.

Method C = All 7 carcinogenic PAHs; TEF approach; Target Risks for each contaminant are proportional to site conditions.

Method D = Benzo(a) pyrene as a sole indicator contaminant.

(3) USEPA Superfund target risk range is 1.0×10^{4} to 1.0×10^{6}.

APPENDIX C

BIOREMEDIATION TREATMENT TIME DATA

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TABLE C-1
HALF LIFE ESTIMATES FOR SELECTED CPAHS
FORT DEVENS

COMPOUND	CONCENTRATION (mg/kg)	k_1 month^{-1}	$t_{1/2}$ months	SOURCE	COMMENT
Benzo(a) anthracene	86	.15	4.6	EPA/600/9-89/073 Table 5	(1) Treatability Data (2) PAH present in oily waste
Benzo(a) anthracene	80	.33	2.1	ABB-ES data	(1) Field data from landfarming (2) PAH present in #6 fuel oil
Benzo(a) anthracene	Unknown	.40	1.7	EPA/600/9-89/073 Table 6	(1) Lab data (2) Manure used as amendment
Benzo(a) anthracene	Unknown	10° - 0.03 20° - 0.05	10° - 23 20° - 14	EPA/600/9-89/073 Table 8	(1) Lab data
Benzo(a) pyrene	Unknown	10° - 0.04 20° - 0.07	10° - 18 20° - 10	EPA/600/9-89/073 Table 8	(1)Lab Data
Benzo(a) pyrene	60	.06	11.5	ABB-ES data	(1) Field data from landfarming (2) PAH present in #6 fuel oil
Benzo(a) pyrene	Unknown	.30	2.3	EPA/600/9-89/073 Table 6	(1) Lab data (2) Manure used as amendment

k^1 = first order rate constant

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United States
Environmental Protection
Agency

Robert S. Kerr
Environmental Research Laboratory
Ada, OK 74820

EPA/600/9-89/073
August 1989

Research and Development

EPA

Bioremediation of Contaminated Surface Soils

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successfully treated, with removal efficiencies averaging 98%; however, volatilization may have contributed to observed losses. More complex halogenated and nitrated compounds exhibited lower removal efficiencies, ranging from 50 to 85%.

Even though a specific organic constituent has been shown to biodegrade under laboratory conditions, whether or not it will degrade in a specific soil/site system is dependent on many factors [54]. Potential degradability requires investigation in site-specific treatability studies. Available oxygen may be limiting in some cases, while other compounds may require the presence of anaerobic conditions. Other environmental conditions that may place restrictions on biological activity include pH, temperature, and moisture. Upon exposure to the soil environment, the constituent may be biologically or chemically altered so as to be rendered persistent and/or toxic in the environment.

The system may lack other nutrients required for microbial activity. Other chemicals present may serve as preferred substrates, or act to repress required enzyme activities. High concentrations of metal salts may be inhibitory or toxic to many microorganisms.

Most chemicals require the presence of a consortium of microbial species for mineralization, some of which may not be present at the specific site. Also, most organisms require a period of acclimation to the constituent before metabolism occurs. During this period, the level of constituent must be high enough to promote acclimation without being toxic or inhibitory. Prior exposure to the constituent or similar constituents may help to shorten the acclimation period.

8. Example of Bioremediation Potential for Polycyclic Aromatic Hydrocarbons (PAHs) in a Soil System

To demonstrate the potential effectiveness of bioremediation, results are presented for the semi-volatile chemical class of compounds known as the polycyclic aromatic hydrocarbons (PAHs). These compounds are of environmental significance because of their recalcitrance to biological degradation, their chronic toxic effects on humans, and their widespread occurrence at contaminated waste sites. Specifically, PAH compounds are associated with oily wastes, such as wastes from petroleum refining operations and wastes from the wood preserving industry. The higher molecular weight PAH compounds are of special concern, because they exhibit mutagenic, carcinogenic, and teratogenic potential.

Table 5. Degradation of PAHs Present in a Complex Oily Waste, Applied at 2% Oil and Grease in Clay Loam Soil [66]

				95% Confidence Interval ($t_{1/2}$) (days)	
Compound	C_0* µg/g	$t_{1/2}$* days	R^2	Lower	Upper
Fluor-anthene	351	15	0.966	13	18
Pyrene	283	32	0.884	26	41
Benzo(a) anthracene	86	139	0.397	87	347
Benzo(g,h,i)perylene	8	1661	0.006	139	ND
Indeno-pyrene	5	69	0.559	43	139

* C_0 = Initial Concentration

* $t_{1/2}$ = Half-life (first order kinetics)

Table 6. Effect of Manure and pH Amendments on PAH Degradation in a Complex Waste Incorporated Into Soil [67]

PAH Compound	Half-Life in Waste/Soil Mixture (days) Without Amendments	With Amendments
Acenaphthylene	78	14
Acenaphthene	96	45
Fluorene	64	39
Phenanthrene	69	23
Anthracene	28	17
Fluoranthene	104	29
Pyrene	73	27
Benz(a)anthracene	123	52
Chrysene	70	42
Benzo(b)fluoranthene	85	65
Benzo(k)fluoranthene	143	74
Benzo(a)pyrene	91	69
benzo(ghi)perylene	74	42
Dibenz(a,h)anthracene	179	70
Indeno(1,2,3-cd)pyrene	57	42

Table 7. Effect of Soil Moisture on PAH Degradation [67]

Moisture	Half-life in Waste/Soil Mixture (Days) Anthracene	Phenanthrene	Fluoranthene
20-40% field capacity	43	61	559
60-60% field capacity	37	54	231

The degradation of PAH compounds in soils has been demonstrated in laboratory treatability studies [66]. The results presented in Table 5 for PAH compounds present in a complex oily waste show that the half-lives for four of the five compounds ranged from only 15 to 139 days. However, the half-life for benzo(g,h,i)perylene, a higher molecular weight PAH compound, was still quite long (1661 days). McGinnis et al. [5] in a laboratory soil treatability study of PAH compounds present in creosote waste sludges also found that degradation of PAH was dependent on molecular weight and number of aromatic rings. PAHs with two rings generally exhibited half-lives less than ten days, while three- ring compounds in most cases exhibited longer half-lives, which were usually less than one hundred days. Most of the four- or five-ring PAHs exhibited half lives of one hundred days or more. The results of these two studies suggest that means of enhancing biological degradation of more recalcitrant PAH compounds should be investigated.

When additional carbon and energy sources were provided and soil pH was adjusted from 6.1 to 7.5, the half-lives of PAH waste constituents present in a complex fossil fuel waste added to a soil were decreased, as shown in Table 6 [67]. In this laboratory study using first-order kinetic modeling of degradation, the use of manure as an amendment and control of soil pH significantly decreased the $t_{1/2}$ of the PAH constituents studied. For example, the half-life of phenanthrene decreased from 69 to 23 days, benz(a)anthracene from 123 to 52 days, and benz(a)pyrene from 91 to 69 days.

The control of soil moisture also resulted in enhanced biodegradation of PAHs, as shown in Table 7 [67]. Soil moisture in this study was described in terms of percent of field capacity. Field capacity is defined as the percentage of soil moisture remaining in a soil after having been saturated and after free drainage has practically ceased. Therefore, soils with moisture levels of 60 to 80% of field capacity are wetter than soils with levels of 20 to 40% of field capacity. At higher levels of soil moisture, the half-life of the PAH constituents studied decreased. For example, for fluoranthene, the half-life decreased from 559 days to 231 days. At a specific site where containment has been achieved, the addition and control of soil moisture may be a tool to accomplish faster degradation of the constituents.

An increase in soil temperature also can decrease the time required to accomplish degradation, especially the loss of lower molecular weight PAHs [68]. In a laboratory study, for example, the half-life of fluorene decreased from 60 days to 47 days to 32 days at 10°, 20°, and 30° C, respectively (Table 8). At a field site, soil temperature may be difficult to control. However, if a cover is used at the site to control the release of volatile materials, an increase in soil temperature may also occur. Seasonal climatic changes will affect the rate of degradation of organic constituents, as well as geographical location of a specific contaminated site.

If a soil has been exposed previously to similar or the same type of contamination, the soil microbial population may have become acclimated to the waste, and waste degradation may occur at a faster rate. In a laboratory study investigating the acclimation of a soil to a fossil fuel waste, a greater reduction in concentration of all the waste PAH compounds studied was achieved in 22 days in an acclimated soil, compared to the reduction seen in 40 days in an unacclimated soil (Table 9) [67]. These results show that at a site that has been contaminated for a period of time, the indigenous microbial population may become acclimated to the presence of wastes, and techniques to stimulate microbial activity may produce significant degradation. Mixing of a small amount of a contaminated soil that has developed an acclimated population with the

Table 8. Percentages of PAH Remaining at the End of the 240 Day Study Period and Estimated Apparent Loss Half Lives [68]

Compound	Percent of PAH Remaining 10°C	20°C	30°C	Estimated Half Life (day)* 10°C	20°C	30°C
Acenaphthene	5	0	0	<60	<10	<10
Fluorene	8	3	2	60(+11/-10)	47(+6/-5)	32(+5/-3)
Phenanthrene	36	19	2	200(+40/-40)	<60	<60
Anthracene	83	51	58	460(+310/-140)	260(+160/-70)	200(+90/-30)
Fluoranthene	94	71	15	+	440(+560/-160)	140(+40/-20)
Pyrene	93	89	43	+	1900(+6200/-800)	210(+160/-60)
Benz(a)anthracene	82	71	50	680(+300/-160)	430(+110/-70)	240(+40/-40)
Chrysene	85	88	86	980(+520/-270)	1000(+900/-250)	730(+370/-180)
Benzo(b)fluoranthene	77	75	62	580(+520/-180)	610(+590/-200)	360(+150/-80)
Benzo(k)fluoranthene	93	95	89	910(+690/-270)	1400(+3300/-560)	910(+4400/-410)
Benzo(a)pyrene	73	54	53	530(+1700/-230)	290(+570/-120)	220(+160/-60)
Dibenz(a,h)anthracene	88	87	83	820(+1100/-300)	750(+850/-260)	940(+12000/-450)
Benzo(g,h,i)perylene	81	76	75	650(+650/-230)	600(+570/-190)	590(+1800/-250)
Indeno(1,2,3-c,d)pyrene	80	77	70	600(+310/-150)	730(+1100/-270)	630(+2500/-280)

* $t_{1/2}$ (95 percent confidence interval)
\+ Least squares slope (for calculation of $t_{1/2}$) = zero with 95% confidence.

Table 9. Acclimation of Soil to Complex Fossil Fuel Waste [67]

PAH Compound	Unacclimated Soil: Initial Soil Concentration (mg/kg-dry wt)	Unacclimated Soil: Reduction in 40 days (%)	Acclimated Soil: Soil Concentration after First Reapplication of Waste (after 168 days incubation at initial level) (mg/kg-dry wt)	Acclimated Soil: Reduction in 22 days (%)
Naphthalene	38	90	38	100
Phenanthrene	30	70	30	83
Anthracene	38	58	38	99
Fluoranthene	154	51	159	82
Pyrene	177	47	180	86
Benz(a)anthracene	30	42	40	70
Chrysene	27	25	33	61
Benz(a)pyrene)	10	40	12	50

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FULL SCALE BIOREMEDIATION OF A No. 6 FUEL SPILL: DATA FROM SIX MONTHS OF ACTIVE TREATMENT AND THREE YEARS OF PASSIVE TREATMENT

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KEY WORDS: Alkanes, Biodegradation, Field Remediation, Fingerprints, In-Situ Soil Treatment, No. 6 Fuel, Polynuclear Aromatic Hydrocarbon, Soil.

I. INTRODUCTION

Bioremediation is a technology which, under optimal conditions can result in destruction of a wide range of petroleum constituents. The extent of treatment that can be achieved depends on several factors such as the starting concentration of petroleum, the types of constituents, available inorganic nutrients, duration of treatment, etc. The main source of information concerning treatment of petroleum in soil has been primarily obtained from laboratory investigations in which soil samples have been well mixed.[1] While laboratory data is useful for short term evaluations, e.g., less than one year, there are, for a number of practical reasons, limits to conducting longer term laboratory evaluations.

Field remediations offer an opportunity to obtain insight into the fate of chemicals over long durations, periods of years under open conditions. In addition, insight can be gained into the question of extent of biodegradation under conditions where active soil processing and mineral nutrient additions have ceased. Not all field remediations however, provide useful information due to circumstances such as lack of uniformity of contaminations, poor data quality, etc. The majority of field remediation projects are in fact not suitable for long-term evaluations.

This paper presents a bioremediation case study in which samples were collected and analyzed from a field remediation project over a three and one-half year period. An earlier report on this work addressed only a six-month period of active bioremediation.[2] The contamination resulted from a single spill of No. 6 fuel from a storage tank into a 60,000-square-foot bermed area. Because of relatively permeable soil at the surface and an impermeable layer at 8 inches, the oil spread over the surface resulting in a relatively homogeneously contaminated site. As a result, composite samples were able to represent the site with good reproducibility. This circumstance gave us an opportunity to obtain very interesting data, cost effectively. Additional site homogenization, during the active 180-day period of remediation, subsequently allowed one composite sample to be analyzed providing representative data for the entire site.

II. NO. 6 FUEL SPILL

A large aboveground storage tank located within a bermed area was overfilled, resulting in a spill of 3,200 barrels of No. 6 Fuel to the surface soils adjacent to the tank (Figure 1). After oil recovery efforts, approximately 900 barrels remained in the surface soils. The oil was evenly dispersed over an area of 60,000 square feet and penetrated only to a depth of 6 to 8 inches due to the presence of an impermeable layer of clayey, textured soil.

III. MEASUREMENT OF OIL CONTAMINATION IN SOIL

No. 6 fuel is a complex mixture of hydrocarbons ranging from 10 to 30 carbons in chain length, including linear and branched chain alkanes, mono- and polynuclear aromatics (PAHs), as well as nitrogen and sulfur containing heterocyclic compounds. Volatiles such as xylenes and 4- to 8-carbon alkanes generally comprise less than 1% of this fuel. Total hydrocarbons, including a portion of biodegradation intermediates, were estimated by solvent extraction and infrared analysis (TPH-IR). Hydrocarbon fingerprints, as well as quantitation of individual linear alkanes, were obtained by gas chromatography with flame ionization detection (GC/FID). Quantitation and identification of polynuclear aromatics was accomplished by gas chromatography and mass spectrometry (GC/MS). Detailed information about these analytical methods is listed in Table 1.

Laboratory analysis of selected soil samples using the methods described in Table 1, indicated approximately 10,000 ppm of GC/FID detectable fuel components. Modified method 418.1 indicated 60,000 ppm total petroleum hydrocarbons based on infrared detection.

IV. TREATABILITY TESTING

The site owner (Florida Power & Light) selected in-place biological treatment as the preferred remediation method pending the results from laboratory treatability tests. These tests were designed to simulate landfarming, a bioremediation technique in which oxygen and mineral nutrients are mechanically tilled into soil to stimulate indigenous bacteria to biodegrade the oil.

A. Treatment Simulation

These laboratory tests were designed to measure the effect of mineral nutrients additions on the rate of biodegradation. Table 2 lists the laboratory test conditions.

Open soil microcosms were constructed by blending mineral nutrient with contaminated soil and adjusting for moisture. A killed control was made by adding mercuric chloride to soil. The soils were aerated by simulated tilling three times per week to provide oxygen. At designated times, aliquots of soil were removed, extracted, and analyzed by GC/FID. The results of the treatability test are presented in Figure 2. During the first 56 days of the test, all nutrient-amended microcosms showed significant biodegradation. The killed control showed no significant changes for 21 days although by Day 56, the contaminant concentration had decreased by 23%. (Our interpretation is that biodegradation occurred due to the likelihood that bacteria were not completely killed by the mercuric chloride.) The greatest decrease occurred in microcosms amended with both nitrogen and phosphorous.

V. REMEDIATION STRATEGY AND DESIGN

The data resulting from treatability testing confirmed that in-situ treatment using naturally occurring bacteria to biodegrade the fuel oil was a suitable remedial approach.

The contaminated site was prepared for treatment in the following manner. 1) Soils were moved away from the storage tank and the area consolidated from 60,000 to 44,000 square feet. 2) Site soil was contoured to form a slope of 1 to 2% to allow drainage of excess rainfall to flow toward the bermed perimeter. 3) A soil sampling program for process monitoring was designed in which the site was divided into five sampling areas (Figure 3). Soils were sampled from five locations within each sampling area and composited. The five resulting soil samples were each analyzed for moisture, pH, ammonium nitrogen, nitrate phosphate, and hydrocarbons by GC/FID. The soils were also analyzed for total petroleum hydrocarbons by infrared spectroscopy. The remedial plan also involved a schedule of aeration, mineral nutrient and moisture addition, and groundwater monitoring.

Soil samples were initially taken for chemical analysis before treatment began (Day 0). Aeration of soil began on Day 4 and was accomplished by a combination of rotovating and plowing to a depth of 12 inches. The soils were plowed one or two times per week and rotovated three times per week. The combination of the two methods insured that deeper soils were brought to the surface during treatment.

Mineral nutrient addition started on Day 36. Nutrients were added to site soils once per week during the initial period of treatment and less frequently during later stages of remediation. The basis or "trigger" for nutrient addition was the level of soluble soil phosphorous and nitrogen which was analyzed on a weekly basis. A liquid fertilizer was formulated as the sole source of mineral nutrients. A 10-3-3 fertilizer was used during the first six weeks, and a 10-1-3 fertilizer during the remainder of the project. Approximately 3,600 lbs. of fertilizer were added during the course of treatment. In addition, water was added to the soil immediately before and after fertilization addition and as dictated by soil moisture analysis. The results of quick turn-around analysis of moisture and nutrient (48 hr.) were used to modify the routine of nutrient and moisture additions.

VI. RESULTS OF FIELD REMEDIATION

The active remedial program complete with mineral nutrient additions and discing ran for a total of 194 days. Due to our interest in evaluating the fate of petroleum constituents in soil with time, additional soil samples were obtained over a period of 1,000 days. These samples were analyzed to determine the extent of biodegradation occurring under passive or non-discing conditions. The initial chemical composition of soil extracted and analyzed by gas chromatography (GC/FID) on Day 4 is shown in Table 3. The data show that the readily identifiable compounds consisted of alkanes and 2-ring polynuclear aromatic hydrocarbons (PAHs). These "indicator" chemicals accounted for approximately 33% of the total GC quantifiable compounds.

It is important to note that the TPH value of this petroleum extract was 60,000 ppm. When the extract was analyzed by the GC/FID method, the petroleum content was observed to be 9,000 ppm. The difference between the two methods of petroleum analysis is explained on the basis that the GC/FID quantitation method measures only the chromatographic peak area located above the baseline as seen in Figure 8. The area located within the "hump" portion of the chromatogram is not measured routinely by the GC/FID method. If measured, it would result in a value much closer to the 60,000 ppm value as reported by the infrared method.

A. Trends in Variation of Field Data

In general, two factors affect variation of field analytical data. These include: 1) the representativeness of sampling locations with regard to contaminant distribution, and 2) variability in soil sampling and analytical procedures. The lack of representativeness among sampling locations is generally the most significant contributor to variations in field data. In this case, and with landfarming in general, it can be expected that continuous tilling and soil mixing will aid uniformity of analytical data.

The variability of sampling and analytical results is illustrated in Figure 4. The data consist of total area counts recorded from GC/FID analyses of five separate soil samples analyzed per sampling event. (Each sample is a composite of five subsamples.) The sampling events shown in Figure 4 span a time frame of two and one-half months. The data show that with time, differences between individual samples, obtained for a single sampling event, decrease. These analytical results demonstrate that continuous tilling and mixing of soil cause the site to become more homogeneous with respect to contaminant distribution.

B. Changes in Petroleum Composition over Time

Figure 5 shows the changes in total hydrocarbons as measured by GC/FID over a period of 280 days. The data for each sampling event were obtained by averaging the values obtained for all five individual samples. The GC data show a steady decline from 9,000 ppm at the first sampling event to 1,700 ppm after six months of active bioremediation, a reduction of 81%. Petroleum as measured by TPH/IR decreased by 70% in the same period (Figure 6).

The biodegradation of individual indicator chemicals present in petroleum containing soil during the active period of bioremediation is shown in Figure 7. The results show a preferential pattern of biodegradation that can be explained on the basis of molecular weight. Thus, methyl naphthalene, a C-11 compound (a chemical containing 11 carbons), is seen to be 90% biodegraded within 30 days whereas C-14 alkane required 60 days for 90% percent degradation. Nearly 120 days are required to achieve 90% biodegradation of pristane, a C-19 branched chain alkane.

At the end of 180 days of active treatment, the site soil no longer showed visual or olfactory evidence of contamination. A decision was made by FP&L to cease active treatment but to continue periodically monitoring of the soil levels of petroleum constituents with time.

VII. RESULTS OF POST-REMEDIATION MONITORING

Soils were sampled periodically over a three-year period and analyzed for petroleum constituents. Table 4 summarizes chemical residue data obtained during both active remediation and post-remediation periods. The results show in the case of TPH-IR, a 60% reduction achieved during six months of active bioremediation. In the absence of tilling, biodegradation (as measured by TPH-IR) continued, reaching 83% removal in three years. It can be seen that when petroleum contaminants are measured in terms of GC/FID, 81% is biodegraded in six months of active tilling. An additional 15% is biodegraded during two and one-half years of passive bioremediation (no tilling). Over 99% of polynuclear aromatic hydrocarbons also biodegraded in the three-year period.

The changes in concentration with time for individual PAHs during field bioremediation is shown in Table 5. All data is based on GC/MS analysis of composited samples. The results show that all 2- and 3-ring PAHs were degraded to nondetect by Day 280. The higher ring PAHs such as pyrene and benzo-a-pyrene continued to degrade over a three-year time period.

Figure 8 shows GC fingerprints from three time periods. Figure 8-A is a "fingerprint" of petroleum extracted from soil at zero time. Figure 8-B is the fingerprint of soil after six months of active bioremediation. Figure 8-C is the fingerprint of soil sampled at approximately three years after start of bioremediation. The dramatic change in the fingerprints indicates extensive destruction of No. 6 fuel constituents.

VIII. DISCUSSION

The spill and subsequent bioremediation effort described herein provided a unique opportunity to document the rate and extent of biodegradation under field conditions. Continued sampling after the period of active bioremediation provided an additional opportunity to document in-situ biodegradation.

The results presented in Figure 4 show that after one month of tilling, soil subsamples taken from five different areas of the site varied from the mean by no more than $\pm 20\%$. One practical results of a well-mixed remediation site is that few samples need to be analyzed in order to document changes with time. In this case, only one composited sample is necessary to provide adequate representativeness after two months of tilling. A second noteworthy feature of this site's uniform distribution of contaminants was that soil bacteria were able to biodegrade similar chemical constituents of petroleum at the same time over the entire site. Thus it was possible to observe under field conditions the phenomenon of preferential utilization or biodegradation, usually only seen under laboratory conditions (Figure 7). The sequential biodegradation of PAHs and alkanes is a result of bacterial preference to biodegrade first the most readily available chemicals (i.e., the most water soluble).[1] Volatilization as an explanation for chemical disappearance under 50 days was ruled out on the basis of the killed control date (Figure 2).

Results obtained in this field remediation project also document the biodegradation of PAHs (Table 5). Particularly interesting is the fate of the higher ring PAHs. Our results show convincingly that 4-, 5-, and 6-ring PAHs degrade significantly under field conditions. For example, benzo-a-pyrene degraded significantly (67%) within one year and to 83% of its original value by the third year. To our knowledge, few if any remediation show similar documented data has been as thoroughly documented.[3] Abiotic processes such as irreversible binding of higher ring PAH may also have played a role in the observed reductions.

Data taken from this site over a period of three years provide insight into the biodegradation process under both tilling and non-tilling conditions. Biodegradation was more rapid when the soil was mechanically mixed than under non-mixed conditions. A quantitative basis for this observation is presented in Table 4 which compares the half-life of different petroleum constituents under active (tilled) and passive (non-tilled) conditions. It can be seen that No. 6 constituents (when measured by GC/FID) have a half-life of 60 days during bioremediation (active/tilling) versus more than 400 days under passive conditions. Similar differences are found when TPH-IR is used as the quantitative measure of petroleum in soil. The data in Table 4 also show that individual chemicals such as C-11 alkanes and PAHs have half-lives as low as 20 days under active bioremediation. Oxygen limitation is the likely explanation for the long half-life under the non-tilled condition.

Although the biodegradation rate is slow under non-tilled conditions, it is noteworthy that biodegradation continued long after active tilling had ceased. Our data support the idea that after a period of active tilling, and when mineral nutrients and carbon sources are available, the biodegradation process will continue for a period of years in a measurable way.

An important issue revealed by this study is the significant difference observed between the GC "fingerprint" method and the TPH-IR method. The fingerprint-GC/FID estimation method indicates greater petroleum biodegradation than is evident based on TPH-IR method (96% biodegraded versus 83%). The exact chemical nature of this residual TPH-IR material (10,000 ppm) is unknown but probably is not petroleum. Some of the residual TPH-IR could be of microbiological origin. Since the residual TPH-IR material does not consist of either analyzable alkanes or PAHs, and thus is chemically non-identifiable by conventional environmental analysis, the TPH infrared method should not be used as a critical measure of bioremediation effectiveness, particularly in the case of No. 6 fuel.

In conclusion, we have demonstrated the destruction of a No. 6 fuel in soil over a period of 33 months. Supporting documentation was based on three different analytical methods. The results clearly show that petroleum constituents contained in No. 6 fuel degrade during periods of active bioremediation (tilling) and during a subsequent period in which no tilling occurred. It is likely that biodegradation continued due to the presence of mineral nutrients and an active population of petroleum-degrading bacteria. Finally, our results show that high molecular weight compounds such as polynuclear aromatic hydrocarbons also biodegrade with time.

IX. ACKNOWLEDGEMENTS

The author wishes to recognize the contributions of Maureen Leahy, Margaret Findlay, and Elizabeth Byrne Dawes.

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3. Sims, J., R. Sims, and J. Mathews. "Bioremediation of Contaminated Surface Soils," EPA 600/9-89/073 (1989), pp. 12-18.

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TABLE 1

ANALYTICAL METHODS

Extraction Procedure				
EPA Method	**Method**	**Solvent: Soil**	**Solvent**	**Detector**
418.1 (Modified)	2 Extractions Shake in Sealed Container	10:1	Freon	IR
SW 846-8100 (Modified)	1 Extraction Shake in Sealed Container	10:1	DCM: Acetone (1:1)	FID
SW 846-8270	Soxlet Extraction	10:1	DCM	MS

TABLE 2

TREATMENT SIMULATION CONDITIONS

1. No Mineral Nutrients (Live Control)
2. Mercuric Chloride (Killed Control)
3. Mercuric Chloride (Killed Control, Duplicate)
4. Nutrients 2000 ppm N & P
5. Nutrients 500 ppm N & P
6. Nutrients 2000 ppm N
7. Nutrients 2000 ppm N + Added Site Bacteria
8. Nutrients 2000 ppm N + Texture Modification
9. Nutrients 2000 ppm N + Extra Moisture

TABLE 3

CHEMICAL COMPOSITION OF PETROLEUM EXTRACTED FROM SOIL

COMPOUND	CONCENTRATION (mg/kg)
m/p-xylene	7
Trimethylbenzene	8
C-10 (alkane)	ND
C-11	28
C-12	33
C-13	41
2-CH_3-naphthalene	474
1-CH_3-naphthalene	309
C-14	96
Farnesane	86
C-15	205
C-16	181
C-17	158
Pristane	148
C-18	143
Phytane	50
C-19	154
C-20	150
C-21	128
C-22	115
C-23	105
C-24	88
C-25	61
C-26	59
C-27	43
Sum of Indicators	2,870
Total GC	8,591

TABLE 4

DATA SUMMARY: NO. 6 FUEL FIELD REMEDIATION

PARAMETER	BEFORE REMEDIATION (ppm)	MONTH 6 (ppm)	MONTH 9 (ppm)	MONTH 21 (ppm)	MONTH 33 (ppm)	PERCENT DEGRADED AT MONTH 33
TPH	60,000	23,700	18,800	12,000	10,100	83%
GC/FID	9,050	1,715	820	430	325	96%
Target PAH	2,770	--	70	40	35	99%

Table 5

Degradation of Selected Polycyclic Aromatic Hydrocarbons During Field Remediation

Compound	Before Remediation (ppm)	Month 9 (ppm)	Month 21 (ppm)	Month 33 (ppm)
naphthalene	490	<3	<2	<3
2-methyl-naphthalene	1,400	<3	<2	<3
acenaphthalene	20	<3	<2	<3
fluorene	80	<3	<2	<3
phenanthrene	201	<3	<2	<3
anthracene	40	<3	<2	<3
fluoranthene	70	<3	<2	<3
pyrene	200	10	5	2.3J
benzo(a)anthracene	80	<3	<2	<3
chrysene	80	10	4	2.8J
benzo-b&k-fluoranthene	40	10	3	2.4J
benzo-a-pyrene	60	20	13	10
benzoperylene	<30	20	15	18

TABLE 6

HALF-LIVES OF NO. 6 FUEL CONSTITUENTS IN SOIL UNDER ACTIVE AND PASSIVE BIOREMEDIATION

	Chemical Parameter Half-Life (days)				
	Total GC/FID Response	TPH	C_{10} - C_{14}	PAH Ring No. 3	PAH Ring No. 4+
Active Bioremediation					
Day 0 - 180	60	110	20-40	<280	<280
Passive Bioremediation					
Day 180 - 1,000	>400	450-700	--	--	300

FIGURE CAPTIONS

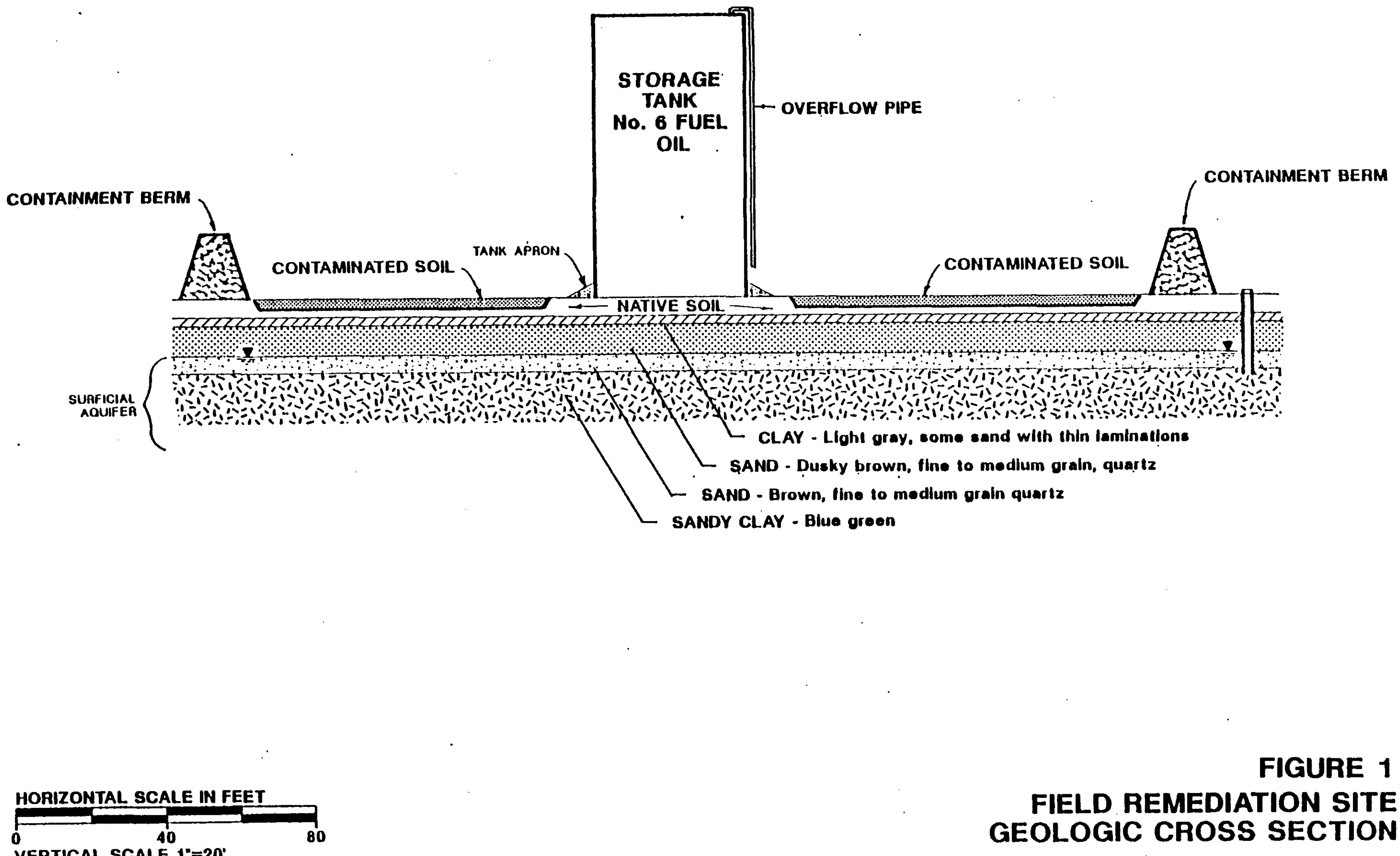


FIGURE 1
FIELD REMEDIATION SITE
GEOLOGIC CROSS SECTION

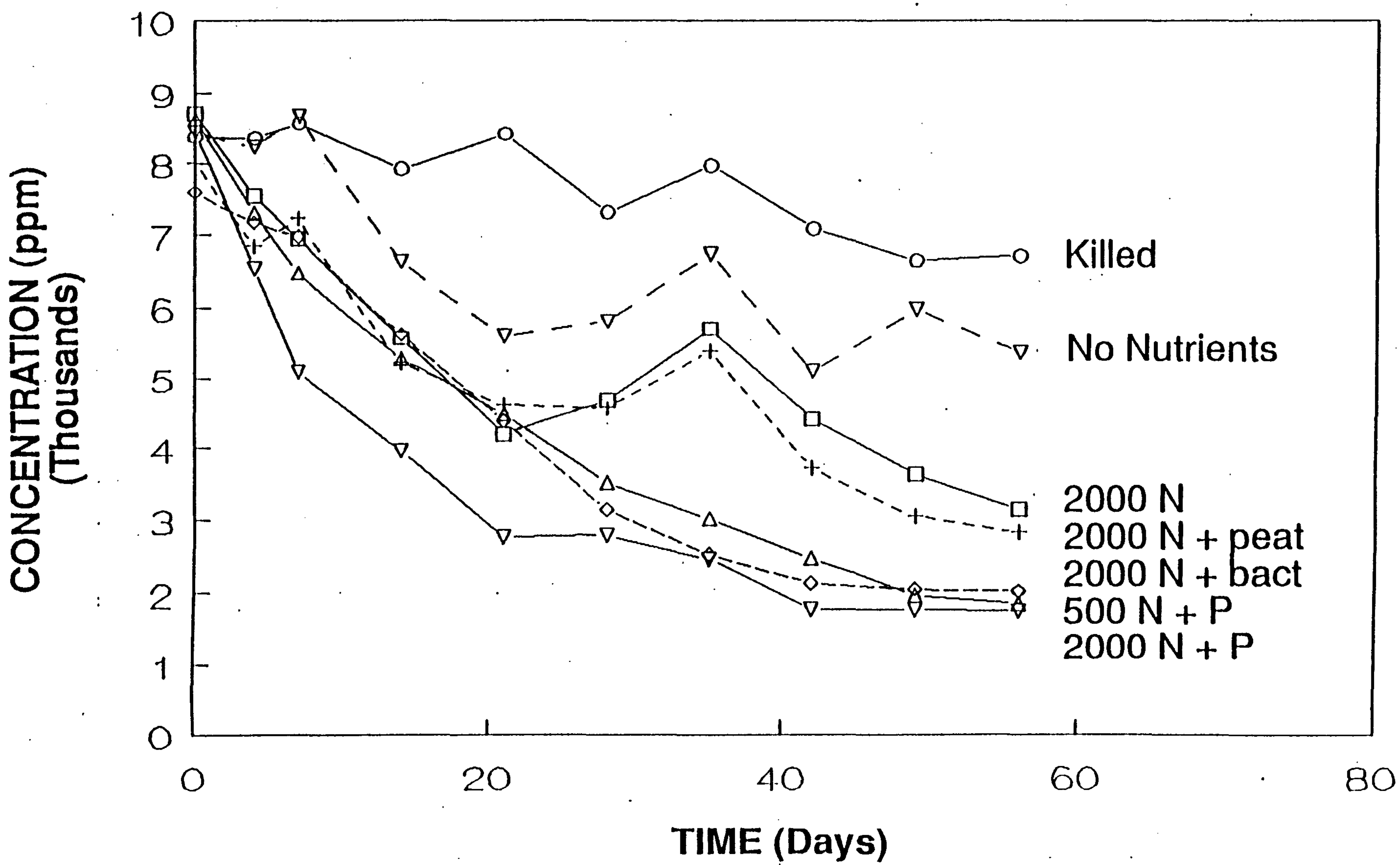
ABB Environmental Services, Inc.

8180-00

FIGURE 2

Land Treatment Simulation

(GC/FID Analyses)



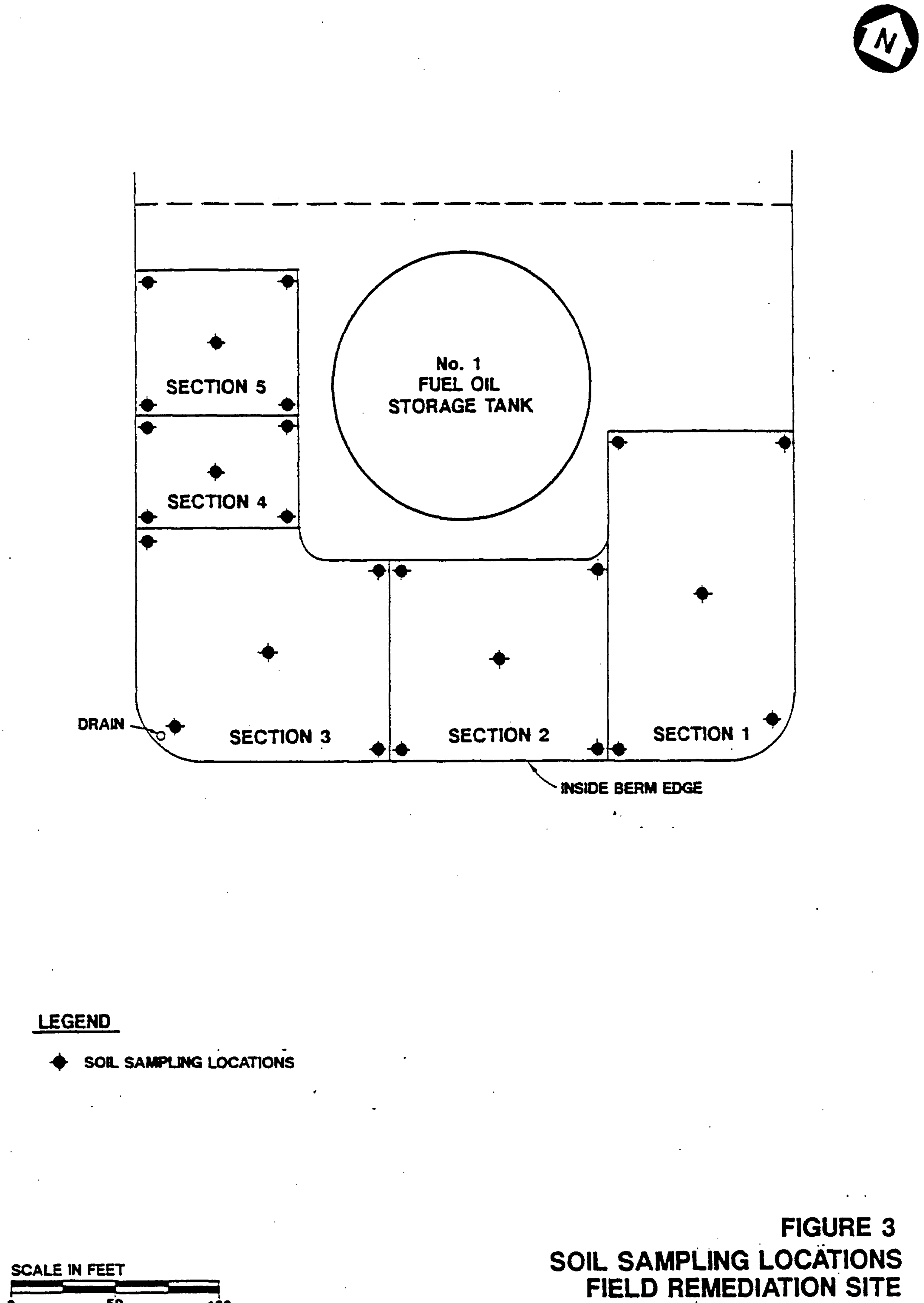


FIGURE 3
SOIL SAMPLING LOCATIONS
FIELD REMEDIATION SITE

ABB Environmental Services, Inc.

8180-00

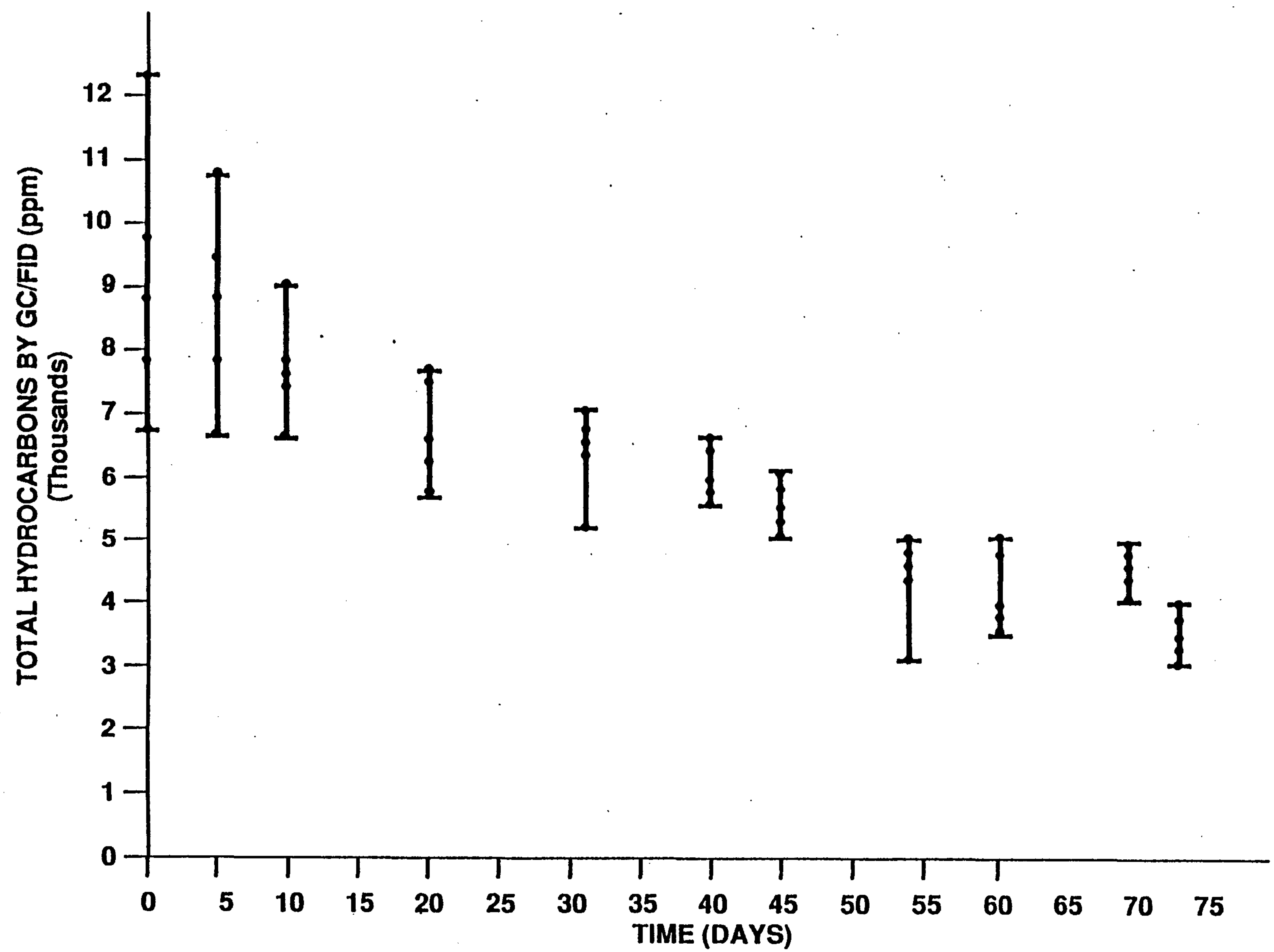


FIGURE 4

TEMPORAL TRENDS VARIATION AMONG SAMPLES

FIGURE 5

Biodegradation of #6 Fuel

Field Remediation Data (GC/FID)

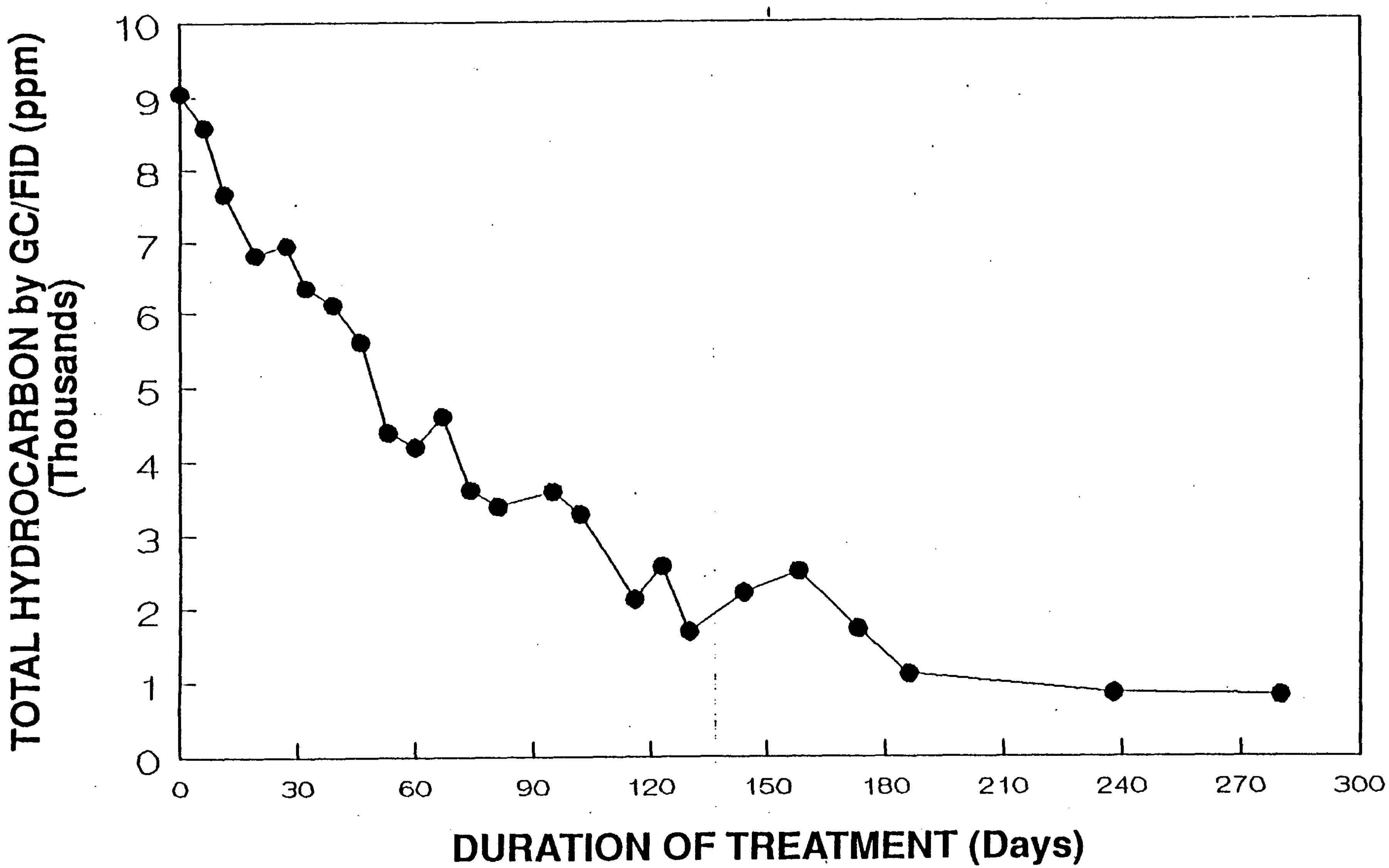


FIGURE 6

Biodegradation of #6 Fuel

Field Remediation Data (TPH)

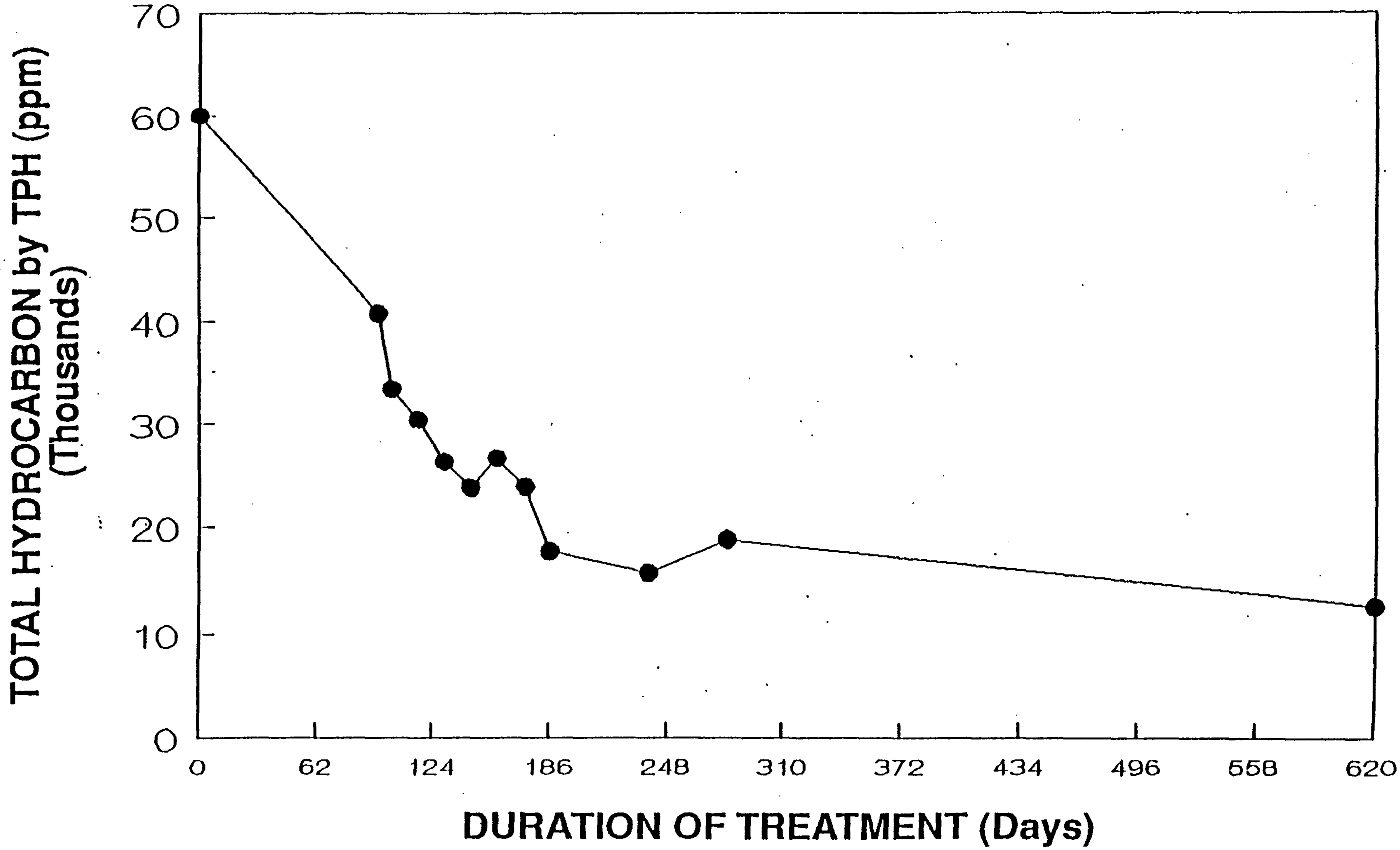


FIGURE 7

PREFERENTIAL BIODEGRADATION OF INDICATOR COMPOUNDS

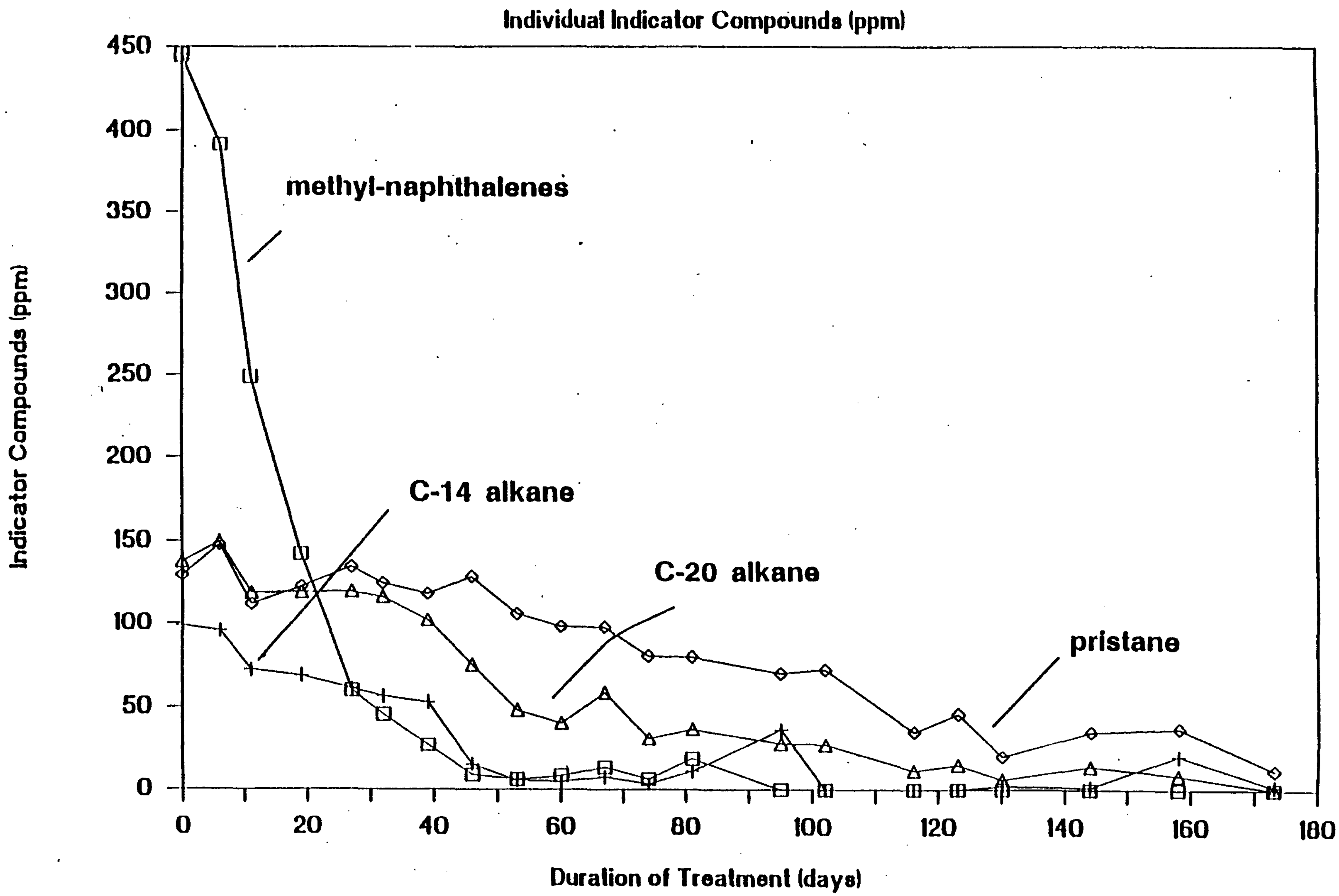


FIGURE 8

GC FINGERPRINTS OF A No. 6 FUEL SPILL

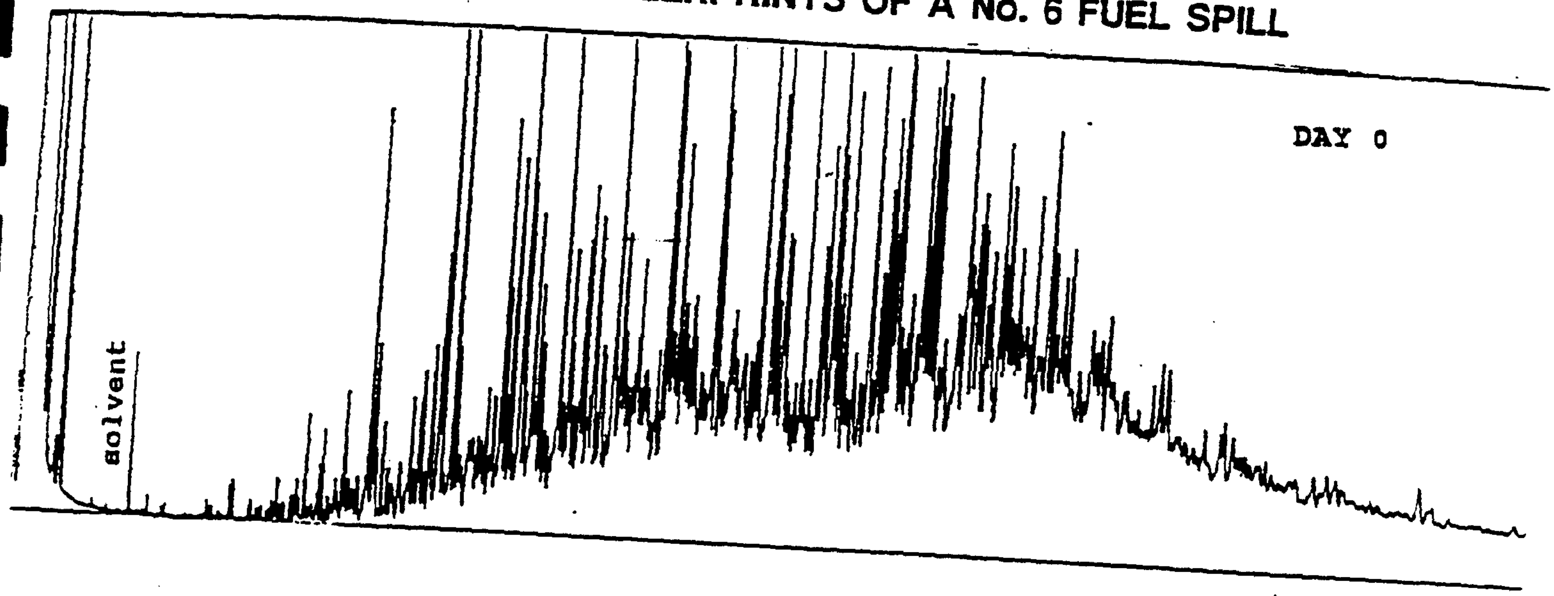


FIGURE 8-A

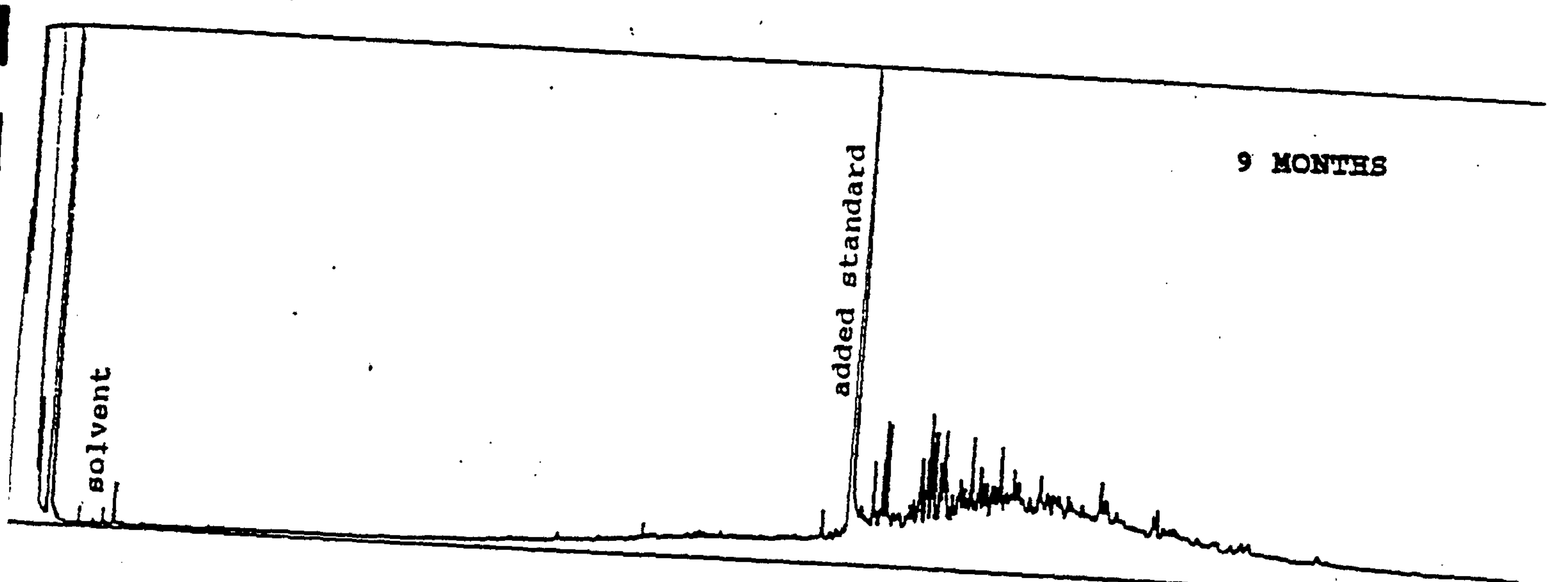


FIGURE 8-B

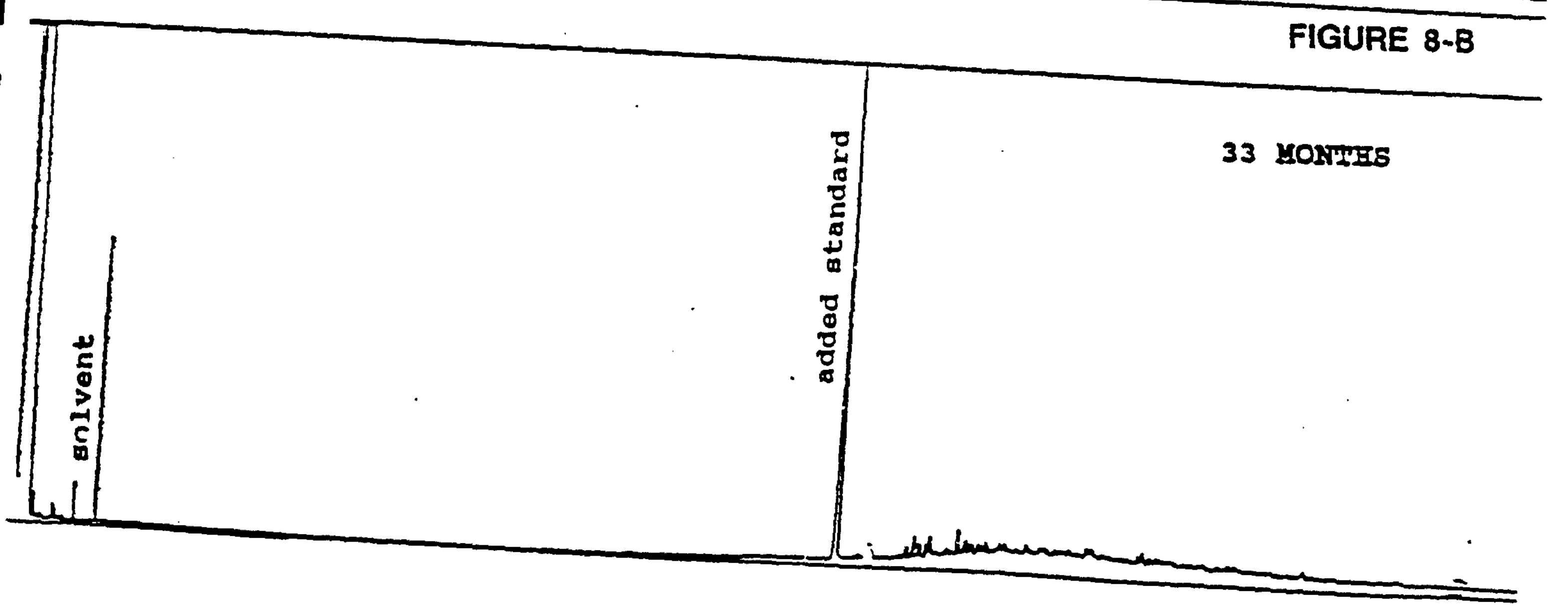


FIGURE 8-C