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U.S. Army Environmental Center

Phase II Site Investigations Report Volume I of III General Annex-Wide Information

Fort Devens Sudbury Training Annex, Massachusetts

September 1994
Contract No. DAAA15-90-D-0012
Delivery Order No. 0004
ELIN A009

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PHASE II SITE INVESTIGATIONS
FORT DEVENS SUDBURY TRAINING ANNEX
MAYNARD, MASSACHUSETTS

VOLUME I OF III
GENERAL INFORMATION

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PREFACE

This is Volume I of a three volume set that comprises the report of the site-specific investigations (SIs) conducted at the Sudbury Training Annex of Fort Devens, Massachusetts. This volume serves to supplement the site-specific reports contained in Volume II by providing procedural and descriptive information common to those sites and thus eliminating the need to repeat this information in each of the reports.

Volume III of this report set includes the appendices which consist of field reports, special studies, and QA/QC results.

TABLE OF CONTENTS

Section			Page
EXECUTIVE SUMMARY			1
1	INTRODUCTION		1-1
	1.1	BACKGROUND AND AUTHORITY	1-4
	1.2	OBJECTIVES	1-5
		1.2.1 Data Requirements	1-6
		1.2.2 Data Quality Objectives	1-6
	1.3	PROJECT APPROACH	1-10
	1.4	PROJECT ORGANIZATION AND RESPONSIBILITY	1-12
		1.4.1 E & E Structure	1-12
		1.4.2 Client Organization	1-12
	1.5	REPORT ORGANIZATION	1-14
2	GENERAL ANNEX CHARACTERISTICS		2-1
	2.1	LOCATION AND GEOGRAPHY	2-1
	2.2	CLIMATE	2-2
	2.3	GEOLOGY	2-5
		2.3.1 Glacial Deposits	2-5
		2.3.2 Bedrock Units	2-5
	2.4	SOILS	2-6
	2.5	HYDROGEOLOGY	2-6
	2.6	SURFACE WATER HYDROLOGY	2-9
	2.7	THE ECOLOGY AT THE ANNEX	2-15
		2.7.1 Wetland Ecosystems	2-19
		2.7.2 Aquatic Ecosystems	2-19
		2.7.3 Terrestrial Ecosystems	2-20
3	GENERAL ANNEX USE HISTORY		3-1
	3.1	SUMMARY CHRONOLOGY OF LAND USE	3-1
	3.2	HISTORIC LAND USE AND OWNERSHIP	3-2
		3.2.1 Early Years of the Maynard Ammunition Sub-Depot (1939 to 1952)	3-2
		3.2.2 Maynard Ordnance Test Station (MOTS) (1952 to 1957)	3-3
		3.2.3 Maynard Quartermaster Test Activity (MAYTAC) (1957 to 1962)	3-3
		3.2.4 Natick Laboratories and the Annex (1962 to 1982)	3-3
		3.2.4.1 Primary Contractors and Users of the Annex	3-4
		3.2.4.2 Special Activities	3-7

Table of Contents (continued)

Section			Page
	3.3	FORT DEVENS SUDBURY TRAINING ANNEX (1982 TO 1994)	3-9
	3.3.1	Continued Natick Use of Annex Land	3-9
	3.3.2	Other Land Use	3-10
4		REVIEW OF PREVIOUS INVESTIGATIONS	4-1
	4.1	INTRODUCTION	4-1
	4.2	PREVIOUS INVESTIGATIONS	4-2
	4.2.1	Site Assessment by USAEC (USATHAMA) (1980)	4-2
	4.2.2	Hydrogeological and Subsurface Investigation by the U.S. AEHA, 1983	4-2
	4.2.3	Remedial Investigation by Dames and Moore for the Army (1986)	4-2
	4.2.4	NUS, Inc., PA and SI of the Annex for EPA Region I	4-3
	4.2.5	Site Investigation of 100-Acre Parcel of Excessed Natick Lab Annex Property by GZA Geoenvironmental, Inc. for the U.S. Army Corps of Engineers (March 1991)	4-3
	4.2.6	Expanded Site Inspection (POL Bladder Testing Area - P48) by Dames and Moore, Inc. (March 1991)	4-4
	4.2.7	Phase I Site, Remedial Investigations by OHM Corporation (July 1993)	4-4
5		FIELD INVESTIGATION AND ANALYTICAL PROCEDURES	5-1
	5.1	FIELD PROCEDURES	5-2
	5.1.1	Geophysical Surveys	5-2
		5.1.1.1 Seismic Surveys	5-2
		5.1.1.2 Ground Penetrating Radar	5-3
		5.1.1.3 Electromagnetic Conductivity Surveys	5-4
		5.1.1.4 Magnetometry Surveys	5-4
	5.1.2	Test Pit Excavation	5-5
	5.1.3	Subsurface Soil Sampling	5-6
	5.1.4	Geotechnical Samples	5-7
	5.1.5	Surface Soil Sampling	5-7
	5.1.6	Field Screening	5-8
	5.1.7	Monitoring Well Installation	5-8
	5.1.8	Monitoring Well Development	5-9
	5.1.9	Groundwater Sampling	5-10
	5.1.10	Surface Water and Sediment Sampling	5-13
	5.1.11	Bioaccumulation Study of Puffer Pond and Ministers Pond	5-15
	5.1.12	Hydrogeologic Assessment	5-15

Table of Contents (continued)

Section				Page
			5.1.12.1 Hydraulic Conductivity Slug Testing	5-15
			5.1.12.2 Groundwater Elevations and Well Location Survey	5-16
			5.1.12.3 Groundwater Modeling	5-16
		5.1.13	Procedures for Ecological Characterization	5-17
		5.1.14	Control and Disposal of Investigation-Derived Wastes	5-20
			5.1.14.1 Screening Procedures	5-20
			5.1.14.2 Material Handling	5-21
			5.1.14.3 Waste Classification Analysis	5-21
			5.1.14.4 Waste Minimization	5-21
		5.1.15	Sample Collection, Preservation, and Handling	5-22
		5.1.16	Decontamination Program	5-23
	5.2		ANALYTICAL PROGRAM	5-24
		5.2.1	Methods, Analytes, and Detection Limits	5-24
		5.2.2	Quality Control Program	5-24
			5.2.2.1 Field QC Samples	5-24
			5.2.2.2 Laboratory Quality Procedures	5-25
	5.3		DATA MANAGEMENT PROGRAM	5-26
		5.3.1	Database Management	5-26
		5.3.2	Data Reduction and Reporting	5-28
		5.3.3	Analytical Data Review	5-28
	5.4		HEALTH AND SAFETY PLAN FIELD PROCEDURES	5-31
		5.4.1	Health and Safety Plan	5-31
		5.4.2	Health and Safety Plan Field Procedures	5-31
6			FACILITY-WIDE INVESTIGATIONS	6-1
	6.1		WATERSHED APPROACH TO ANNEX INVESTIGATIONS	6-1
	6.2		E & E BACKGROUND	6-4
		6.2.1	Background Surface Soil Sampling Locations	6-4
		6.2.2	Background Surface Water and Sediment Sampling	6-7
		6.2.3	Background Pond Surface Water and Sediment Sampling	6-11
7			PRELIMINARY SCREENING METHODOLOGY FOR SITE INVESTIGATIONS	7-1
	7.1		METHODOLOGY	7-1
	7.2		HUMAN HEALTH PRELIMINARY SCREENING	7-2
		7.2.1	Groundwater Criteria for Human Health Preliminary Screening	7-2
			7.2.1.1 Draft Applicable Requirements for Cleanup of Groundwater	7-3

Table of Contents (continued)

Section — Page

7.2.1.2 Draft Relevant and Appropriate Requirements for Cleanup of Groundwater 7-4
7.2.1.3 Draft TBC Guidance for Cleanup of Groundwater 7-4
7.2.2 Soil Criteria for Human Health Screening 7-5
7.2.3 Surface Water Criteria for Human Health Screening 7-6
7.2.4 Sediment Criteria for Human Health Screening 7-7
7.3 ECOLOGICAL PRELIMINARY SCREENING 7-7
7.3.1 Surface Water Criteria for Ecological Screening . . . 7-7
7.3.2 Sediment Criteria for Ecological Screening 7-8

8 CONCLUSIONS AND RECOMMENDATIONS 8-1
8.1 GENERAL ANNEX-WIDE CONCLUSIONS 8-1
8.2 RECOMMENDATIONS 8-3

9 REFERENCES 9-1

Appendix — Page

A BORE LOGS A-1
B WELL CONSTRUCTION LOGS B-1
C TEST PIT LOGS C-1
D GEOTECHNICAL DATA D-1
E GEOPHYSICAL SURVEYS E-1
F ANALYSIS OF QA/QC PROGRAM F-1
G AQUIFER HYDRAULIC CHARACTERIZATION (SLUG TESTING) . G-1
H GROUNDWATER MODEL REPORT H-1
I APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS) I-1
J SUDBURY BACKGROUND DATA J-1
K ECOLOGICAL INVESTIGATION FIELD FORMS K-1
L RAPID BIOASSESSMENT REPORT L-1
M IRDMIS LEVEL 3 DATA M-1
N LEGEND OF GROUND FEATURES N-1
O WATER QUALITY PARAMETERS O-1
P WATER LEVEL MEASUREMENTS AND GROUNDWATER ELEVATION DATA P-1

LIST OF TABLES

Table		Page
ES-1	Summary of Recommendations	3
1-1	Consecutive Listing of Sudbury Annex Sites and Concerns Identified Prior to Phase II Investigations for Delivery Order No. 0004	1-3
1-2	EPA General Levels of Analytical Data Quality	1-8
2-1	Birds that are Likely to Occur at the Sudbury Annex, Massachusetts	2-22
2-2	Mammal Species Likely to Occur at the Sudbury Annex, Massachusetts	2-25
2-3	Amphibians and Reptiles That are Likely to Occur Within Sudbury Annex, Massachusetts	2-26
2-4	Common Plant Species Identified at the Sudbury Annex, Massachusetts	2-27
2-5	Species of Concern Known to Occur at the Sudbury Annex, Massachusetts	2-30
3-1	USAF Leases	3-5
3-2	Raytheon Leases	3-6
3-3	Police and National Guard Leases	3-8
6-1	Background Soil Samples Maximum Analyte Concentrations	6-8
6-2	Background Stream Samples Maximum Analyte Concentrations	6-12
6-3	Background Pond Samples (Minister's Pond) Maximum Analyte Concentrations	6-14
7-1	Groundwater Values for Human Health Screening	7-11
7-2	Soil Values for Human Health Screening	7-15
7-3	Surface Water Values for Human Health Screening	7-19

List of Tables (continued)

Table		Page
7-4	Other Comparison Values for Human Health Screening	7-20
7-5	Surface Water Values for Ecological Screening	7-23
7-6	Sediment Values for Ecological Screening	7-25
7-7	Other Sediment Comparison Values for Ecological Screening	7-27
8-1	Recommended Status of Sites and Proposed Actions	8-6

LIST OF FIGURES

Figure		Page
1-1	Location of Fort Devens Sudbury Training Annex in Massachusetts	1-2
1-2	Project Organization	1-13
2-1	Surface Geology at the Annex	2-3
2-2	Bedrock Geology at the Annex	2-7
2-3	Wetland Types at the Sudbury Annex	2-11
2-4	Surface Water Drainage Pattern at the Sudbury Annex	2-13
2-5	Vegetation Cover Types at the Sudbury Annex	2-17
6-1	Background Soil, Stream Sediment, and Stream Water Sample Locations at the Sudbury Annex	6-5
Plate 1	Sites at the Sudbury Annex	
Plate 2	Monitoring Well and Staff Gauge Locations at the Sudbury Annex	
Plate 3	Site-Wide Interpretation of Groundwater Contours	
Plate 4	Surface Water, Sediment, and RBA Sample Locations at the Sudbury Annex	

LIST OF ACRONYMS

AA	Atomic Absorption
AEHA	U.S. Army Environmental Hygiene Agency
AMSL	Above Mean Sea Level
ARARs	Applicable or Relevant and Appropriate Requirements
ARIEM	Army Research Institute of Environmental Medicine
AST	Aboveground Storage Tank
AWQC	Ambient Water Quality Criteria
BGS	Below ground surface
BNAs	Base/neutral/acid extractables
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAA	Clean Air Act
CEMEL	Clothing Equipment Material Engineering Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFHA	Capehart Family Housing Area
CLP	Contract Laboratory Program
CWA	Clean Water Act
cm/sec	Centimeters per second
DDD	dichlorodiphenyldichloroethane
DDE	dichlotodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEC	Digital Equipment Corporation
DERP	Defense Environmental Restoration Program
DoD	U.S. Department of Defense
DQOs	Data Quality Objectives
E & E	Ecology and Environment, Inc.
EM	Electromagnetics
EPA	U.S. Environmental Protection Agency
EMO	Environmental Management Office (Fort Devens)
ERL	Effects-Range Low
ERM	Effects-Range Median
FEL	Food Experiment Laboratories (Natick Laboratories)
FEMA	Federal Emergency Management Agency
FIT	Field Investigation Team
FORSCOM	U.S. Army Forces Command
FS	Feasibility Study
GC	Gas Chromatography
gpm	Gallons per minute
GPR	Ground Penetrating Radar
GW	Groundwater
GZA	Goldberg Zoino and Associates

HEPA	High-efficiency particulate air
ID	Inside diameter
IRDMIS	Installation Restoration Data Management Information System
IRP	Installation Restoration Program
LEL	Lowest observed Effect Level
LFS	Leupold Forestry Service
MADEQE	Massachusetts Department of Environmental Quality and Engineering
MA/CWA	Massachusetts/Clean Water Act
MA SMCL	Massachusetts Secondary Maximum Contaminant Level
MBSA	Maynard Back-up Storage Area
MCL	Maximum Contaminant Level
MCLs	Maximum Contaminant Levels
MCLGs	Maximum Contaminant Level Goals
MCP	Massachusetts Contingency Plan
MDEP	Massachusetts Department of Environmental Protection
MA DEQE	Massachusetts Department of Environmental Quality and Engineering
MEP	Master Environmental Plan
MFFA	Massachusetts Fire Fighting Academy
MMCL	Massachusetts Maximum Contaminant Level
MOE	Ontario Ministry of the Environment
MOTS	Maynard Ordnance Test Station
MREs	Meals Ready to Eat
MS/MSD	Matrix spike/Matrix spike Duplicates
µg/g	Micrograms per gram
µg/L	Micrograms per liter
NARADCOM	U.S. Army Natick Research and Development Command
NCO	Non-Commissioned Officer
NDIR	Non-Disperse Infra-Red Spectroscopy
NFA	No Further Action
NFADD	No Further Action Decision Document
NHESP	Natural Heritage and Endangered Species Program (Massachusetts)
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NTU	Nephelometric Turbidity Unit
NYSDEC	New York State Department of Environmental Conservation
OHM	OHM Remediation Services Corporation, A Subsidiary of OHM Corporation
OVA	Organic Vapor Analyzer
PAH	Polynuclear Aromatic Hydrocarbons or Polycyclic Aromatic Hydrocarbons
PARCC	Precision, accuracy, representativeness, capability, and completeness
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene or Perchloroethene
PHC	Petroleum hydrocarbons
PID	Photoionization Detector
POLs	Petroleum, Oil, or Lubricants
PRP	Potentially responsible party

QA	Quality Assurance
QAPjP	Quality Assurance Project Plan
QC	Quality Control
RAS	Routine Analytical Services
RBA II	Rapid Bioassessment Protocol II
RBC	Risk-Based Concentration
RI	Remedial Investigation
RPD	Relative percent difference
S	Soil
SAS	Special Analytical Services
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SED	Sediment
SI	Site Investigation
SM	Scanner Magnetrometric
SMCL	Secondary Maximum Contaminant Level
SOW	Scope of Work
SQC	Sediment Quality Criteria
SSI	Supplemental Site Investigation
TAL	Target Analyte List
TCL	Target Compound List
TEPS	Total Environmental Program Support
TIC	Tentatively Identified Compound
TOC	Total Organic Carbon
TPHC	Total Petroleum Hydrocarbons
TRC	Technical Review Committee
TSS	Total Suspended Solids
USAEC	United States Army Environmental Center
USATHAMA	United States Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USDOI	United States Department of the Interior
USGS	United States Geological Survey
UST	Underground Storage Tank
UXO	Unexploded ordnance
VOC	Volatile Organic Compound
WQC	Water Quality Criteria

EXECUTIVE SUMMARY

Site Investigations (SIs) at Fort Devens Sudbury Training Annex (the Annex), Massachusetts, were performed by Ecology and Environment, Inc. (E & E) for the United States Army Environmental Center (USAEC) under Total Environmental Program Support (TEPS) Contract No. DAAA15-90-D-0012, Delivery Order No. 0004. Volume II describes all of the 38 sites assigned to E & E in the second phase of activity at the Annex using a watershed approach where each of the sites are grouped based upon their surface water and groundwater drainage characteristics and locations within one of six watersheds at the Annex. As described in Volume I (General Volume) of this report set, the SIs were conducted in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as directed under the Federal Facility Agreement between the United States Army and the United States Environmental Protection Agency (EPA). Volume III contains the appendices which present field notes, drilling logs, geotechnical data, geophysical investigation summaries, analytical qualification results, ecological investigation results, and other data produced during the SIs.

Thirty-eight sites were assigned to E & E in the second phase of activities at the Annex. A total of 31 SIs were conducted (Sites A8/P10 and P31/P58, were combined for SIs because of their proximity to each other). Two Remedial Investigations (RIs), involving five sites at the Annex (Sites P11/P13, and P36/A12/P37, respectively), are currently underway. Conclusions regarding these RI sites will be made when the RIs are complete. Information on these sites is presented in this report to help in watershed-wide assessments.

Results of the 31 SIs (at 33 sites) indicate that the status of each site falls into one of the following five categories: (1) No Further Action (NFA), 12 sites; (2) Further action pending results of other investigations at related areas at the Annex, 4 sites; (3) Further action such as removal of debris and limited amounts of contaminated soil, followed by confirmatory testing, 5 sites; or (4) Supplemental SIs, 12 sites.

Twelve sites showed no contaminant levels at concentrations that pose a threat to human health or the environment. It is recommended that NFA Decision Documents (NFADDs) be initiated for the following sites: A6, A8/P10, P3, P26, P40, P42, P43A/P43B, P48, P52, P56, and P57. (Sites A8 and P10 are counted as two individual sites; Site P43A/P43B is one site.)

Site A11 is one of the four sites that is recommended for further action, pending investigations at other sites. In sampling of Marlboro Brook near Site A11, elevated concentrations of metals were found in surface water and sediment, but sampling of groundwater and soil at the site did not establish any relation of the Marlboro Brook results to these sites. Further investigation of Marlboro Brook has been recommended in relation to Sites P28 and P38. These investigations may establish that there is no connection between

Site A11 and the contaminants in Marlboro Brook, in which case there would be no further need for action at Site A11.

Three sites (A10, P1, and P6) are recommended for further action pending arsenic investigations at other sites at the Annex. Sampling results at the sites indicated some low levels of arsenic in soils. The potential risk at these three sites to human health or the environment is likely to be low given the relatively limited extent of low-level arsenic in soils. However, the exact source of the arsenic at these sites has not been identified. Further investigation at ten other sites at the Annex, where arsenic has been identified, as a concern has been recommended. If a site-related source is identified through those investigations, then further action may be necessary at these three sites.

Five sites at the Annex (A1, A2, P2, P22, P39) contain debris and/or limited soil contamination. No widespread contamination has been found at these sites. However, it is recommended that further action, including consideration of limited removal actions, be taken regarding these sites.

Further action, in the form of Supplemental Site Investigations (SSIs) is recommended regarding arsenic at 10 sites: P9, P16, P23, P27, P28, P31/58, P38, P45, and P54. Overall sampling results indicate that arsenic contamination may be a facility-wide concern that requires further field investigations. Although naturally high arsenic levels are common in the northeast region of the United States, sampling results indicate that additional arsenic sources are present at the Annex and may be due to past site-specific activities. Some of these sites also have concerns other than arsenic including: lead and TPHC at Site P23; and lead and other metals at Site P31/P58. Removal actions in conjunction with the SSIs are suggested regarding the arsenic, lead, and TPHC in soils at Site P23, and regarding arsenic in soils at Site P45.

SSIs are also recommended for 2 other sites, A5, and P41, where arsenic is not a concern. Site A5 is recommended for continued monitoring due to the detection of PCE in concentrations slightly above drinking water standards in two rounds of groundwater sampling in one well at the site. P41 is recommended for an SSI due to the presence of elevated levels of DDT and its degradation products.

It is recommended that the two sites located off Sudbury Road near Boons Pond and Hallocks Point (Sites P31 and P58) be combined into one SSI for further action. Elevated metals concentrations were found in the groundwater, surface water, and sediments at Sites P31 and P58 at levels which require further investigations. An SSI is recommended to characterize the impact past dumping has had on the groundwater, surface water, and sediments near the sites and the potential risks to human health and the environment. Further investigation should include the sampling of off-site private drinking wells near the site to identify if any migration of contaminants off site may have occurred.

The following table (Table ES-1) provides a summary of the current status of all 38 sites based upon the recommendations presented in Volume II. The sites are listed in alphanumeric order with any contaminant(s) of concern which may be present at each site.

Table ES-1

SUMMARY OF RECOMMENDATIONS

Site	Site Name	Watershed	Recommended Status	Contaminant(s) of Concern
A1	Decontaminated Mustard Area	1B	Further action (removal)	Lead at drum location
A2	Demolition Ground I	1B	Further action (removal)	Metals, explosives in soil
A5	Solvent/Waste Dump	5	SSI continued monitoring	PCE in groundwater
A6	Demolition Ground II	4	NFADD	None
A8	Food Burial Area	3	NFADD	None
A10	Railroad Pit/UST Area	2	Further action, pending arsenic studies	Arsenic in surface soil
A11	Leach Field	2	Further action, pending study of Marlboro Brook (as part of P28/P38 SSI)	Metals in sediment and surface water in Marlboro Brook
A12	PCB Spill Remediation Area	2	RI combined with P36/P37 currently underway	PCBs in soil
P1	UST Across Road from Building 223	6	Further action, pending arsenic studies	Arsenic in subsurface soil
P2	Building T267 Fuel Spills	6	Further action (removal)	Pesticides in soils
P3	Building T209 UST	6	NFADD	None
P6	Puffer Pond Dump Area	1A	Further action pending arsenic studies	Arsenic in soil
P9	Stream Dump Near A7 & A9	3	SSI	Arsenic in soil
P10	Confidence Course Dump Area	3	NFADD	None
P11	Building T405 Dump Area	2	RI, combined with P13, currently underway	Lead in surface water and sediment
P13	Massachusetts Fire Fighting Academy	2	RI, combined with P11, currently underway	Metals in surface water and sediment
P16	Chemical and Waste Storage Bunkers: 302, 306, 309	1A	SSI	Arsenic in soil
P22	Old Gravel Pit	4	Further action (removal)	Limited PAHs in soil
P23	Building T465 (Drums)	1B	SSI with removal	TPHC, lead in soil
P26	Taylor Drop Zone	1B	NFADD	None
P27	Pyrotechnics Testing Area	1A	SSI	Arsenic in soil and possibly other media
P28	Rocket Range/Railroad Classification Yard	2	SSI with P38	Arsenic in soils, surface water, sediment and possibly groundwater
P31	Sudbury Road Dump	5	SSI, combined with P58	Arsenic, lead, other metals in groundwater, surface water, and sediment
P36	Former Raytheon Building T104	2	RI, combined with A12/P37, currently underway	PCBs around Building T104
P37	Former Raytheon Building T106	2	RI, combined with A12/P36, currently underway	Metals, pesticides in Marlboro Brook

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Table ES-1

SUMMARY OF RECOMMENDATIONS

Site	Site Name	Watershed	Status	Contaminant(s) of Concern
P38	Former Railroad Inspection Pit	2	SSI with P28	Arsenic (see P28)
P39	Dump Area	2	Further action (removal)	Metals from debris
P40	Building T452 Area	5	NFADD	None
P41	Bunker 303-Pesticide/ Herbicide Storage	1A	SSI	Pesticides in soil and possibly groundwater
P42	Off-site Dump	1B	NFADD	None
P43A & P43B	Cleared Areas Distressed Vegetation	1A	NFADD	None
P45	Burned Area by Outside Fence	1B	SSI with removal	Arsenic, at drum, in surface water and sediment
P48	Fuel Bladder Testing Area	2	NFADD	None
P52	Possible Dump near FEMA	1A	NFADD	Arsenic in one soil sample
P54	Bunkers 301, 303, 311, 312, & 318	1A	SSI pending SSI for arsenic at P16	Arsenic in soil and possibly groundwater
P56	Cleared Area South of Bunker 313	1A	NFADD	None
P57	Former Building S449	3	NFADD	None
P58	Sudbury Road Dump	5	SSI - (including off-site well sampling)	Arsenic, lead, other metals in groundwater, surface water, and sediment

Source: Ecology and Environment, Inc. 1994.

1. INTRODUCTION

Under Total Environmental Program Support (TEPS) Contract No. DAAA15-90-D-0012, Delivery Order No. 0004, *Phase II Site Inspection, Remedial Investigation of Sudbury Annex*, the United States Army Environmental Center (USAEC) tasked Ecology and Environment, Inc. (E & E) to perform 31 Site Inspections (SIs) (also known as site investigations) at 33 sites and two SI/Remedial Investigations (SI/RIs) at 5 sites. The 38 sites assigned to E & E in the second phase of activities at the Annex represent a subset of the 70 sites identified or investigated through previous Phase I activities, conducted by OHM Remediation Services Corporation (OHM) at the Annex between 1990 and 1992.

Investigation activities were carried out at the Fort Devens Sudbury Training Annex (the Annex), Massachusetts. Figure 1-1 depicts the location of the Annex in Massachusetts. Table 1-1 lists all of E & E sites, provides their investigation status, and identifies which of the seven watersheds encompasses each site. Plate 1, located in the back pocket of this document, presents all sites in each of the seven watersheds.

Site activities have been conducted in accordance with the Inter-Agency Agreement between the United States Army and the United States Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. In 1990, the Annex was placed on the National Priorities List (NPL), the list of sites to be investigated under CERCLA (Superfund). The EPA analysis of the Annex was based in part on ongoing Army environmental studies under the Defense Environmental Restoration Program.

This report is based on the results of field work E & E conducted from April through December 1993 at the Annex to evaluate the sites assigned under Phase II, and incorporates the results of document searches, interviews, previous and ongoing environmental assessment efforts, and a review of previous studies produced by agencies of the U.S. Army and their contractors at the Annex. E & E evaluated each site based on the results of the current as well as previous investigative activities undertaken to characterize it as a potential contaminant source or as an area affected by contaminant movements. Recommendations are presented for No Further Action (NFA), supplemental site investigation (SSI), removal action, and remedial investigation (RI), according to the conclusions reached during the evaluation.

Volume I of this document presents general information about the Annex, including information on general physical characteristics, historic uses of the Annex while it was government property, previous investigations conducted at the Annex, the type of field work conducted, and the approach used at the Annex as part of this effort. Volume I also includes a discussion of preliminary screening values used in evaluating each site and presents general

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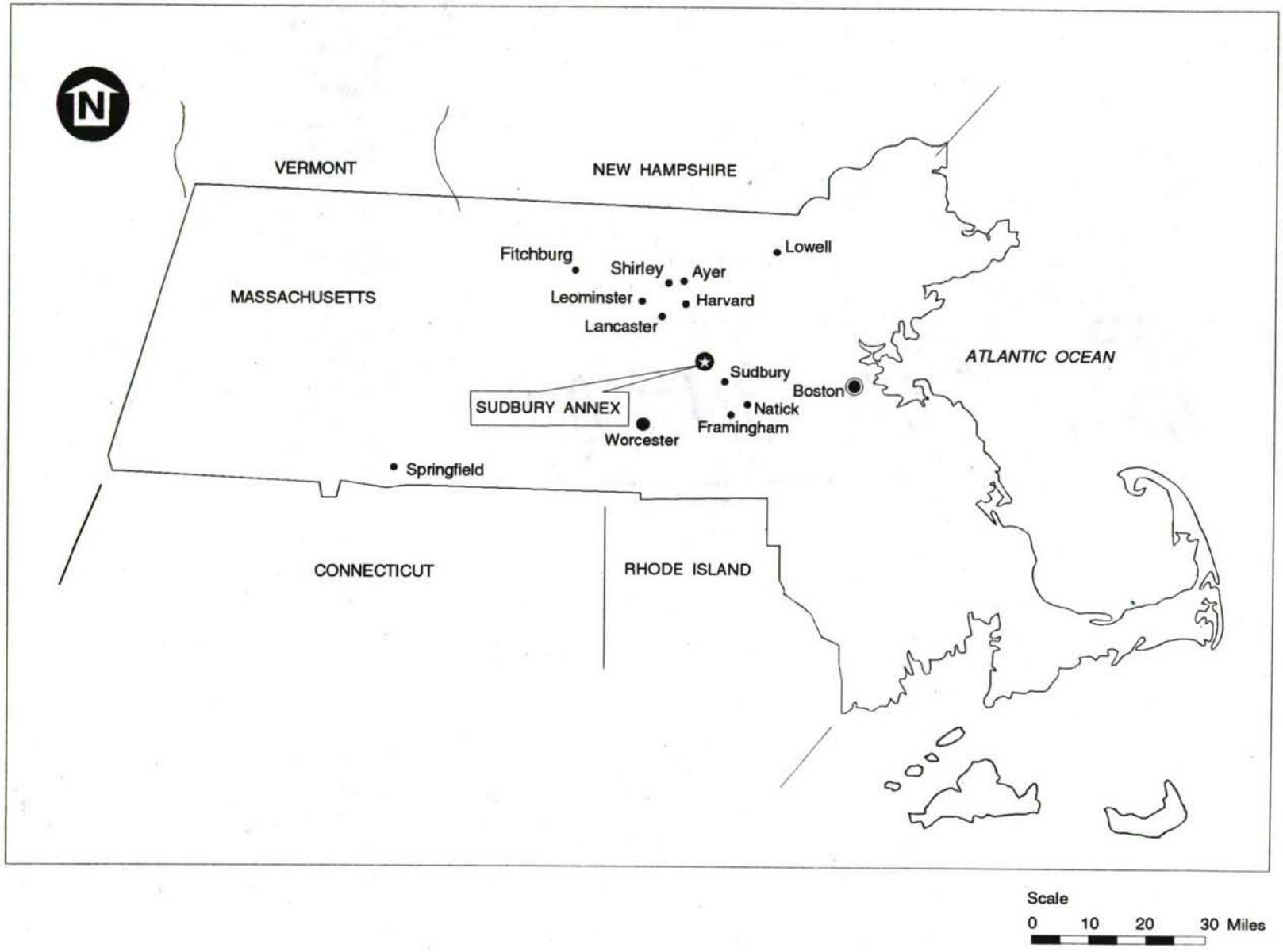


Figure 1-1 LOCATION OF FORT DEVENS SUDBURY TRAINING ANNEX IN MASSACHUSETTS

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Table 1-1

CONSECUTIVE LISTING OF SUDBURY ANNEX SITES AND CONCERNS IDENTIFIED PRIOR TO PHASE II INVESTIGATIONS FOR DELIVERY ORDER NO. 0004

Site	Watershed	Site Name	Activity	Initial Site Concerns
A1	1B	Decontaminated Mustard Burial Area	SI	Metals, PAHs, pesticides
A2	1B	Demolition Ground I	SI	Explosives, metals, pesticides
A5	5	Solvent/Waste Dump	SI	Buried food tins, some pesticides
A6	4	Demolition Ground II	SI	Metals, PCB, DDT
A8	3	Food Burial Area	SI	PAHs, metals, pesticides
A10	2	Railroad Pit/UST Area	SI	Debris, metals, carbon disulfide
A11	2	Leach Field	SI	PCBs, SVOC, DDT
A12	2	PCB Spill Remediation Area	RI	PCBs
P1	6	UST Across from Building T223	SI	POL (UST removed)
P2	6	Building T267 Fuel Spills	SI	Pesticides/PCBs in building; organics, metals
P3	6	Building T209 UST	SI	POL (leaking UST removed)
P6	1A	Puffer Pond Possible Dump Area	SI	Metals, trace explosives, some pesticides
P9	3	Stream Dump Area Between A7, A9	SI	Pesticides in sediment, metals
P10	3	Confidence Course Dump Area	SI	See A8
P11	2	Building T405 Dump Area	RI	Pesticides in GW; exceedances of metals
P13	2	Massachusetts Fire Fighting Academy	RI	DDT, DDE
P16	1A	Chemical and Waste Storage Bunkers	SI	Metals, BNAs, pesticides by doors
P22	4	Old Gravel Pit	SI	Debris, nitroglycerin, metals, organics, residual DDT
P23	1B	Building T465 -- Drums	SI	Metals, PAHs, pesticides, miscellaneous organics
P26	1B	Air Drop Zone Clearing	SI	Debris, drums
P27	1A	Pyrotechnics Test Area	SI	Building debris
P28	2	Rocket Range/Railroad Classification Yard	SI	None
P31	5	Old Dump	SI	Debris, metals, pesticides, PAHs
P36	2	Former Raytheon Building T104	RI	Site activities, PCB
P37	2	Building T106 UST	RI	POL (leaking UST removed)
P38	2	Former Railroad Inspection Pit	SI	Possibility of waste oil
P39	2	Dump Area	SI	Debris, PAHs, pesticides, metals in sediment
P40	5	Building T452	SI	PCE, metals
P41	1A	Bunker 303-Pesticide/Herbicide Storage	SI	DDT around drains
P42	1B	Off-Site Dump	SI	Debris
P43A/B	1A	Disturbed Area/Stained Soils	SI	Human disturbance
P45	1B	Burned Area Outside Fence	SI	Arsenic, potassium
P48	2	Fuel Bladder Area	SI	Buried tank
P52	1A	Possible Dump Near FEMA Property	SI	Construction and scrap metal dump
P54	1A	Bunkers 305, 307, 314	SI	None
P56	1A	Cleared Area East of Bunker 313	SI	Cable, disturbed soil
P57	3	Former Building S449	SI	Possibly fumigants, pesticides
P58	5	Sudbury Road Dump	SI	Debris, possibly metals in sediment

Key: SI = Site Investigation; SI/RI = Site Investigation/Remedial Investigation
Source: Ecology and Environment, Inc. 1994.

conclusions and recommendations for the Annex, as a whole, based on individual site findings.

Volume II presents a site-by-site evaluation. At this stage, SI reports have been prepared for each of the sites, including those recommended for NFA and those sites requiring an RI. The NFA Decision Documents (NFADD) and the RI reports will be issued at a later date.

The third and final Volume consists of all supporting appendices.

1.1 BACKGROUND AND AUTHORITY

The Army assembled the Annex property between 1939 and 1942, at which time it became fully functional as an Army installation. During its history, from 1942 until today, the Annex has had several names and has had multiple uses, including ammunition storage, ordnance research and development, laboratory research, field testing of equipment, railroad operations, troop training, and possible burial and disposal of cloth, food, and chemicals.

In 1978, the Department of Defense (DoD) established the Installation Restoration Program (IRP). Under the IRP, the DoD sought to identify, investigate, and clean up contamination from hazardous substances at Federal facilities. Environmental investigations were started at the Annex in 1980 under the IRP in order to address the potential for environmental impacts from past land uses.

As a first step in the program, the USAEC (formerly USATHAMA--the United States Army Toxic and Hazardous Materials Agency) conducted a preliminary site assessment (PA), which primarily consisted of a detailed records search. The 1980 initial site assessment report indicated that certain portions of the Annex may have been contaminated with the following:

- explosive residues,
- laboratory quantities of chemical wastes,
- petroleum, oil, or lubricants (POLs), and
- other toxic or hazardous materials.

USAEC, in partial fulfillment of the IRP, contracted the services of Dames and Moore of Bethesda, Maryland, to conduct an RI at the Annex. The results were presented in the 1986 *Final Remedial Investigation Report* by Dames and Moore (Dames & Moore 1986).

Prior to final publication of the RI report, the EPA Region I, Waste Management Division, contracted the services of NUS Corporation of Bedford, Massachusetts, to conduct a PA of the Annex under the Superfund Field Investigation Team (FIT) program. The PA included a review of Dames and Moore's final RI report. On the basis of the PA, the EPA instructed FIT to conduct an SI of the Annex.

On January 29, 1987, the Annex became a Federal facility under the jurisdiction, custody, and control of the DoD, within the meaning of Executive Order 12580, 52 Federal

Regulations 2923, and within the meaning of the Defense Environmental Restoration Program (DERP), 10 U.S.C., Section 2701 *et seq*. The Annex is, as a consequence, participating in the DERP. The Master Environmental Plan (MEP), authored by OHM in 1992 (OHM 1992) and updated by E & E in 1993 (E & E 1994a), is consistent with the intent and objectives of the IRP. Annually updated, the MEP is a key element in the attainment of DERP goals.

On May 26, 1987, NUS Corporation completed an SI report on the Annex for EPA Region I. The EPA determined that the Annex should be added to the NPL, and it was included in the EPA NPL Update No. 9 in the July 14, 1989 Federal Register (Federal Register 1989). On February 21, 1990, the Annex was placed on the NPL.

1.2 OBJECTIVES

Delivery requirements for the E & E Phase II SI/RI project were outlined in the Scope of Work (SOW). The sites to be investigated as part of the E & E Phase II effort were selected by the USAEC in an ongoing process that took into account recommendations made by OHM in their *Final Site/Remedial Investigation Report* (OHM 1994) and the results of discussions with the Technical Review Committee (TRC), including the Fort Devens Environmental Management Office (EMO). SIs were carried out on all sites for which additional characterization was recommended to confirm the presence or absence of contaminants of concern. The type of investigation undertaken at each site was tailored according to recommendations and information available on the site and on past practices in the site area. The objective of the site characterization effort was to collect sufficient information on each site to support a recommendation for NFA, additional field activities, a removal action, or an RI/Feasibility Study (FS).

This involved reviewing existing data, evaluating current site conditions, and performing field sampling and analysis. Objectives included:

- describing physical and environmental conditions at the sites;
- determining the nature, extent, and source (as possible) of hazardous substances and/or wastes present at the site;
- defining the geologic and hydrogeologic characteristics of the site that may affect contaminant migration and assess possible migration off-site;
- presenting information on contaminant concentrations, potential migration pathways, methods of contaminant release, sources of hazardous substances (as possible), and data summaries; and,
- comparing analytical data to Federal and State regulatory standards.

1.2.1 Data Requirements

For the Annex project, the intended uses of the data generated through sampling and analysis are to allow for accurate site characterization and to identify exceedances of Applicable or Relevant and Appropriate Requirements (ARARs) or other standards to be considered. These data will be used to determine whether there is a basis for proceeding to the RI/FS process, or for generating an NFADD.

1.2.2 Data Quality Objectives

Data Quality Objectives (DQOs) were developed for the Annex sites to ensure that data collected during the investigation will be of sufficient quality to support decision-making. Site-specific questions such as why data are to be collected, how data will be used, and how much are required were addressed while developing the DQOs. In addition, the required data quality was addressed to indicate the magnitude of error that could be tolerated by the data user. Tables and figures in this section present the results of this evaluation.

This section of the report focuses on the objectives of the investigation while the remaining sections express the capabilities of the sampling and analytical teams. Compromises between DQOs and these capabilities are addressed within the framework of sound fiscal management for the Annex. Overall, the rationale and justification for each data-collection activity, as well as alternative approaches to meeting project objectives, are provided in the work plans and sampling plans.

DQOs are qualitative or quantitative statements developed by the data user to specify the quality of data needed from a particular data collection activity to support specific decisions. DQOs represent the starting point in the design of a given study. The process of developing DQOs helps to identify critical data points and eliminate data points with limited applications, and thereby promote overall fiscal accountability. In addition, the DQO development process matches sampling and analytical capabilities to the data targeted for specific uses and ensures that the quality of the data does not overestimate or underestimate project requirements. The DQO development process is outlined in EPA guidance publication, *Data Quality Objectives for Remedial Response Activities*, EPA/540/G-87/003/4, March 1987 (USEPA 1987).

EPA has identified five general levels of analytical data quality as being potentially applicable to site investigations conducted under the CERCLA. These levels are summarized as follows:

- **Level I - Field Screening:** This level is characterized by the use of portable instruments that can provide real-time data to assist in the optimization of sampling point locations and for health and safety support. Data can be generated regarding the presence or absence of certain contaminants (especially volatiles) at sampling locations.

- **Level II - Field Analysis:** This level is characterized by the use of portable analytical instruments that can be used on site or in mobile laboratories stationed near a site (close-support labs). Depending upon the types of contaminants, sample matrix, and personnel skills, qualitative and quantitative data can be obtained.

- **Level III - Laboratory Analysis:** This level uses methods other than the Contract Laboratory Program (CLP) Routine Analytical Services (RAS). This level is used primarily in support of engineering studies using standard EPA-approved procedures. Some procedures may be equivalent to CLP RAS, without the CLP requirements for documentation.

- **Level IV - CLP RAS:** This level is characterized by rigorous quality assurance/quality control (QA/QC) protocols and documentation, that provide qualitative and quantitative analytical data.

- **Level V - Non-Standard Methods:** This level includes analyses which may require method modification and/or development. CLP Special Analytical Services (SAS) are considered Level V.

For the Annex, field measurements (such as pH, temperature, conductivity, and readings from an organic vapor analyzer (OVA) or HNu photoionization detector (PID) and MSA Model 260 0_2/Explosimeter will constitute Level I field analytical data. More sophisticated instrumentation (such as Photovac 10S 50, QVA in GC mode, X-MET 880) used for on-site analysis of volatiles, metals, etc., will be considered as Level II analytical data supported by more extensive logbook documentation, calibration, and quality control.

Analyses for Target Compound List (TCL) organics, Target Analyte List (TAL) metals, and explosives will be considered approximately equivalent to EPA analytical support Level IV quality data. That is, all data will be generated according to USAEC guidelines, the same level of quality and documentation as Region I CLP protocol. Appendix D contains a detailed discussion of such revisions. Table 1-2 presents a list of various analyses and data uses according to the five levels of analytical data quality described above. Historical USAEC precision and accuracy data will be used as the basis for developing acceptance criteria for assessing the precision and accuracy of generated data. The historical data will be obtained from the Installation Restoration Data Management Information System (IRDMIS) database prior to the start of the sampling and analytical program. Several physical and water quality parameters will be evaluated using standard EPA methods or USAEC-validated methods. The data generated will be comparable to EPA Level III data.

Data assessment procedures involve the application of precision, accuracy, representativeness, capability, and completeness (PARCC) parameters to determine whether DQOs have been achieved. PARCC parameters are integrated throughout the QAPjP and applied throughout the data collection process. In this section, qualitative statements

Table 1-2

EPA GENERAL LEVELS OF ANALYTICAL DATA QUALITY

Level	Data Uses	Type of Analysis
I	Site characterization Monitoring during implementation of remedial action.	Total organic/inorganic vapor detection using portable instruments. Field Test Kits
II	Site characterization Evaluation of alternatives. Monitoring during implementation of remedial action.	Field analysis using sophisticated portable instruments or mobile lab. Variety of organics by Gas Chromatography (GC); inorganics by Atomic Absorption (AA) and XRF. Identification only tentative, but analyte-specific. Detection limits vary from low parts per million to low parts per billion.
•III	Risk Assessment Potentially-responsible party (PRP) determination. Site characterization. Evaluation of alternatives. Engineering design of remedial action. Monitoring during implementation of remedial action.	Analysis performed in off-site lab. Organics/inorganics using EPA procedures other than CLP can be analyte-specific. RCRA characteristic tests.
IV	Risk Assessment PRP Determination. Evaluation of Alternatives. Engineering design of remedial action.	CLP routine analytical services. TCL organics by GC/MS, TAL metals by AA, ICP. Low parts per billion detection limit. Rigorous QA/QC protocols and documentation.
V	Risk Assessment Engineering design of remedial action. PRP determination.	Non-conventional parameters Method-specific detection limits Modification of existing methods; method development Appendix IX 40 CFR 264 parameters

Source: Ecology and Environment, Inc. 1994.

regarding PARCC will be summarized for each data collection activity. PARCC parameters are briefly defined below:

- ***Precision***: a measure of the variability in measurements on the sample compared to the average value. Reported as relative percent difference (RPD), the difference divided by the average of two positive samples results. The overall precision is a mixture of sampling and laboratory variability. Laboratory duplicate and field duplicate analyses are used to determine precision, with laboratory duplicate RPDs providing a measure of analytical precision and field duplicate RPDs providing a measure of overall precision.

- ***Accuracy***: the degree of agreement of a measurement with an accepted reference or "known" value, which is a measure of bias of the system. This "known" can take the form of EPA or National Institute of Standards and Technology-traceable standards, laboratory-prepared solutions of target analytes, or solutions of surrogate compounds spiked into each sample. Accuracy is calculated in terms of percent recovery, correcting for analytes/compounds present in the original sample, if necessary.

- ***Representativeness***: the degree to which sample data represent the actual situation at the sampling site. Representativeness is maximized by proper selection of sampling locations and collection of sufficient number of samples. It can be assessed quantitatively by evaluation of field duplicate RPD and qualitatively by evaluation of the degree of homogeneity of the site and of any one sample from the site.

- ***Completeness***: a measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under normal operating conditions.

- ***Comparability***: expresses the confidence with which one set of data can be related to another. Quantitatively, comparability can be assessed in terms of precision and accuracy of two sets of data. Qualitatively, data subjected to strict QA/QC procedures will be deemed more reliable than data obtained without the use of these procedures. To maintain comparability, proper sampling methods, chain-of-custody procedures, EPA-approved analytical methods, and strict QA/QC procedures provide the basis for uniformity in all data collection and analysis activities.

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1.3 PROJECT APPROACH

The field activities were designed to address the possible contamination and potential migration of hazardous substances from the 38 assigned sites. Because of the size of the Annex (approximately 4.3 square miles) and the large number of scattered sites of suspected waste disposal, it was decided to develop an overall approach to assessing the possible impacts of Annex sites on the surrounding environment, in addition to conducting the more specific site evaluations required.

The Army's use of the Annex for various purposes over the past 50 years has been considered to be a primary potential source of pollution. Other institutions such as the Massachusetts Fire Fighting Academy (MFFA), and even the general public, have added to possible sources of pollution on and adjoining the area. The question of overall impact was therefore best addressed by determining which media (soil, air, groundwater, surface water, and sediment) were contaminated.

This approach led to dividing the Annex into seven distinct watersheds, so that each site could be evaluated for its potential as a contaminant source or repository, as well as its potential for impact on neighboring sites, on the watershed in which it is located, on the Annex as a whole, and on surrounding areas.

The most important mobile material at the Annex is water, and this is the medium that may carry contamination off the Annex, and transport contaminants within the Annex from soil to groundwater, from soil to surface water, from groundwater to surface water, and from within a specific site to more widely exposed populations and to the environment.

Thus the cumulative impacts of all the sites within a given watershed tend to be concentrated in the sediments within the surface water draining the watershed and in the surface water itself, and can affect the health and diversity of the biota living in the surface water when compared to appropriate background locations.

The climate, geology, and hydrology of the Annex, while not studied in exhaustive detail, are all well enough known to permit considerable confidence in determining the overall flux of water within the Annex, its volume, its origin, and its destination. This information allowed the selection of a strategy to both characterize the impact of individual sites and to determine which sites may have joint cumulative impacts on any specific body of water, such as a stream, pond, or river.

The watershed approach to investigation of potential contamination at the Annex entailed a review of possible contamination linked to specific sub-zones within the Annex, thereby providing a further level of detail and a new reference measure for the possible impacts of the Annex on the surrounding environment or the potential human health risks through access to the Annex.

Specific techniques used to investigate sites within the seven watersheds designated at the Annex include the following:

- A facility-wide groundwater model was prepared as a 3-dimensional flow model using MODFLOW, a United States Geological Survey (USGS) model, which can be used to model volumes of groundwater flow off the sites through various media, and establish relative proportions of flow. It also provides confirmation of probable mass transport of contaminants from specific sites to supplement individual site studies.

- Surface geophysics were employed, such as seismic, ground penetrating radar (GPR), and electromagnetic conductivity (EM), to help define the subsurface conditions or the extent of disposed materials.

- Test pits were excavated to assess anomalies and areas of concern.

- Borings were installed to collect subsurface samples and to estimate the horizontal and vertical extent of soil contamination.

- Monitoring wells were installed providing a hydrological framework. The wells were sampled to determine groundwater quality and extent of contamination.

- Depth-to-water measurements on new monitoring wells to provided data on the water elevation and the groundwater flow direction.

- Surface water measurements taken during the same time as the monitoring well measurements provided data for the groundwater flow model.

- Slug tests determined the hydraulic conductivity of the overburden and the rate of groundwater migration, and assessed the feasibility of groundwater remediation.

- Surface soil samples were collected to assess the extent of contamination and potential impacts on human health and ecology.

- Surface water and sediment samples were collected to determine the extent of contaminant migration by surface runoff, to drainage areas, streams, and ponds, to further characterize contaminant migration.

- Off-site soil samples were collected to establish a background level for comparison.

- Surveys of stream benthic communities, wetlands, terrestrial fauna and flora, and pond/lake communities, provided data on current ecological conditions.

- Bioaccumulation of metals and pesticides was studied in Puffer Pond and in a comparable off-site pond.

1.4 PROJECT ORGANIZATION AND RESPONSIBILITY

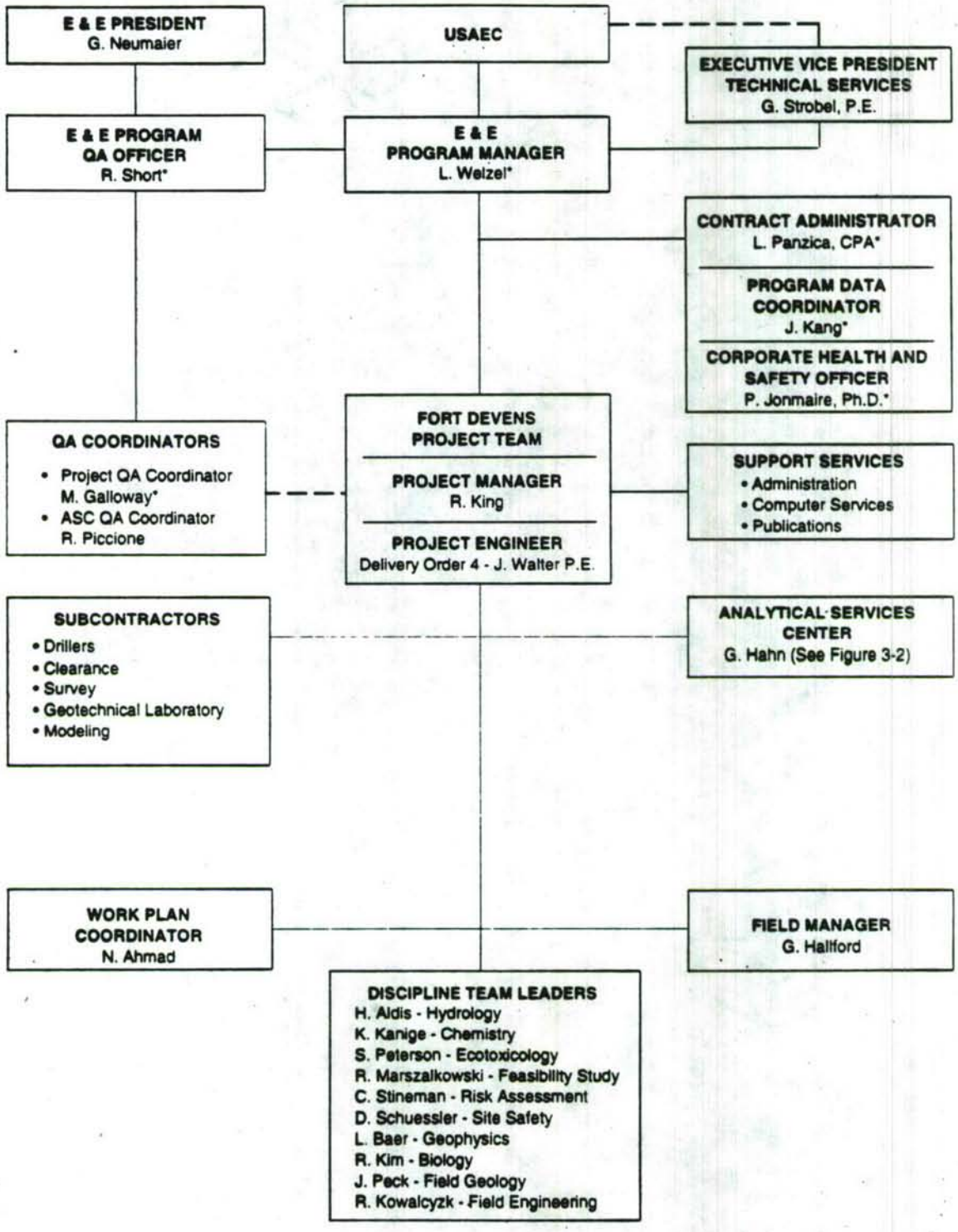
1.4.1 E & E Structure

E & E organizes and implements its management functions based on a matrix corporate structure. E & E provides technical services/administrative support within a permanent corporate structure and performs delivery order assignments as specifically tailored projects. Each of the firm's operating divisions is headed by an executive vice president. The Program Manager for this contract reports to the Executive Vice President—Technical Services, Mr. G. Strobel, P.E. Within the contract organization, the Project Manager reports to the Program Manager. Figure 1-2 presents the organization structure that E & E uses to manage Delivery Order No. 0004 and also indicates the key individuals selected for Delivery Order No. 0004, from the Program Manager through the various team leaders. E & E has identified team leaders in the following functional areas critical to the implementation of this delivery order: SI leader, geology, chemistry, ecology, risk assessment, and site safety. Key support personnel have been identified in the areas of field geology, ecology, and field safety. Figure 1-2 also identifies, by function, other support personnel that will be used for this delivery order.

E & E used subcontractors to support specialized work elements of Delivery Order No. 0004. They included subcontractors for surveying, specialty analytical, drilling, and the development of the hydrogeological model.

1.4.2 Client Organization

E & E receives direction through the USAEC Contracting Officer's Representative and coordinates field activities at the Annex with the Fort Devens Environmental Management Office. E & E's principal project contact at USAEC is Ms. Dianna Feireisel. She coordinates the project technical activities and provides day-to-day technical oversight of the project. E & E's contact at Fort Devens is Mr. Tom Strunk. He serves as the principal contact between USAEC and Fort Devens and coordinates the Fort's contact with the representatives on the Technical Review Committee. E & E's Project QA Officer coordinates the submission of analytical data with Mr. Ivan Sosa, the USAEC Project Chemist. Mr. Sosa is responsible for monitoring the operation of the laboratory according to the approved QA Program (May 1993) and providing formal notification to E & E of any unapproved deviations from the program.



* Key Personnel/Positions

Figure 1-2 PROJECT ORGANIZATION

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This delivery order has been awarded by the Chemical and Biological Defense Agency, Procurement Directorate, AMSCB-PCD, APG, MD, 21010-5423 for USAEC. Ms. Angie Sawyer is the Contracting Specialist for this delivery order. Additional USAEC project support is provided by the technical services branch and includes the following:

Mr. Larry Nutter	-	USAEC Geologist
Mr. William P. Houser	-	USAEC Safety Officer
Ms. Lori Summers	-	USAEC Public Affairs

1.5 REPORT ORGANIZATION

This SI Report is presented in three volumes: Volume I discuss the project's background, objectives, organization, and approach; characteristics and use history of the Annex; previous investigations; field investigation and analytical procedures; screening methodology; and conclusions and recommendations. Volume II — Site Investigations — presents the history, field work, findings, and recommendations for each site investigated. Individual sites are grouped under the heading of the Watershed in which they reside. Volume III — Appendices A through P — presents the reports and data collected as a result of field work performed at the individual sites and from broader surveys and computer modeling at the Annex. These technical field reports can be used to support and provide greater detail about the information given for sites in earlier sections. The full analytical data has been placed in electronic format and is submitted with this report on diskettes containing USAEC's IRDMIS Level 3 analytical data. It can be found in Appendix M.

2. GENERAL ANNEX CHARACTERISTICS

2.1 LOCATION AND GEOGRAPHY

The Fort Devens Sudbury Training Annex (the Annex) is located 20 miles west of Boston, one mile south of Maynard, and two miles northwest of the Town of Sudbury, in Middlesex County, Massachusetts. The installation includes portions of the towns of Maynard, Hudson, Marlborough, Stow, and Sudbury.

The installation covers approximately 4.3 square miles (2,752 acres) and is on the Maynard, Massachusetts 7.5-minute USGS quadrangle map. Hudson Road divides the installation into two unequal sections: the larger, northern section (approximately 2,370 acres), and the smaller, southern section (approximately 380 acres). In the late 1970s, the Army identified all of the southern section, except the Capehart Family Housing Area (CFHA), for potential return to the public through excessing. Excessing activities are presently on hold for most of the southern section pending the outcome of facility-wide investigation activities. Any previously excessed areas found to be contaminated will be included in the evaluation and cleanup process.

Current activities in the southern part of the Annex include continuing use of the CFHA as a military family housing area and testing of cloth durability, which is performed in a reserved area. Activities in the northern part include use of several individual housing units, a USAF radar installation, a drop zone for aerial testing done with remote-controlled aircraft, the Federal Emergency Management Agency (FEMA) regional operations center, the 50 bunkers used for storage by the Army and various leaseholders, and a guardhouse at the main gate. Periodic training exercises are conducted at the site by State Police and National Guard units. The Massachusetts Air National Guard is currently planning to build a communications electronics training complex along the southern boundary of the northern part of the Annex. The installation is also available to a number of permitted recreational users for fishing and other recreational activities. Also, trespassers frequent the Annex because it is easily accessible.

The Annex lies near the western boundary of the Seaboard Lowland Section of the New England-Maritime Physiographic Province. Broad, flat plains with elevations between 190 and 220 feet above mean sea level (AMSL) dominate the land surface at the Annex. Hills are scattered throughout, most of them lying in an arc along the northern boundary and concentrated in the central section of the northern part of the Annex. Elevations range from 321 feet AMSL along the northern boundary of the installation to 170 feet AMSL in Marlboro Brook, near Site P37. A previous investigation classified the topographic features as follows: 81 percent lowlands, 16 percent hills, and 3 percent water bodies (USATHAMA 1980). Unconsolidated deposits of glacial origin cover nearly the entire site. Bedrock outcrops are irregularly distributed, and in places bedrock is deeply buried.

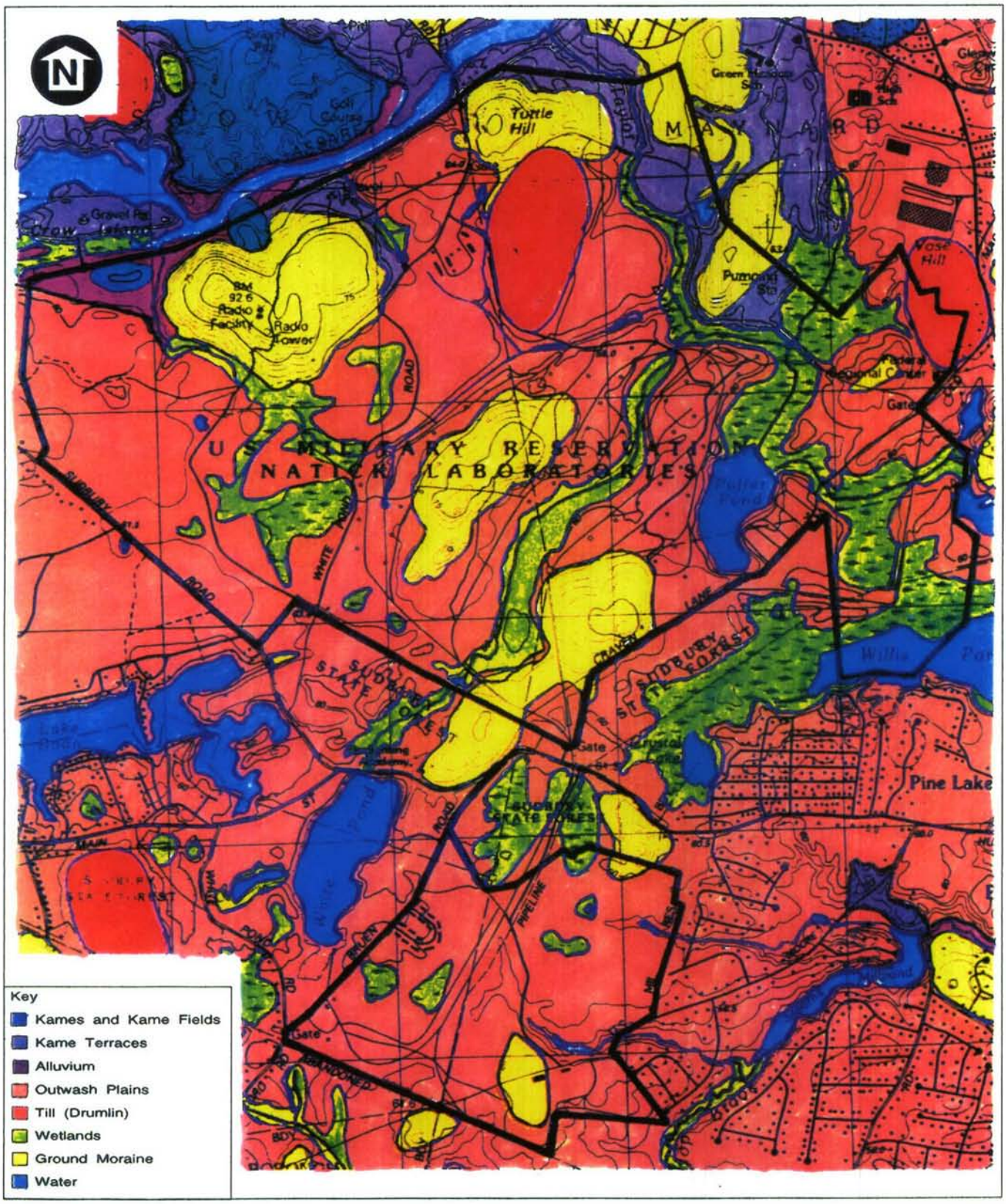
2.2 CLIMATE

Meteorological data indicate moderately cold, moist winters and warm, moist summers, with an annual mean precipitation level of 121 centimeters (44 inches) per year. Winter precipitation is usually in the form of snow and occasional ice storms. July is recorded as the warmest month, with a mean temperature of 22.2 degrees Celsius (72 degrees Fahrenheit). Temperatures at or above 27 degrees Celsius (81 degrees Fahrenheit) generally occur during the months of June through August with the possibility of temperatures dropping below freezing during the months of December through March. Hurricane-influenced weather patterns can occur during the late summer to early fall months.

Precipitation is usually distributed evenly throughout the year. The driest months are July and October, with an average mean precipitation of 8.5 centimeters (3.3 inches), and the wettest months are March and November, with an average mean precipitation of 12 centimeters (4.7 inches). Summer precipitation is usually confined to short-duration, high-intensity thunderstorms (frontal and convection). Winds are light to moderate throughout the year.

The air quality status at Sudbury is regulated by Federal, State, and local environmental laws. The Sudbury Annex is in the Metropolitan Boston Interstate Air Quality Control Region (AQCR 119). The towns of Maynard, Hudson, Marlboro, Stow, and Sudbury are designated as Unclassifiable/Attainment for carbon monoxide. The entire Commonwealth of Massachusetts is designated as a serious non-attainment area for ozone. The region is, however, in attainment for the rest of the criteria pollutants.

The Clean Air Act (CAA) (42 U.S.C. 7401, *et seq*) has been enacted by the Federal government to preserve the quality of ambient air. The National Ambient Air Quality Standards (NAAQS) are presented in 40 CFR 50. Management practices, such as wasted dumping and open-burning, are regulated by Federal, State, and local environmental laws. State and local toxic air pollutant regulations provide stringent exposure or source emission control requirements for remedial activities or for evaluating site contamination. These regulations will be considered when site investigation results are evaluated. It is noteworthy, at this juncture, that the Commonwealth of Massachusetts has accepted National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations for asbestos, beryllium, and vinyl chloride. In addition, the State has set "acceptable ambient levels" (AALs) for 112 toxic air pollutants. New, modified, or "problem" sources of toxic air pollutants are required to use either best available control technology or lowest achievable emissions reductions to ensure AALs attainment. The entire Commonwealth is in the Northeast Transport Region as created under the 1990 CAA Amendments, and is therefore subject to more stringent ozone control, including the emissions of Volatile Organic Compounds (VOCs). The Massachusetts Air Pollution Control Regulations are presented in 310 CMR 7.00. The State Ambient Air Quality Standards are presented in MDEP regulations (310 CMR 6.00).



Source: USGS 1:25000 Series (Topographic) Map, Maynard, MA
USGS 1:31,680 Surface Geology, 1956

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Figure 2-1 SURFACE GEOLOGY AT THE ANNEX

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2.3 GEOLOGY

2.3.1 Glacial Deposits

Wisconsin-stage continental glaciation has had the greatest impact on the topography across the Annex and the New England states in general. Figure 2-1, Surface Geology Map (Hansen 1956), shows eight surficial sediment deposits at the Annex, six of which are associated with glacial processes: kame terraces, kames, kame fields, outwash plains, ground moraines, and drumlins. The other two deposit types are alluvium (reworked outwash sand and gravel) and swamp and lake deposits (gray organic silt and peat). Glacial till, an ice-laid deposit formed during glacial advances, is a compact, unsorted mixture of clay, silt, sand, gravel, and boulders. Generally, the hilly areas of the Annex are composed of till and the broad flat areas of glacial outwash.

Glacial till at the Annex may reach thicknesses of up to 40 feet in ground moraine areas and up to 120 feet in drumlins. In some elevated locations, bedrock is exposed. Over much of the Annex, the till is covered by sand and gravel known as kame and outwash.

Kames are irregular mounds of poorly sorted sand and gravel; kame fields consist of closely spaced mounds. Kame terraces were formed by glacial meltwater streams depositing their load between stagnant ice sheets. Terrace deposits also contain sand and gravel, but are commonly well stratified. Over most of the Annex, till has been overlain by outwash plains. Outwash plains were deposited by meltwater during glacial retreat and consist of sand, silt, and gravel. A one-million-year-old, preglacial river valley, filled with outwash, lies under Boons Pond, White Pond, and the northern part of the detached portion of the Annex (USGS Water Supply Paper 1539-E, Perlmutter 1962). The top of bedrock is below 100 feet AMSL along its center line, with thicknesses of outwash reaching over 100 feet in places.

2.3.2 Bedrock Units

The Annex is underlain by igneous and metamorphic rocks of the Precambrian and Paleozoic Era. As shown on Figure 2-2 (Hansen 1956), six formations underlie the area as part of a tightly folded, northeast-plunging, asymmetrical anticline with a northeastern-southwest strike. The Marlboro Formation, a fine-grained amphibolitic schist (Precambrian) is exposed on the Annex in a band extending from Vose Hill to White Pond. Two formations cross the southeast corner of the Annex: the Salem Gabbrodiorite, and a quartz diorite facies of the Dedham Granodiorite. Both formations are presumed to be of Devonian age. The Nashoba Formation (Carboniferous), a light gray, biotite gneiss, runs along the northern boundary of the site and underlies the extreme northwest corner of the Annex. Central and northern portions of the Annex are underlain by the Gospel Hill Gneiss (Carboniferous). The Gospel Hill is a medium-to-coarse-textured granite gneiss and is probably a granitized product of the Nashoba and Marlboro Formations. Small bodies of the Assabet Quartz Diorite (Late Paleozoic) crop out in northern portions of the Annex. Past glaciation of the tightly folded bedrock units in the area has produced an irregular bedrock surface.

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2.4 SOILS

Generalized stratigraphic units prevalent across the Annex are soil, outwash, till, and bedrock. Weathering of the glacial deposits and the bedrock has produced the existing soil, but in certain areas, erosion may have removed this soil. Surface soils developed on the kame landforms, the outwash plain, and the alluvium are sandy loam with lenses of gravel. Soils in the lowland swamps and bogs are composed of muck and peat. Soils developed on ground moraines and drumlins are stony loam (U.S. Department of Agriculture (USDA) 1989).

Soils within the Annex typical of Middlesex County are described below. These soils can be encountered up to 60 inches BGS, and consist of the Paxton, the Merrimac, and the Swansea.

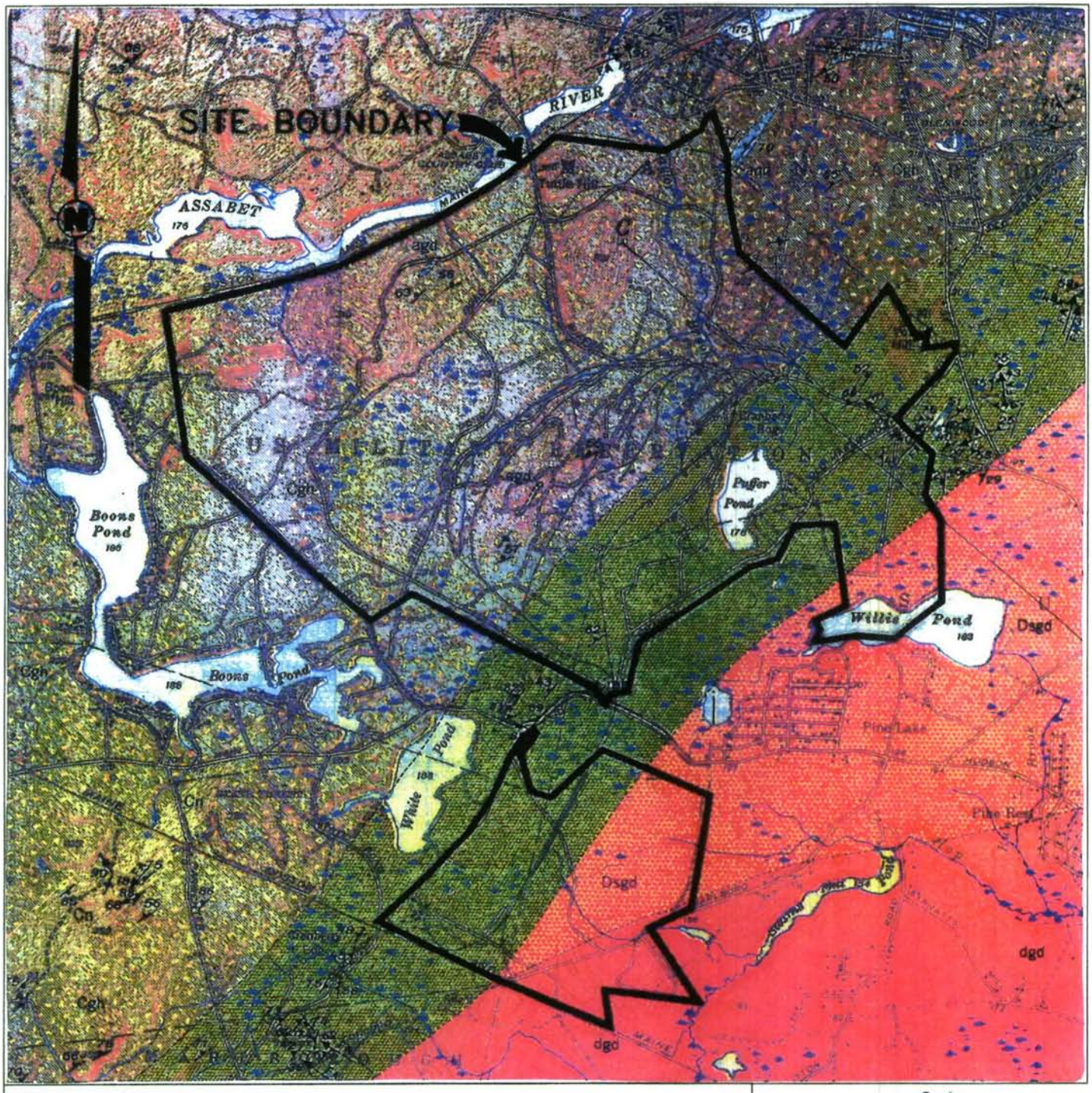
The Paxton is developed within the till deposits and is a well-drained loam. This soil has a 3-to-12-percent clay content, and a permeability of from 0.6 to 2 inches per hour (4×10^{-4} to 1.4×10^{-3} centimeters per second (cm/sec)) at up to 26 inches in depth. Below this depth, compacted tills are encountered with permeability of less than 0.2 inches per hour (4.4×10^{-4} cm/sec). Organic content ranges from 2 to 5 percent.

The Merrimac soils associated with the outwash deposits are very well-drained and sandy. Clay content ranges from 3 to 7 percent in the first 15 inches, but is less than 4 percent from 15 to 60 inches. Permeability ranges from 2 to 6 inches per hour (1.4×10^{-3} to 4×10^{-3} cm/sec) from 0 to 22 inches of soil, and up to 20 inches per hour (1.4×10^{-2} cm/sec) from 22 to 60 inches of soil. Organic content ranges from 1 to 5 percent in the first 15 inches of soil.

The Swansea muck soil is a very poorly drained soil developed in organic deposits of the wetland swamps, bogs, and marshes associated with the low-lying areas scattered throughout the Annex. Clays are found only in the bottom layers (26 to 60 inches) and can range between 1 to 5 percent. Permeability of this highly organic material runs between 0.6 to 6 inches per hour (4×10^{-4} to 4×10^{-3} cm/sec) to a depth of 26 inches, and greater than 20 inches per hour (1.4×10^{-2} cm/sec) from 26 to 60 inches of soil, which is below most of the organic muck and peat. Organic content is high (greater than 50 percent) within the first 9 inches of soil (*Middlesex County Soil Survey, A Resource Planners Guide*, USDA SCS 1989; *Middlesex County Survey Report*, Middlesex Conservation District USDA SCS, 1986).

2.5 HYDROGEOLOGY

The water table at the Annex is generally shallow, as indicated by the numerous wetland areas. Groundwater flow occurs mostly through the outwash plain underlying the lowlands. A preliminary site wide interpretation of groundwater contours is presented in Plate 3 at the end of this volume. Most of the hills comprising the northwestern third of the Annex, such as Tuttle Hill, are composed of relatively impermeable till or bedrock. These deposits are hydraulically continuous with the outwash, but groundwater moves slowly between these layers and the outwash deposits. The lateral distance of groundwater flow in



Key

aqd Assabet Quartz Diorite	dgd Quartz Diorite Facies of the Dedham Granodiorite
Cgh Gospel Hill Gneiss	Dsgd Salem (?) Gabbro-Diorite
Cn Nashoba Formation	pЄmb Marlboro Formation

Source: USGS 1:31,680 Surface Geology, 1956
OHM Corporation, 1991

Figure 2-2 BEDROCK GEOLOGY AT THE ANNEX

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the glacial aquifers is controlled by changes in glacial and surface geology (i.e., extent of the outwash sand area, impermeable boundary conditions, bedrock outcrops), and groundwater discharges to surface water bodies, such as at streams, rivers, ponds, and wetlands. Transmissivity calculated from investigations conducted in areas of till indicates low yields to wells [less than 10 gallons per minute (gpm)], and hence, low hydraulic conductivity (Dufresne-Henry, Inc. 1982).

E & E found that hydraulic conductivities in shallow monitoring wells up to 20 feet deep ranged from 2.25×10^{-4} feet per minute to 3.27×10^{-2} feet per minute with an average hydraulic conductivity of 6.48×10^{-3} feet per minute, which is in the range of that expected for fine or silty sands. Hydraulic conductivities in the two deeper wells, OHM-P40-29 and E3-A05-M01, drilled into the finer outwash at 83.5 and 50 feet, respectively, averaged 6.17×10^{-4} feet per minute.

Conductivity in the deeper well at Site P58, E3-P58-M01, drilled to fine sand at 49 feet, was 2.01×10^{-2} feet per minute and was clearly not located in the less conductive, silty, lake sediments of the typical, lower levels of the outwash. This well was possibly in or on the edge of the buried valley of the preglacial Assabet River.

Water supply wells, in the most favorable areas have yields of up to 400 gpm (FEMA Well) at Puffer Pond and up to 600 gpm at S115 in Watershed 2, south of Hudson Road. Yields obtained from exploration wells installed during water supply investigations in the elevated hilly areas have produced only negligible quantities of water during standard aquifer pump tests (Dufresne-Henry 1982).

Depth to the groundwater table is generally less than 15 feet, except under hills. Groundwater flow directions are complex, but readily deduced from local topography, since flow is generally from the hills to the swamps, and groundwater divides apparently coincide with topographic divides. Exceptions may occur where buried till or bedrock ridges do not coincide with surface water divides, yet create groundwater divides within the glacial outwash. An example of this occurs under Sites P11 and P13 in Watershed 1B.

A USGS Water Supply Paper (Perlmutter 1962) located and described an important potential water-supply aquifer in outwash, filling in a buried preglacial valley of the former Assabet River. This runs under the west end of Boons Pond, the south end of White Pond in Watershed 5, and turns northeast across Watershed 2, to probably pass under the wetlands adjoining Crystal Lake and Willis Pond in Watershed 6.

2.6 SURFACE WATER HYDROLOGY

A recent survey (Butler 1992) concluded that approximately 25 percent of the Annex area consists of wetlands, approximately one-third is in lowland areas (see Figure 2-3).

The wetlands on and around the Annex are the origin of the streams that traverse and discharge from the area. The four most important wetlands noted are as follows:

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- A complex of wetlands associated with Taylor Brook (formerly Puffer Brook) that begins off the Annex to the east above Cutting Pond and Vose Ponds, and continue along the course of Taylor Brook through Puffer Pond, to the Assabet River (Watersheds 1A and 1B).

- A group of wetlands south and southeast of the U.S. Air Force Weather Science Radar Laboratory. This group is the source of surface water flows to Honey Brook (Watershed 1B) and to two unnamed streams, which flow to Watershed 4 to the northwest and to Boons Pond in Watershed 5.

- A large, linear wetland lying between two main groups of bunkers and between Puffer Pond to the east and Honey Brook to the west. This wetland reportedly drains north to Taylor Brook and is therefore in Watershed 1A. Surface water flow is surprisingly inconspicuous for such a large area, so it may also partly discharge via groundwater, which could include flow to Taylor Brook to the north and flow to White Pond to the south.

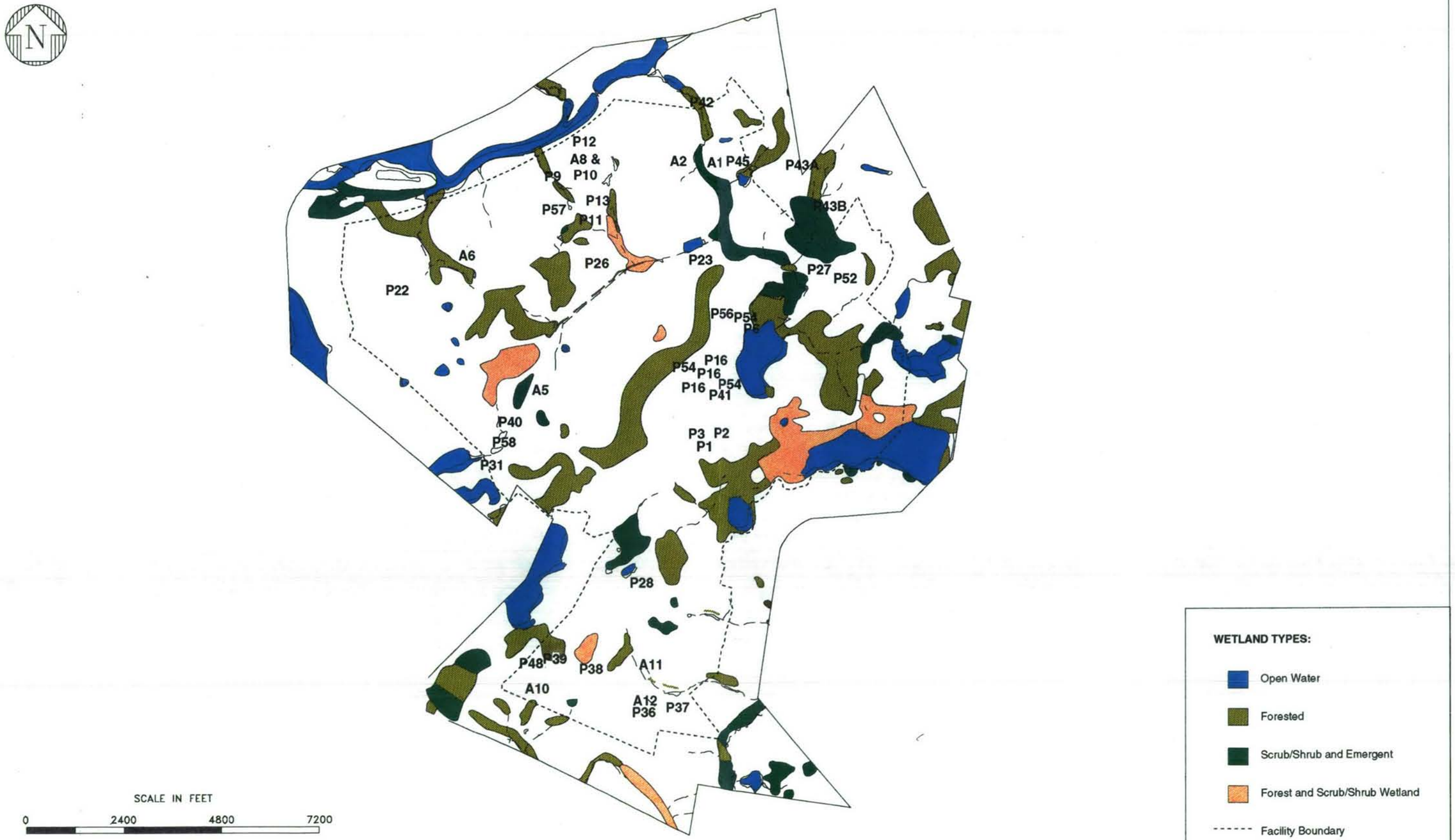
- The wetlands south of the main gate, which connect to the Willis Pond wetlands north of Hudson Road and receive drainage from both the detached southern portion of the Annex and the southeast side of the larger northern portion. This entire area is designated as Watershed 6.

Most of the northern portion of the Annex drains northward via Taylor Brook and its tributaries, which flow into the Assabet River (Figure 2–4). Honey Brook, which drains into Taylor Brook, originates in the western section of the Annex and flows just northwest of and along the bunkers. Two small, intermittent streams also flow from the north portion of the Annex directly into the Assabet.

The southwestern and western sides of the Annex drain primarily into either White Pond or Boons Pond, which discharge to the Assabet River. White Pond has no outlet, but the balance of evidence suggests that its use as a source of water supply serving the Town of Maynard has resulted in a net in-flow to the pond from the surrounding area. The remainder of the Annex, including nearly all of the detached portion south of Hudson Road, drains into Hop Brook or its tributaries. These include Run Brook, receiving flow from Crystal Lake and Willis Pond, and Marlboro Brook, which originates on the Annex. Hop Brook discharges to the Sudbury River, which joins the Assabet River northeast of the Annex to form the Concord River.

The Assabet River, located in the Concord River Basin and in the vicinity of the Annex, has a water quality classification of Class B, designated by the Massachusetts Department of Environmental Quality and Engineering (MADEQE 1989) for use, protection, and propagation of fish, other aquatic life, and wildlife, and for primary and secondary

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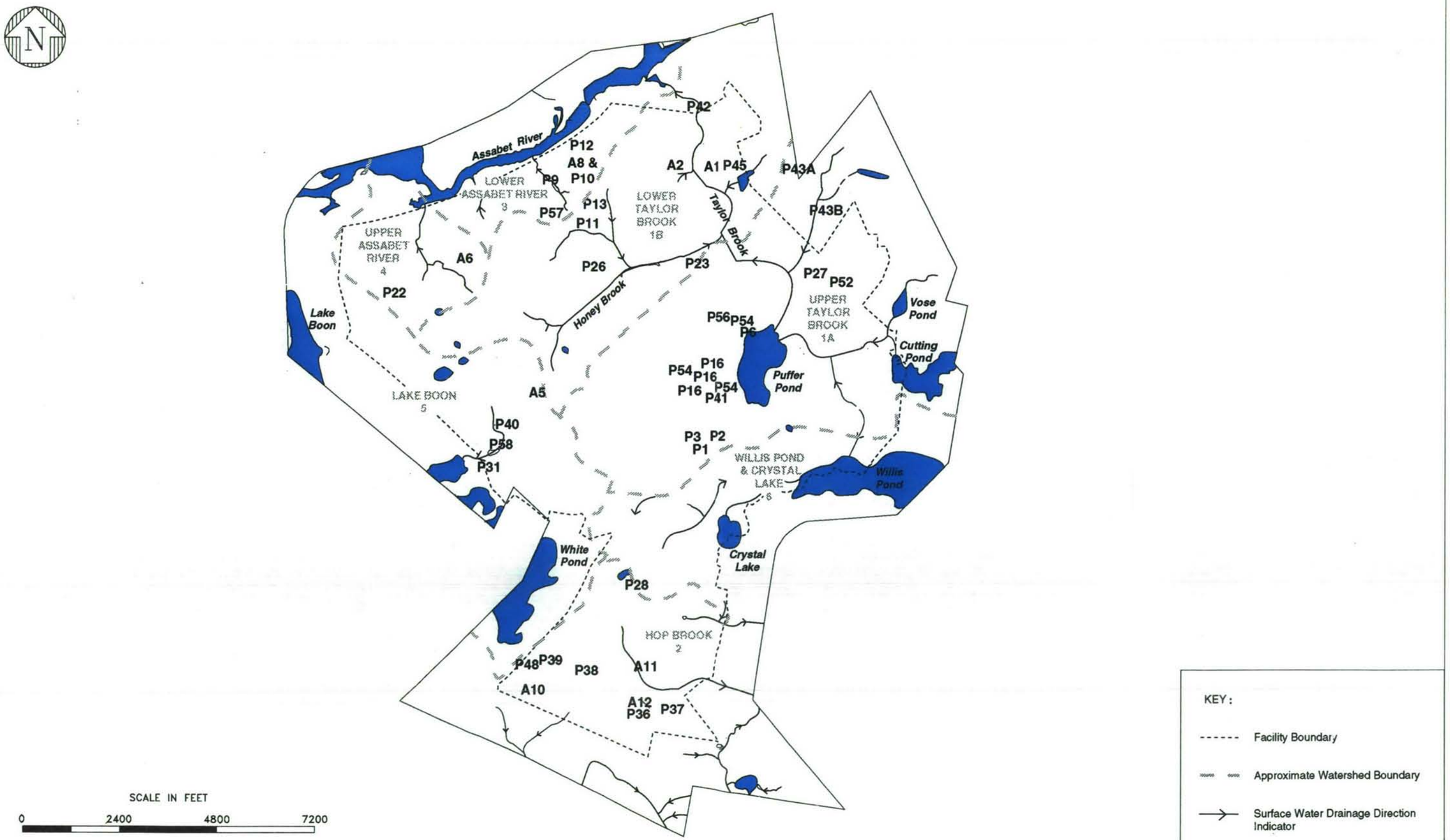


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SOURCE: Compiled by Ecology and Environment, Inc. from National Wetland Inventory Map 1977.

Figure 2-3 WETLAND TYPES AT THE SUDBURY ANNEX

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SOURCE: Compiled by Ecology and Environment, Inc. 1994.

Figure 2-4 SURFACE WATER DRAINAGE PATTERN AT THE SUDBURY ANNEX

contact recreation. Wherever so designated, the Massachusetts Department of Environmental Protection (MDEP - formerly MADEQE) states that Class B waters "shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses. These waters shall be consistently good aesthetic quality." Several wastewater treatment plants in the towns of Westborough, Shrewsbury, Marlborough, and Hudson discharge into the Assabet River upstream of the Annex.

On-site conditions are conducive to good infiltration/percolation rather than runoff. The little runoff that does occur from the small hills is presumed to infiltrate into the well-drained outwash soils or to discharge directly to wetlands and stream. It may be assumed that lakes and swampy areas indicate areas where the top of the saturated zone (water table aquifer) is above the surface, either permanently or seasonally. Flow direction from these relatively flat wetland areas is sometimes difficult to determine and may in fact change direction during local storm events. No detailed studies were performed on surface flow during either of the previous remedial investigations conducted for sites at the Annex (Dames and Moore 1986; OHM 1993).

2.7 THE ECOLOGY AT THE ANNEX

This section contains a brief introduction to the regional ecology of the Annex, a partial description of past and present land use, and an overview of ecosystems and habitat types encountered at the Annex. Volume II contains more detailed, site ecological characterizations, which identify habitat types, sensitive environments downgradient of the various sites, use by wildlife, and species-of-concern associated with each site.

Because of the long growing season, abundant rainfall, and fertile soils, inland areas of the Commonwealth of Massachusetts support a variety of productive ecosystems. The regional vegetation consists primarily of mixed coniferous and deciduous forest. According to Eyre (1980), the Annex is within the Eastern White Pine and Scarlet Oak forest cover types.

More specifically, the varied topography, the diversity of soil types, and the relatively complex drainage of the Annex, in combination with human interference, have resulted in a mosaic of forests, grasslands, wetlands and open water areas. The forest vegetation is dominated by oak and white pine in drier areas, and red maple and ash in wetter areas. Mixed oak forests cover most of the southern portion of the Annex, and a mixture of white pine and oak is the predominant forest type in the northern portion (Figure 2–5). Open areas vegetated with grasses, forbs, and cherry bushes are scarce, mostly occurring in the southern (drier) part of the Annex and around the abandoned buildings found throughout the Annex. Grass-leaved Ladies Tress was identified in an unmowed field northwest to the site (Aneptek 1991).

Wetlands cover approximately 25 percent of the Annex area (US Department of the Interior (USDOI) 1977; Butler 1992)) and are a combination of forested, scrub/shrub, and emergent wetlands, occurring primarily along streams, rivers, and open bodies of water. The most common wetland type at the Annex is the forested wetland (Figure 2–5). No state-

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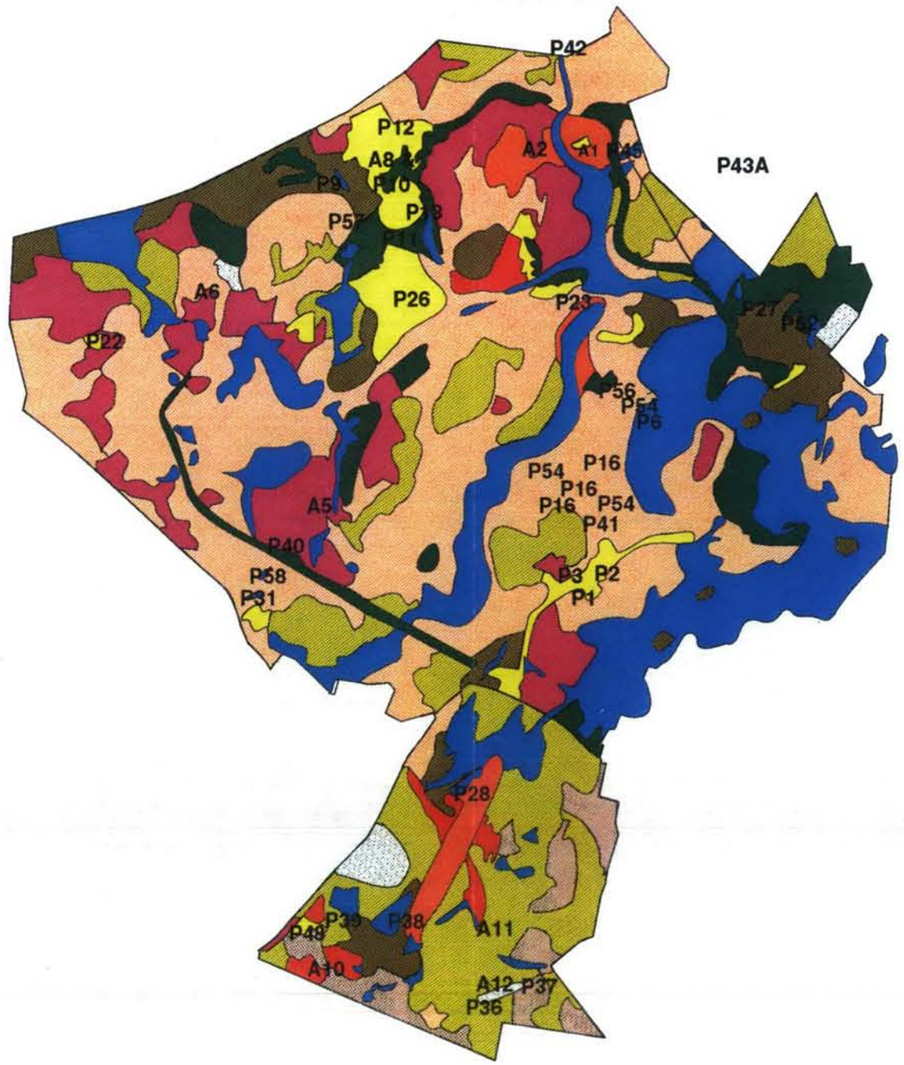
listed, rare wetlands have been identified within a 1.5 mile radius of the Annex (Natural Heritage and Endangered Species Program (NHESP) 1992).

Open bodies of water at the Annex include lakes such as Puffer Pond, Crystal Lake, and Willis Pond; several small vernal pools such as Gas Shack Pool, South Sphagnum Pool, and North Gate Pool (Butler 1992); oxbow ponds found along the Assabet River; and the Assabet river itself.

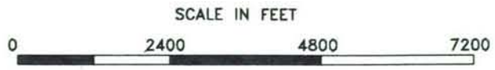
The presence of old stone foundations, small fields bounded by stone walls, and numerous overgrown roads suggest that prior to the Army's acquisition of the Annex, the land was predominantly used for agriculture. Since acquisition by the Army, the Annex has been allowed to revegetate naturally to its present, largely forested state. Occasional logging practices and military activities do not appear to have had any impact on the forested areas. The largest, recent timber harvest occurred in 1983, a salvage operation after a hurricane. There have been smaller harvests since that time; to date, approximately one million board feet of lumber has been harvested.

The following subsections briefly describe the prevalent ecosystems at the Annex. Tables 2–1 through 2–4 provide a list of birds, mammals, reptiles and amphibians, as well as plants likely to occur on the Annex. Table 2-5 identifies Federal- or state-listed species that have been observed at the Annex.

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SOURCE: Forest and Land Cover Map, Leupold Forestry Service 1983, compiled by Ecology and Environment, Inc.

Figure 2-5 VEGETATION COVER TYPES AT THE SUDBURY ANNEX

2.7.1 Wetland Ecosystems

Wetlands are transitional ecosystems that occur between upland (terrestrial) and aquatic environments. Water is the primary factor controlling these habitats and the associated plant and animal communities. Occurring in a wide variety of forms, wetlands normally have three factors in common: dominance of hydrophytes (water tolerant plants), presence of hydric (saturated) soils, and a water table at or near the ground surface for a long enough duration during the growing season to develop anaerobic conditions. The wetland types commonly found in the Annex region include forested wetlands, scrub/shrub wetlands, and emergent (i.e., herbaceous) wetlands. Each of these wetland types and communities is discussed below.

In general, the most abundant type of forested wetland in the region is the bottomland hardwood forest, which occurs on river floodplains and along the edge of many other water bodies throughout the area. Nutrients are constantly being flushed into these systems by periodic flooding. As a result, they are very productive and support an abundant and diverse flora and fauna. The most common bottomland hardwood trees in this region include red maple, American elm, and sycamore. The presence of a variety of woody species, the abundance of fresh water, and the cover attract a diverse array of wildlife. Both aquatic and upland species as well as species specifically adapted to wetlands (e.g., wood duck, mink, and beaver) frequent these types of habitats.

Scrub/shrub wetlands are scattered throughout the region, often forming in areas which were originally cleared for agriculture and then abandoned. Scrub/shrub wetlands represent an intermediate successional stage between emergent and forested wetlands; however, some scrub/shrub wetlands may persist for many years or decades. Vegetation in these areas consists of various species of shrubs such as buttonbush and dogwoods, intermingled with tree seedlings, saplings, emergent grasses, sedges, and rushes. The numerous berry-producing shrubs found in this habitat type provide an excellent food source and serve as cover for songbirds, small mammals, and deer (Martin *et al.* 1951).

Generally, emergent freshwater wetlands are dominated by grasses and sedges. Plant species commonly found include reed grass, cattail, wild rice, bulrush, spike rush, pickerelweed, arrowhead, smartweed, jewelweed, horsetail, and various species of ferns. Emergent wetland areas are particularly favored by both migrating and breeding waterfowl, which use this habitat's abundant food sources and cover. Other birds common to emergent wetlands include bitterns, herons, rails, plovers, and icterids. Various mammals such as muskrats and beavers are also likely to use this type of wetland.

2.7.2 Aquatic Ecosystems

The aquatic ecosystem at the Annex consists of a complex network of intermittent and perennial streams, rivers, and ponds. In general, aquatic habitats are valuable to wildlife because they support a diverse, benthic macroinvertebrate community as well as

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phytoplankton and zooplankton which constitute the base of the food chain and in turn provide food sources for all other wildlife.

The largest body of standing water within the facility boundaries is Puffer Pond (see Plate 1). This habitat supports many aquatic insects, crustaceans, molluscs, fish, amphibians, reptiles, waterfowl, and piscivorous birds. Several species of fish, including chain pickerel, largemouth bass, bluegill, yellow perch, and brown bullhead, have been identified in Puffer Pond (OHM 1994). During a field survey conducted by E & E in November 1993, two Massachusetts state watch-list species, an osprey (*Pandion haliaeetus*) and a great blue heron (*Ardea herodias*), were observed feeding in Puffer Pond. The bald eagle is also likely to frequent the pond and dive for fish in the deeper portions. Finally, snapping turtles, painted turtles, and northern water snakes are also known to occur in this pond (OHM 1993).

Streams and rivers are also of great value to wildlife because they provide easy access to drinking water, protected sites for dens and nests, sunny areas for berry-producing bushes to grow, and safe travel corridors for many species. Fish, crustaceans, insects, plants, reptiles, amphibians, birds, and many upland species can be observed in this habitat type. The largest perennial stream at the Annex, Taylor Brook, originates in Puffer Pond and flows north towards the Assabet River. The major tributary to Taylor Brook is the north-flowing Honey Brook. These streams are also known to support rich, benthic macroinvertebrate communities which include mayflies, stoneflies, caddis flies, blood worms, and side swimmers (OHM 1993). Finally, black crappies, bluegills, brown bullheads, eastern brook trout, redbreast sunfish, and white perch are some of the fish known to occur in the Assabet river, which is located immediately adjacent to the northwestern boundary of the Annex (Maietta 1986).

2.7.3 Terrestrial Ecosystems

The terrestrial ecosystems encountered at the Annex primarily include upland forests, but scattered reverting fields and grasslands and developed/disturbed areas can also be found at the Annex. Forests in this region have historically been subjected to heavy logging as a result of commercial use and clearing for agriculture and urban development. Logging activities have changed the structure and composition of so many of these areas that virtually no virgin stands remain. Common tree species include red maple, Eastern white pine, Northern red oak, scarlet oak, white oak, quaking aspen, bigtooth aspen, shagbark hickory, American elm, and scotch pine. Numerous additional species are found in fewer numbers throughout the region. The undergrowth consists of various shrubby species, including sassafras, blueberries, and dogwoods. Upland forests support a wide array of songbirds, passerine birds, upland gamebirds, small mammals, and deer.

Reverting fields and grasslands, such as meadows, shrub thickets, and immature forests, are areas in a transitional successional stage between a cleared, open area and an area vegetated with upland forest. These cleared areas, once used for agriculture, were later abandoned and are currently in the process of revegetating. The fruits of the juneberry and dogwood shrubs found here provide an abundant source of food for wildlife. Seeds from many grasses and forbs are used by many species of ground nesting birds, songbirds, and

small mammals (Martin *et al.* 1951). Deer are also likely to browse in this habitat type and raptors are known to forage for prey over open areas such as these.

Vegetation in the developed and disturbed areas of the Annex consists mainly of grasses and forbs, maintained lawns, hedgerows, and scattered ornamental trees. Disturbance from human activity makes the wildlife value of this type of habitat relatively low. Species that are likely to occur in developed open areas are sparrows, wrens, grackles, crows, pigeons, rabbits, squirrels, and small rodents. Transient visitors to this habitat include species such as deer, raccoon, opossum, and skunk.

One potential state-listed rare orchid, grass-leaved Ladies' Tress (*Spiranthes vernalis*) was identified by Aneptek Corporation (1991) in the Taylor Drop Zone's unmowed field. However, Hunt (1992) disputed this identification.

Table 2-1

BIRDS THAT ARE LIKELY TO OCCUR AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Alder flycatcher	*Empidonax alnorum*
American black duck	*Anas rubripes*
American crow[b]	*Corvus brachyrhynchos*
American goldfinch[b]	*Carduelis tristis*
American kestrel[b]	*Falco sparverius*
American redstart	*Setophaga ruticilla*
American robin[b]	*Turdus migratorius*
American tree sparrow	*Spizella arborea*
American woodcock	*Scolopax minor*
Bald eagle	*Haliaeetus leucocephalus*
Barn swallow	*Hirundo rustica*
Barred owl	*Strix varia*
Belted kingfisher	*Ceryle alcyon*
Black and white warbler[b]	*Mniotilta varia*
Black-billed cuckoo	*Coccyzus erythrophthalmus*
Black-capped chickadee[b]	*Parus atricapillus*
Black-crowned night-heron	*Nycticorax nycticorax*
Black-throated blue warbler	*Dendroica caerulescens*
Black-throated green warbler	*Dendroica virens*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue jay[b]	*Cyanocitta cristata*
Bobolink	*Dolichonyx oryzivorus*
Broad-winged hawk	*Buteo platypterus*
Brown creeper	*Certhia americana*
Brown-headed cowbird[b]	*Molothrus ater*
Brown thrasher	*Toxostoma rufum*
Canada goose	*Branta canadensis*
Canada warbler	*Wilsonia canadensis*
Cedar waxwing[b]	*Bombycilla cedrorum*
Chestnut-sided warbler	*Dendroica pensylvanica*
Chimney swift[b]	*Chaetura pelagica*
Chipping sparrow	*Spizella passerina*
Common grackle	*Quiscalus quiscula*
Common yellowthroat[b]	*Geothlypis trichas*
Dark-eyed junco	*Junco hyemalis*
Downy woodpecker	*Picoides pubescens*
Eastern bluebird[a]	*Sialia sialis*
Eastern kingbird[b]	*Tyrannus tyrannus*
Eastern meadowlark	*Sturnella magna*
Eastern phoebe[b]	*Sayornis phoebe*
Eastern screech owl	*Otus asio*
Eastern wood-pewee	*Contopus virens*
European starling[b]	*Sturnus vulgaris*

Table 2-1

BIRDS THAT ARE LIKELY TO OCCUR AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Evening grosbeak	*Coccothraustes vespertinus*
Field sparrow[b]	*Spizella pusilla*
Golden-crowned kinglet	*Regulus satrapa*
Gray catbird[b]	*Dumetella carolinensis*
Great blue heron	*Ardea herodias*
Great crested flycatcher[b]	*Myiarchus crinitus*
Great horned owl	*Bubo virginianus*
Green-backed heron[a]	*Butorides striatus*
Hairy woodpecker	*Picoides villosus*
Herring gull[b]	*Larus argentatus*
Horned lark	*Eremophial alpestris*
House finch[b]	*Carpodacus mexicanus*
House sparrow[b]	*Passer domesticus*
House wren	*Troglodytes aedon*
Indigo bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferus*
Least flycatcher	*Empidonax minimus*
Mallard	*Anas platyrhynchos*
Mourning dove[b]	*Zenaida macroura*
Nashville warbler	*Vermivora ruficapilla*
Northern cardinal[b]	*Cardinalis cardinalis*
Northern flicker[b]	*Colaptes auratus*
Northern mockingbird[b]	*Mimus polyglottos*
Northern oriole[b]	*Icterus galbula*
Northern saw-wet owl	*Aegolius acadiars*
Nothern waterthrush	*Seiurus noveboracensis*
Osprey	*Pandion haliaetus*
Ovenbird[b]	*Seiurus aurocapillus*
Pileated woodpecker	*Dryocopus pileatus*
Pine siskin	*Carduelis pinus*
Pine warbler	*Dendroica pinus*
Prairie warbler	*Dendroica discolor*
Purple finch[b]	*Carpodacus purpureus*
Purple martin	*Progne subis*
Red-breasted nuthatch	*Sitta canadensis*
Red-eyed vireo	*Vireo olivaceus*
Red shouldered hawk	*Buteo lineatus*
Red-tailed hawk[b]	*Buteo jamaicensis*
Red-winged blackbird[b]	*Agelaius phoeniceus*
Ring-billed gull	*Larus delawarensis*
Ring-necked pheasant	*Phasianus colchicus*
Rock dove[b]	*Columba livia*
Rose-breasted grosbeak	*Pheucticus ludovicianus*

Table 2-1

BIRDS THAT ARE LIKELY TO OCCUR AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Rough-legged hawk	*Buteo lagopus*
Ruby-throated hummingbird	*Archilochus colubris*
Ruffed grouse[b]	*Bonasa umbellus*
Rufous-sided townhee[b]	*Pipilo erythrophthalmus*
Savannah sparrow	*Passerculus sandwichensis*
Scarlet tanager	*Piranga olivacea*
Snow bunting	*Plectrophenax nivalis*
Song sparrow[b]	*Melospiza melodia*
Sora	*Porzana carolina*
Spotted sandpiper	*Actitus macularis*
Swamp sparrow	*Melospiza georgiana*
Tree swallow	*Tachycineta bicolor*
Tufted titmouse	*Parus bicolor*
Veery	*Catharus fuscescens*
Virginia rail[a]	*Rallus limicola*
Warbling vireo	*Vireo gilvus*
White-breasted nuthatch	*Sitta carolinensis*
White-throated sparrow	*Zonotrichia albicollis*
Wild turkey[b]	*Meleagris gallopavo*
Willow flycatcher	*Empidonax traillii*
Wood duck	*Aix sponsa*
Wood thrush	*Hylocichla mustelina*
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-throated vireo	*Vireo flavifrons*
Yellow-rumped warbler	*Dendroica coronata*
Yellow warbler	*Dendroica petechia*

a Species observed during field survey conducted by Brian O. Butler ("Fort Devens Sudbury Annex Inventory Summary Report" by Butler, B.O., 1992).

b Species observed during field surveys conducted June 21-23, 1993.

Source: Ecology and Environment, Inc. 1993; DeGraaf and Rudis 1986.

Table 2-2

MAMMAL SPECIES LIKELY TO OCCUR AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Beaver	*Castor canadensis*
Big brown bat	*Eptesicus fuscus*
Bobcat	*Lynx rufus*
Deer mouse	*Peromyscus maniculatus*
Eastern chipmunk[a]	*Tamias striatus*
Eastern cottontail[a]	*Sylvilagus floridanus*
Eastern gray squirrel[a]	*Sciurus carolinensis*
Eastern mole	*Scalopus aquaticus*
Eastern pipistrel	*Pipistrellus subflavus*
Fisher	*Martes pennanti*
Hairytail mole	*Parascalops breweri*
House mouse	*Mus musculus*
Keen's myotis	*Myotis keenii*
Little brown bat	*Myotis lucifugus*
Long-tail weasel	*Mustela frenata*
Masked shrew	*Sorex cinereus*
Meadow jumping mouse	*Zapus hudsonius*
Meadow vole	*Microtus pennsylvanicus*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethica*
Norway rat	*Rattus norvegicus*
Pine vole	*Pitymys pinetorum*
Raccoon[a]	*Procyon lotor*
Red bat	*Lasiurus borealis*
Red fox	*Vulpes vulpes*
Red squirrel[a]	*Tamiasciurus hudsonicus*
Short-tail weasel	*Mustela erminea*
Shorttail shrew	*Blarina brevicauda*
Silver-haired bat	*Lasionycteris noctivagens*
Smokey shrew	*Sorex fumeus*
Southern flying squirrel	*Glaucomys volens*
Star-nosed mole	*Condylura cristata*
Striped skunk	*Mephitis mephitis*
Virginia opossum	*Didelphis virginiana*
White-footed mouse	*Peromyscus leucopus*
White-tailed deer[a]	*Odocoileus virginianus*
Woodchuck[a]	*Marmota monax*

a Evidence of these species was observed during the June 21-23, 1993, field survey (i.e., scats, tracks, dens, or individuals).

Source: Ecology and Environment, Inc. 1993; DeGraaf and Rudis 1986.

Table 2-3

AMPHIBIANS AND REPTILES THAT ARE LIKELY TO OCCUR WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
American toad	*Bufo americanus*
Bullfrog[a]	*Rana catesbiana*
Common musk turtle	*Sternotherus odoratus*
Common snapping turtle	*Chelydra serpentina*
Eastern garter snake[a]	*Thamnophis sirtalis*
Eastern milk snake	*Lampropeltis triangulum*
Eastern painted turtle[a]	*Chrysemys picta*
Eastern ribbon snake	*Thamnophis sauritus*
Eastern smooth green snake	*Opheodrys vernalis*
Gray treefrog	*Hyla versicolor*
Green frog[a]	*Rana clamitans*
Northern black racer	*Coluber constrictor*
Northern brown snake	*Storeria dekayi*
Northern dusky salamander	*Desmognathus fuscus*
Northern leopard frog	*Rana pipiens*
Northern redbelly snake	*Storeria occipitomaculata*
Northern ringneck snake	*Diadophis punctatus*
Northern two-lined salamander	*Eurycea bislineata*
Northern water snake	*Nerodia sipedon*
Pickerel frog	*Rana palustris*
Red-spotted newt	*Notophthalmus viridescens*
Redback salamander	*Plethodon cinereus*
Spotted salamander	*Ambystoma maculatum*
Spring peeper	*Hyla crucifer*
Wood frog	*Rana sylvatica*

[a] Observed during the June 21-23, 1993 field surveys.

Source: Ecology and Environment, Inc. 1993; DeGraaf and Rudis 1986.

Table 2-4

COMMON PLANT SPECIES IDENTIFIED[a] AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Alternate-Leaved Dogwood	*Cornus alternifolia*
American Chestnut	*Castanea dentata*
Arrow-leaved tearthumb	*Polygonum sagittatum*
Big-Toothed Aspen	*Populus grandidentata*
Birds-foot Trefoil	*Lotus Corniculatus*
Black Cherry	*Prunus serotina*
Black Locust	*Robinia pseudoacacia*
Blackberry	*Rubus allegheniensis*
Boneset	*Eupatorium perfoliatum*
Broad-Leaved Cattail	*Typha latifolia*
Canada Mayflower	*Malanthemum canadense*
Cinnamon Fern	*Osmunda cinnamomea*
Common Cinquefoil	*Potentilla rects*
Common Greenbriar	*Smilax rotundifolia*
Common Milkweed	*Asclepias syriaca*
Cottonwood	*Populus deltoides*
Cow Vetch	*Vicia cracca*
Dwarf Snapdragon	*Chaenorrhinum minus*
Eastern White Pine	*Pinus strobus*
Field Hawkweed	*Hieracium pratense*
Field Sorrel	*Rumex acetosella*
Fire Cherry	*Prunus pensylanica*
Flowering Dogwood	*Cornus florida*
Gray Birch	*Betula populifolia*
Green Ash	*Fraxinus pennsylvanica*
Ground cedar	*Lycopodium tristachym*
Hairy Solomon's Seal	*Polygonatum pubescens*
Hop Clover	*Trifolium agrarium*
Indian Cucumber	*Medeola virginiana*
Indian Paintbrush	*Hieracium aurantiacum*
Indian Pipe	*Monotropa uniflora*
Jack-in-the-Pulpit	*Arisaema atrorubens*
Japanese barberry	*Berberis thunbergii*

Table 2-4

COMMON PLANT SPECIES IDENTIFIED[a] AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Little Bluestem	*Schizachyrium scoparium*
Lowbush Blueberry	*Vaccinium angustifolia*
Meadowsweet	*Spiraea latifolia*
Mountain Laurel	*Kalmia latifolia*
Multiflora Rose	*Rosa multiflora*
Northern Arrowwood	*Viburnum recognitum*
Northern Red Oak	*Quercus rubra*
Orchard Grass	*Dactylis glomerata*
Panic Grass	*Panicum sp.*
Paper Birch	*Betula papyrifera*
Partridge-Berry	*Mitchella repens*
Pink Ladyslipper	*Cypripedium*
Poison Ivy	*Toxicodendron radicans*
Poverty Grass	*Danthonia spicata*
Privet	*Ligustrum vulgare*
Queen Anne's Lace	*Daucus carota*
Rabbit-foot Clover	*Trifolium arvense*
Red Cedar	*Junipernus virginiana*
Red Clover	*Trifolium pratense*
Red Maple	*Acer rubrum*
Red Pine	*Pinus resinosa*
Reed Canary Grass	*Thalaris arundinacea*
Rice Cutgrass	*Leersia oryzoides*
Round-Headed Bush Clover	*Lespedeza prucumbens*
Royal Fern	*Osmunda regalis*
Rugosa Rose	*Rosa ritida*
Scarlet Oak	*Quercus coccinea*
Scotch Pine	*Pinus sylvestris*
Sensitive Fern	*Onclea sensibilis*
Shagbark Hickory	*Carya ovata*
Sheep Laurel	*Kalmia angustifolia*
Skunk Cabbage	*Symplocarpus foetidus*
Slender Blue Flag Iris	*Iris primatica*

Table 2-4

COMMON PLANT SPECIES IDENTIFIED[a] AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Slippery Elm	*Ulmus rubra*
Small Yellow Pond Lily	*Nuphar microphyllum*
Smooth Sumac	*Rhus Glabra*
Speckled Alder	*Alnus rugosa*
Sphagnum Moss	*Sphagnum sp.*
Spotted Jewelweed	*Impatiens capensis*
Starflower	*Trientalis borealis*
Stiff clubmoss	*Lycopodium annotinum*
Swamp Candles	*Lythrum terrestris*
Sweetfern	*Comptonia pergrina*
Timothy Grass	*Phleum pratense*
Tree Clubmoss	*Lycopodium obscurum*
Unidentified Aster	*Aster sp.*
Unidentified Goldenrod	*Solidage sp.*
Virginia Creeper	*Parthenocissus quinquefolia*
White Ash	*Fraxinus americana*
White Clover	*Trifolium repens*
White Spruce	*Picea glauca*
White Sweet Clover	*Melilotus alba*
Whorled Loosestrife	*Lythrum quadrifolia*
Wild Grape	*Vitis sp.*
Wild Sarsaparilla	*Aralia nudicaulis*
Winterberry	*Ilex verticillata*
Yarrow	*Achillea millefolium*
Yellow Sweet Clover	*Melilotus officinalis*
Yellow Wood Sorrel	*Oxalis montana*

[a] Plant species were identified during a field survey conducted June 21-23, 1993.

Source: Ecology and Environment, Inc. 1993.

Table 2-5

SPECIES OF CONCERN KNOWN TO OCCUR AT THE SUDBURY ANNEX

Common Name	Scientific Name	Status[a]	Reference
Plants			
Blazing Star	*Liatris borealis*	Watch List (Massachusetts)	Hunt 1992
Few-Seeded Sedge	*Carex oligosperma*	Threatened (Massachusetts)	Hunt 1992
Grass-leaved Ladies' Tress[1]	*Spiranthes vernalis*	Species of Special Concern (Massachusetts)	Anaptek 1991
Lacegrass	*Eragrotis capillaries*	Watch List (Massachusetts)	Hunt 1992
Midland Sedge	*Carex mesochbrea*	Endangered (Massachusetts)	Hunt 1992
Northern Starwort	*Stellaria calicantha*	Watch List (Massachusetts)	Hunt 1992
Red Pine	*Pinus resinosa*	Watch List (Massachusetts)	Hunt 1992
Small Beggar Ticks	*Bidens discoidea*	Watch List (Massachusetts)	Hunt 1992
Wood Witchgrass	*Panicum philadelphicum*	Species of Special Concern (Massachusetts)	Hunt 1992
Birds			
Bald Eagle	*Haliaeetus leucocephalus*	Endangered (Federal List)	Anaptek 1992, OHM July 1993
Eastern Bluebird	*Sialia sialis*	Watch List (Massachusetts)	Anaptek 1992
Great Blue Heron	*Ardea herodias*	Watch List (Massachusetts)	E & E November 1993
Osprey	*Pandion haliaeetus*	Watch List (Massachusetts)	E & E November 1993
Purple Martin	*Progne subis*	Watch List (Massachusetts)	Anaptek 1992
Red-Shouldered Hawk	*Buteo lineatus*	Watch List (Massachusetts)	OHM July 1993
Reptiles and Amphibians			
Blanding's Turtle	*Emydoidea blandingii*	Threatened (Massachusetts)	OHM July 1993
Blue Spotted Salamander	*Ambystoma laterale*	Species of Special Concern (Massachusetts)	Butler 1992
Spotted Turtle	*Clemmys guttata*	Species of Special Concern (Massachusetts)	Butler 1992
Spotted Salamander	*Ambystoma maculatum*	Watch List (Massachusetts)	Butler 1992

[a] The following definitions of endangered, threatened, and special concern species were obtained from the Natural Heritage and Endangered Species Program, Boston, Massachusetts.

ENDANGERED: "Any species of plant or animal in danger of extinction throughout all or a significant portion of its range and species of plants or animals in danger of extirpation as documented by biological research and inventory."

THREATENED: "Any species of plant or animal likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and any species declining or rare as determined by biological research and inventory, and likely to become endangered in the foreseeable future."

SPECIAL CONCERN: "Any species of plant or animal which has been documented by biological research and inventory to have suffered a decline that could threaten the species if allowed to continue unchecked or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become threatened within Massachusetts."

(Source: 321 CMR 10.03)

WATCH LIST: Any species of plant or animal which has been documented by biological research and inventory to have suffered a decline or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become a species of special concern within Massachusetts.

(Source: Natural Heritage and Endangered Species Program, Boston, Massachusetts)

[1] This species was seen by Anaptek, but its presence was disputed by Hunt.

Source: Compiled by Ecology and Environment 1993.

3. GENERAL ANNEX USE HISTORY

The land use history of the area currently known as the Annex has been researched by the USAEC and its contractors. E & E presents the information gathered from this research in Section 3 of the *1994 Draft Master Environment Plan* (E & E 1994a). A general information summary is repeated here.

The bulk of the research discusses the Annex's history after acquisition of the land by the U.S. Government in the early 1940s. Information tied to specific activities at individual sites has been included in the historical sections of the relevant areas.

3.1 SUMMARY CHRONOLOGY OF LAND USE

In 1942, the U.S. government established the Annex to store surplus ammunition for the World War II war effort and named it the Maynard Ammunition Backup Storage Point (MABSP). In 1946, the facility became part of Watertown Arsenal and was subsequently referred to as Watertown Arsenal (Maynard). The Annex continued to be used as a storage depot until 1950, when it was transferred to the First Army and for two years became a storage and training subinstallation of Fort Devens. In 1952, the facility was renamed the Maynard Ordnance Test Station (MOTS) and kept that name through at least 1957. From 1952 to 1957, the Annex was principally used for Ordnance Research and Development activities under the Chief of Ordnance.

In 1958, control of the Annex was transferred to the Quartermaster Research and Engineering Center at Natick. While troop training activities continued, the Annex was now also available for the field testing of experiments developed in the laboratories at Natick. Other agencies and or operators were also granted permission to use the Annex for a variety of activities primarily related to materials testing and personnel training. In 1962 the CFHA was established and constructed by Natick Laboratories to house its employees. The designation for the Quartermaster Research and Engineering Center was changed to Natick Laboratories in 1962 and to Natick Research and Development Command (NARADCOM) in 1976. NARADCOM maintained overall control of the Annex until 1982.

Fort Devens, located some 15 miles to the northwest of the Annex, received custody of the entire Annex in 1982. Fort Devens' current mission is to command and train the duty units and to support the U.S. Army Security Agency Training Center and School, the U.S. Army Reserves, the Massachusetts National Guard Reserve Officer Training Programs, and the Air Defense sites in New England. The Annex has been used primarily for personnel training activities for active duty Army units, for the Army Reserve, as well as for Army and Air National Guard troops. Currently, the Annex is a part of Fort Devens and includes several areas actively in use.

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3.2 HISTORIC LAND USE AND OWNERSHIP

Before the Annex was formally established as a military facility in 1942, the land was privately owned and primarily used as farmland. According to the Goldberg Zoino and Associates (GZA) Report (SI on 100-Acre Parcel of Excessed Natick Lab Annex Property, 3/1991) some of the land "was owned by industrial companies, including the Diamond Match Company and Maynard Woolen Mills." More detailed information on land ownership and use is presented in the E & E 1994 MEP. Salient information, however, has been repeated in this report in support of site investigation activities.

3.2.1 Early Years of the Maynard Ammunition Sub-Depot (1939 to 1952)

A historical sketch of the site prepared in 1960 by the Office of the Quartermaster General, Department of the Army, states that the Annex, initiated in the late 1930s, was first known as the Maynard Ammunition Sub-Depot. Located principally in the Town of Maynard, but including tracts in the towns of Stow, Hudson, Marlborough and Sudbury, a total of 3,000 acres were government-owned by early 1942.

Formal creation of the Annex came after a petition was filed by the United States to acquire the land by eminent domain (District Court of United States for District of Massachusetts, Misc. Civil No. 6507, March 25, 1942). On 10 November 1942, the then 3,100-acre property area was designated the Boston Backup Storage Facility and control transferred to the Commanding General of Boston Port of Embarkation.

The Annex was specifically tied to Castle Island Port, the loading point for ammunition being transported overseas through the Boston Port of Embarkation system. When ships were not available for loading or a surplus of ammunition had been received, ordnance would be stored at the Maynard Ammunition Backup Storage Point. Provision for the safe storage of ordnance was ensured by the construction of 50 earth-covered, concrete bunkers around the central section of the Annex. Railroad spurs were developed to provide access between bunkers and four existing main railroad lines.

On 1 September 1945, the location was redesignated the Maynard Backup Storage Area (MBSA) and transferred from the Chief of Transportation to the Chief of Ordnance. In November 1945, Watertown Arsenal acquired jurisdiction over the Maynard Ammunition Sub-Depot from Picatinny Arsenal in Dover, New Jersey. Operations at Maynard had practically ceased though the Annex was now designated The Maynard Ordnance Storage Depot.

On 1 September 1950, all real property was transferred to the control of the First Army, and the MBSA was established as a Class 1 subinstallation of Fort Devens, for use as a storage and training area.

3.2.2 Maynard Ordnance Test Station (MOTS) (1952 to 1957)

In January 1952, ordnance research and development activity under the administrative control and technical direction of Picatinny Arsenal, New Jersey, was established at the Annex, now designated the MOTS. Also in 1952, authority was granted to Watertown Arsenal to take over the 512 acres of the sub-depot south of Hudson and Sudbury Roads for use as a proving ground in tank-testing operations after the tanks had been overhauled at Watertown. During this period, explosives were also tested at the Annex under the control of Picatinny Arsenal.

From 1952 to 1957, the primary military activities at Maynard involved the research and development operations of the Universal Match Corporation and the Arthur D. Little Company. According to an interview with Mr. Sokolowski (Superintendent of the Maynard Public Works Department) reported by GZA in their SI report entitled, "100–Acre Parcel of Excessed Natick Lab Annex Property, 1991," the DoD hired A.D. Little Company to detonate and clean up the remaining unexploded ammunition located in the "underground ammunition bunkers" constructed during World War II. When the Universal Match Company's contract expired on 30 June 1957, the Ordnance Field Safety Officer surveyed and decontaminated the area. Because the Ordnance Corps had no further use for the area, it was transferred to the Quartermaster Corps and on 16 December 1957, through Department of the Army, General Order, Number 61 (dated 17 December 1957), was redesignated the Maynard Quartermaster Test Activity.

The Quartermaster Corp's research may have included rocket, pyrotechnics, and explosives testing, as noted in a map of testing areas that seems to be from this period. No specific records confirming actual operations at the Annex were located.

3.2.3 Maynard Quartermaster Test Activity (MAYTAC) (1957 to 1962)

The Annex was acquired for use by the Quartermaster Research and Engineering Center to help relieve restrictions placed on projects assigned to a nearby facility, the Natick Laboratories, which, since 1949, was located some 12 miles southeast of the Annex in Natick, Massachusetts. The laboratories had reached the limit of available land and organizational capacity, and it was hoped that the Annex would provide sufficient space to meet future needs, especially given an ongoing push to centralize Quartermaster test and evaluation activities.

Other agencies and or operators were also granted permission to use the Annex for a variety of activities, primarily related to materials testing and personnel training. During the early 1960s, for example, some bunkers were used for the storage of a honey-combed packing material used in air drop tests conducted by the U.S. Army Materials Command.

3.2.4 Natick Laboratories and the Annex (1962 to 1982)

The Annex was now primarily available for use as a field resource in testing and experimentation by the Natick Laboratories in support of their mission of research and

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development in the physical, behavioral, biological and engineering sciences. Natick also developed such commodities as clothing and protective equipment. Physical research and development activities included the development of air drop techniques, field shelters and equipment, field organization equipment, fuel delivery systems, as well as food and food service systems. Scientific research and development activities included determination of the stability of various fungicides in materials exposed to outdoor environments; foamed plastics field tests; flame testing of clothing and equipment; toxic fumigant effects on insects; and the study of climatic data in support of various test programs and air drop testing. (Fort Devens undated).

Use of the Annex by the different divisions of Natick Laboratories appears to have been primarily on a contract-and-lease basis, through which certain facilities at the Annex were made available for predetermined periods of time for specific field test activities. Two of these special projects are of particular interest in current SI activities due to the use of radiological materials and the establishment of an animal laboratory.

3.2.4.1 Primary Contractors and Users of the Annex

This section is limited to a very general discussion of the use of the Annex by contractors and other agencies operating on major, long-term or multiple contracts, or with storage leases. Other contracts may have included Annex use, but documentation could not be identified or verified.

United States Air Force

The USAF leased several sites at the Annex for use in different test activities conducted by various contractors. There is not enough information to generate a comprehensive list of all USAF leases for use of Annex land or descriptions of each contract. However, a cross-section of activities is presented in Table 3-1.

Raytheon Corporation

Because the Raytheon Corporation does not maintain files beyond the period mandated in individual contracts, usually for a maximum of ten years, detailed information about the activities undertaken by Raytheon at the Annex is unavailable. However, it has been possible to develop an idea of the type of work probably carried out through review of Leases maintained by the Natick Laboratories. These leases are detailed in Table 3-2.

Table 3-1

USAF LEASES

Lease	Contractor	Contract Title	Location Used
DA-19-016-ENG-6485	Geophysics Research Directorate, Photo Chemistry Laboratory	Project 6690, L. G. Hanscom. Field calibrate accelerometers.	Building T449 200 square feet. Leased 1958 to 1967.
DACA-51-4-73-439	Cambridge Research Laboratory	Project 7635 - Upper Atmosphere Chemical Physics.	Along fence, near Gate G8 and Building T452. Leased 1964 to 1973. Sites P28, P38.
DACA-33-4-70	USAF - CRL	Contract AF 08(635)6046: Field incendiary trials.	Burning grounds, 4 months in 1967.
N/A	Monsanto Research Corporation	Project 8330 Contract F19628-68-C-0365.	Rocket Range/Railroad Classification Yard, Site P28. 25 acres: moveable seismic array experiment 1970 to 1971.
DACA-51-4-71-81	MITRE Corporation	IGLOO Storage for explosives.	Storage USAF

Source: Ecology and Environment, Inc. 1994.

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Table 3-2

RAYTHEON LEASES

Lease	Contractor	Contract Title	Location Used
N/A (lease begun in 1958)	Raytheon	Test "huge equipment to be developed in the area" (125 acres).	Buildings 1, 2 (also known as Buildings T104, T106)
N/A (proposed term 1960-1965)	Raytheon	Pincushion - test prototype, possibly using a tower.	Buildings 1, 2
DA-04-495-ORD-1951 (unknown dates)	Raytheon for General Dynamics	"Mauler"	Buildings 1,2 (Sites P36, P37)
N/A (3 weeks in 1967)	Raytheon	Use low power Radar Range in Remote Audio Detection System Study.	Roadbed of Rocket Range/Railroad Classification Yard, Site P28
No. 5877 (2-4 months in 1971)	Raytheon	N00017-70-C-4409: Electro-magnetic Interference Tests on NATO Sea Sparrow Guided Missile Launcher Subsystem.	Use of Building S-4 (also known as Building 2, T104)

Source: Ecology and Environment, Inc. 1994.

Fort Devens

Fort Devens has had a long association with the Annex, beginning between 1950 and 1951, when the Annex was placed under the Fort Devens Command for a year. In 1959, an inter-service agreement was developed to provide Fort Devens with regular access to an average total of 15 "igloos" (bunkers) for the storage of ordnance and other material. Availability of bunkers was especially valuable because the railroad spurs leading to the bunkers enabled safe shipment of ordnance to and from storage. In 1959, an amendment was requested and approved to allow certain areas to be used in developing transport experience through helicopter training.

In 1964, it was determined that much of the railroad trackage available at the Annex was unsafe for use and needed to be removed. At this time, Fort Devens was re-assigned 15 bunkers that would still be accessible by track, and continued to use these for storage. In 1982, the Annex was placed fully under the Command of Fort Devens, and remains so to the present (see Section 3.3.1).

Massachusetts Fire Fighting Academy

The Massachusetts Fire Fighting Academy (MFFA) had a long relationship with the Annex, which continued until new facilities were built for the MFFA in an off-Annex location. Over the years, several occasions have been described when excess POL was given to the MFFA for use in training exercises.

Air National Guard and State Police Visits

A variety of contractors used the Annex, under inter-service agreements as well as rental contracts. Among the local organizations most often found to have access to the facility were the Massachusetts Air and Army National Guards and the Massachusetts State Police. Table 3–3 illustrates some of the lease agreements maintained by Natick Laboratories with these units.

3.2.4.2 Special Activities

Radiological Materials

As part of the Natick Laboratory mission, radiological materials were used for instrument calibration, instrument source, tracers, and food irradiation research activities. The majority of the materials used were small-quantity, short half-life, low-activity materials. No reference has been found through interviews and record searches to suggest or indicate that any radiological materials were disposed of at the Annex.

Two radiological materials handled by the laboratory in slightly larger quantities were unenriched uranium and cobalt-60. The uranium received by the laboratory was not used and

Table 3-3

POLICE AND NATIONAL GUARD LEASES

Lease	Unit	Purpose of Lease
DACA 33 67 122 DA19-016-ENG-8216	Massachusetts Air National Guard	Bunker for storage of Class 2 ammunition. Renewed. Effective 1965 to 1969
DACA 33-1-69-109	Massachusetts State Police Academy	Police Training. Records from 1969.
N/A	Massachusetts Army National Guard, 26th Military Police Company	Outdoor training camp. Records from May 4, 1967 to August 21, 1969
DACA 51-3-71-210	Massachusetts Army National Guard	Training. Record from April 1, 1976

Source: Ecology and Environment, Inc. 1994.

was subsequently disposed of (via shipment to an approved disposal facility) in accordance with Atomic Energy Commission and Army regulations (Interviews 1991a; 1991b). The cobalt-60 source was maintained in a special area at the Natick Laboratories in Natick (Interview 1993a). When the cobalt source material was depleted to a level the laboratory could not use, it was shipped to properly licensed facilities.

Food irradiation and sterilization experiments conducted by the Natick Laboratories depended on the cobalt-60 source for radiation and on a 24 multi-electron volt (MeV) linear accelerator. The food irradiation experiments using the accelerator were conducted by scaling down the linear accelerator from 24 MeV to 10 MeV, a dose level that would not leave any residual radiation in the food. Exposure to the cobalt-60 source could not leave residual radiation in food. Some of the excess food was buried at the Annex, however no food was allowed to leave the Natick Laboratory radiological control area without being tested by a safety officer for residual radiation (Interview 1993a). The Army also has published documentation discussing the lack of radiation residue in food tested in both types of experiments.

The 1994 MEP provides a more complete discussion of Natick Laboratory handling of radioactive materials and related experiments. In summary, based on interviews and record searches, it does not appear that the Annex received radiological waste for the Natick Laboratory.

Animal Testing

In 1958, there was discussion of establishing an animal testing laboratory at the Natick Laboratories or at the Annex. Much of the available documentation was originally generated in connection with obtaining access to funding for future activities proposed by the Natick Laboratories. In reading through the documentation, it becomes evident that thought was given to situating an animal laboratory at one of three locations at the Annex: Buildings

T446, T449 or T452. Evidence was found that Building T452 was informally modified at a cost of $11,000 (primarily to add refrigeration boxes outside and inside) for use as an interim animal laboratory facility. At this time, the animal testing consisted primarily of heat and cold stress testing, psychological testing, and testing of blast cream (cream to protect skin against high heat blasts). The subsistence evaluation laboratories at Natick eventually became the animal testing laboratories in 1962, and were fully equipped as such.

3.3 FORT DEVENS SUDBURY TRAINING ANNEX (1982 TO 1994)

In 1982, operational control of the Annex was transferred to Fort Devens. The major mission of Fort Devens is to train active duty and reserve personnel, and to support the U.S. Army Security Agency Training Center and School; the U.S. Army Reserves; the National Guard; ROTC; and Air Defense sites in the six New England states. The Annex is currently used to support this mission (Dames and Moore 1986).

3.3.1 Continued Natick Use of Annex Land

Under mutual agreement between Fort Devens and Natick Laboratories, certain use and occupancy needs of the Annex real estate property were retained by Natick Laboratories after acquisition by Fort Devens:

- Exclusive use of Building T452 as a Guest House (Natick Laboratories may have ended its actual use of T452 in 1992);
- Exclusive, conditional use of a certain number of bunkers for storage, until any or all are required by Fort Devens (with a 30-day prior notice to vacate);
- Exclusive, conditional use of approximately eight acres of land known as "POL Burn Area" together with Buildings T401 and T402;
- Use of a relatively flat, 30-acre area off White Pond Road currently used as a drop zone by the Airdrop Engineering Laboratory of Natick Laboratories for testing equipment in actual parachute drops using remote-controlled aircraft;
- Use of an area, of some 780 acres, still used by the U.S. Army Research Institute of Environmental Medicine (Natick Laboratories) as a field evaluation test course; and
- Access to all above facilities via the Hudson Road Gate (OHM 1990; OHM 1991).

11:UC6101-3/RC1132_V1-09/22/94-F1
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3.3.2 Other Land Use

There is a troop practice area of approximately 48 acres partly enclosed by a security fence in the northern portion of the Annex.

Approximately 500 acres in the western portion of the Annex are leased to the USAF for radar instrumentation by Bradford Research Laboratories. The FEMA Region I Office leases approximately 262 acres in the eastern boundary of the Annex. According to FEMA past and present activities at the Annex have been restricted to administrative work areas, communications facilities, and administrative storage of vehicles.

The CFHA in the southern portion of the Annex consists of approximately 18 acres, which includes housing and a small recreational area for children. Domestic and fire-fighting water pumping stations for CFHA are in this area. Approximately 48 acres situated between White Pond and the CFHA (Bruen Road) are owned on easement for the Town of Maynard for pumping rights from White Pond.

A large section in the central lowland of the northern portion of the Annex (approximately 850 acres) contains the concrete, earth-covered bunkers built during the earliest years of the Annex. These bunkers, like most of the present-day Annex, are under-utilized by the U.S. Army Forces Command (FORSCOM). An inventory of the present use and users of these bunkers was last conducted in 1992.

An easement associated with the Annex includes a right-of-way for pipeline installation and maintenance for the Tennessee Gas Company.

4. REVIEW OF PREVIOUS INVESTIGATIONS

4.1 INTRODUCTION

The DoD established the IRP in 1978 to identify, investigate, and clean up contamination from hazardous substances at Federal facilities. IRP activities began in 1980 at the Annex to assess and address the environmental impact of past land usage.

Pursuant to the IRP's mission, the Army has contracted the following organizations to investigate sites at the Annex:

- USATHAMA (now USAEC) — detailed record search in 1980;
- AEHA, Aberdeen Proving Ground, Maryland — hydrogeological and subsurface investigation in 1983;
- Dames and Moore, Inc. — RI in 1986;
- Dames and Moore, Inc. — Expanded SI (Site P48) in 1991;
- GZA Geoenvironmental, Inc. — SI, 100-Acres Excessed Land in 1991;
- OHM, Inc. - Master Environmental Plan in 1992;
- OHM, Inc. — Phase I SI, RI investigation in 1993;
- E & E, Inc. - Master Environmental Plan update in 1994;
- OHM, Inc. — Phase II RI investigation (ongoing); and
- E & E, Inc. — Phase II Site/Remedial investigation (ongoing).

In addition, the EPA contracted NUS Corporation in 1985 to conduct a PA/SI at the Annex to fulfill CERCLA requirements under their Superfund Field Investigation Team contract. Several remedial actions have been performed and underground storage tanks (USTs) and drums have been removed from various Annex locations. These are described in the site discussions presented in Volume II of this document.

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4.2 PREVIOUS INVESTIGATIONS

4.2.1 Site Assessment by USAEC (USATHAMA) (1980)

The Preliminary Installation Site Assessment conducted by USAEC in 1980 was primarily a historic records search of various activities, including disposal, at the Annex that could have resulted in contamination. The site assessment report indicated that certain areas of the Annex may have been contaminated by:

- explosive residues;
- laboratory quantities of chemical solvents;
- POLs; and
- other toxic or hazardous materials.

Based on the site assessment research, 11 areas were identified at the Annex (Plate 1) as being possibly contaminated by past usage.

4.2.2 Hydrogeological and Subsurface Investigation by the U.S. AEHA, 1983

The AEHA conducted a hydrogeological and subsurface investigation of the 11 sites identified in the 1980 study to evaluate the hydrogeologic setting and groundwater quality associated with each location. The final report was prepared for USAEC in May 1983, and includes discussions on:

- geologic features;
- soils characterization;
- groundwater hydrology;
- monitoring well locations;
- installation of seven monitoring wells; and
- groundwater sampling and analytical results.

The results of the study showed the potential for contamination to be sufficient to justify conducting an RI at the Annex.

4.2.3 Remedial Investigation by Dames and Moore for the Army (1986)

The 1986 investigation was undertaken to further characterize the 11 sites identified in the previous studies by collecting and analyzing groundwater, soil, surface water, and sediment samples. In addition to the 11 sites, Dames and Moore reviewed and studied potential contamination sources in the vicinities of the CFHA, Puffer Pond, and associated streams. The program was designed to:

- identify and characterize environmental contaminants, especially with respect to Puffer Pond, the vicinity of the leach field (Site A11), the food burial site (Site A8), and the CFHA;

- provide additional information on site hydrogeology; and
- assess the potential for contaminant migration.

To obtain supplemental information on the sites, a monitoring well network of 17 wells was established to detect potential contaminant migration within and around the sites.

Based on preliminary data reviews, additional samples were collected to further evaluate possible soil contamination at the CFHA and surface water and sediment contamination at the leach field (Site A11) and in the Puffer Pond and associated stream area. The presence of anomalous compounds in samples collected from these areas led to their inclusion on the list of suspected sites. Other aspects of the sampling effort have been covered, as relevant, in the site sections.

4.2.4 NUS, Inc., PA and SI of the Annex for EPA Region I

Prior to the final publication of the Dames and Moore RI Report, EPA's Region I Waste Management Division tasked NUS Corporation's Field Investigation Team (FIT) to conduct a PA at the Annex in June 1985. The PA included a review of the Dames and Moore Final Draft RI/FS Report. Based on the PA, EPA instructed the FIT to conduct a SI of the Annex. In May 1987, the FIT completed an SI report on the Annex. The SI results were used by EPA to determine that the Annex should be included on the National Priorities List (NPL) of all sites identified under CERCLA as having an immediate and direct potential for impact on human health and the environment. Details on a polychlorinated biphenyls (PCB) spill were considered as key information in the evaluation of the site. The spill occurred in an area designated by the Army as A12, which is just south of A11. Remediation of the PCB spill took place in 1985 and 1986, and the cleanup was approved by MDEP in 1989.

4.2.5 SI of 100-Acre Parcel of Excessed Natick Lab Annex Property by GZA Geoenvironmental, Inc., for the U.S. Army Corps of Engineers (March 1991)

GZA was asked to conduct an SI at an excessed 100-acre parcel of land, which formerly comprised the north limit of the Natick Laboratory Annex in Maynard, Massachusetts. The study was performed as part of the DERP to determine the presence or absence of chemical contamination that may have resulted from DoD activities since about 1942 at the site. The SI included site walkovers, environmental media sampling, monitoring well installations, and background research.

GZA's background research indicated that the 100-acre area had remained "buffer land" since 1942, undergoing no improvements since that time. Part of the site had been used for an obstacle course, but no documentation of waste dumping or storage at the site was found. GZA conducted a stereoscopic aerial photography review of the site, using photographs generated in 1957, 1986, and 1989. The site area was observed to be increasingly overgrown.

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After reviewing background information and observations made during site visits, GZA concluded that there was no evidence of past disposal of chemicals in the previously identified EPA Sites 8a and 8b, nor was there evidence of dumping or other surficial sources of environmental contamination attributable to DoD-related activities in the remaining portions of the area. Laboratory analyses revealed that petroleum hydrocarbons were identified within some soil and sediment samples near the detection limit. These could result from urban runoff. No petroleum hydrocarbons (PHCs) were detected in water samples. BNAs were identified in trace to low levels in soil and sediment samples, at levels consistent with those normally associated with urban runoff, oil-based insecticides, and residuals from brush or forest fires. Metal levels were elevated, and, while some may be attributable to urban runoff, lead and chromium levels were outside the normally expected range of concentrations typical of hydrogeological conditions in New England.

4.2.6 Expanded Site Inspection (POL Bladder Testing Area — P48) by Dames and Moore, Inc. (March 1991)

The Expanded Site Inspection was conducted to assess the extent of potential soil, groundwater, and surface water contamination at three sites identified by Natick Research Development and Engineering Center, only one of which was at the Annex: the old Petroleum, Oil, and Lubricant (POL) Bladder Testing Area (POL Test Area). The field activities consisted of coordinating a soil-gas survey conducted by Northeast Research Institute, Inc. (NERI), to characterize potential soil-gas contamination in the vicinity of the bladder test area.

The soil-gas survey detected the presence of low levels (reported as ion counts) of benzene, toluene, ethylbenzene and xylenes (BTEX), moderate- to heavy-weight petroleum hydrocarbons, trichloroethene (TCE), and tetrachloroethylene (PCE). Because the suspected releases occurred more than 20 years ago, degradation, migration, and dispersal of the contaminants probably occurred, resulting in their widespread distribution and apparently low levels. While the identity of the contaminated media and the absolute contaminant concentrations are not known, the low levels of contamination detected in the soil gas do not appear to present a current or future threat to public health or the environment. Dames and Moore suggested that a single monitoring well be installed and sampled to verify the absence of significant contamination and that a limited number of soil samples be analyzed.

4.2.7 Phase I Site, Remedial Investigations by OHM Corporation (July 1993)

OHM Corporation was tasked by the USAEC to perform an SI/RI of the Annex, and asked to conduct record searches, study area reconnaissances, and a field investigation consisting of geophysical surveys, soil-gas surveys, test pit excavations, installation of monitoring wells, and the advancement of soil borings. Sampling activities included soil and sediment sampling, drum removal and confirmatory soil sampling (to confirm that the soil did not have residual contamination at the removal site), surface water and ground water sampling, transformer sampling, an ecological assessment, and air monitoring. Several facility-wide assessment, inspection, and reconnaissance activities were also performed. As a

result of the initial research effort, 68 sites were identified for review, including Sites A1 through A12, previously investigated.

After the SI/RI investigation, 28 sites were proposed for No Further Action (NFA), three for RI/FS, two for SI/RIs, and the remainder for SI activities. As a result of discussions between the Army and Regulators, eight sites (P15, P29, P30, P44A/B, P46, P47, P53, and P55) were accepted for NFA, and NFADD on these sites are being developed. An additional 15 sites required some additional SI activity to further evaluate conditions: P3, P8, P12, P14, P18, P19, P21, P24, P32, P33, P34, P49, P50, P54, and P56.

5. FIELD INVESTIGATION AND ANALYTICAL PROCEDURES

The field investigation activities performed at the Annex were designed to follow up on previous site studies and provide information on the nature, extent, and degree of contamination at each site, for each of the seven watersheds and for the Annex as a whole. Data produced will be used for potential treatability studies, risk assessments, and evaluation of remedial alternatives as well as to justify NFA decisions as appropriate. Field investigations performed at the Annex included the following:

- Geophysical Surveys using ground penetrating radar (GPR), electromagnetic (EM) ground conductivity radar, and magnetometry studies to better define the location of buried drums and material; seismic surveys to assist in well location and to establish depth to bedrock;

- Test pit excavations to define and classify anomalies identified by geophysical surveys and to visually identify subsurface soil contamination;

- Subsurface soil sampling to estimate the horizontal and vertical extent of soil contamination;

- Monitoring well installation with subsequent groundwater sampling to provide data on site groundwater quality;

- Depth-to-water measurements on all new monitoring wells and selected OHM, Dames and Moore, and GZA wells to provide data on head elevation and groundwater flow direction;

- Slug tests to determine hydraulic conductivity, aquifer transmissivity, and the rate of groundwater migration of the overburden aquifer and to assess the feasibility of groundwater remediation;

- Surface soil sampling to determine the potential human health and ecological risk and the extent of contamination, if found;

- Surface water and sediment sampling to determine the extent of contaminant migration by surficial runoff and groundwater discharge;

- Field survey of stream benthic communities, wetlands, terrestrial fauna, flora, and pond/lake communities to provide data on current ecological conditions;

11:UC6101-3/RC1132_V1-09/22/94-F1
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- Bioaccumulation studies in Puffer Pond and Minister's Pond, a comparable off-site pond;

- Development of a facility-wide groundwater model for the Annex; and

- Collection of background soil, surface water, and sediment samples and site-boundary surface water and sediment samples to evaluate the potential for the release of contaminant to the environment from the watersheds at the Annex.

The field work performed at each site and the rationale for sample locations are discussed in the individual SI reports and in Appendix F. These sections describe the standard procedures followed for field investigations at the Annex and the related analytical program.

5.1 FIELD PROCEDURES

Field procedures approved for use in this investigation have been described in several previous documents, including the January 1994, *Final E & E Field Sampling Plan Addenda* (E & E 1994a), and the April 1992, *Final OHM Field Sampling Plan* (OHM 1992). For further information related to field procedures, please refer to these documents. This section briefly describes the procedures E & E followed during site investigations at the Annex. Any Annex-wide deviations from the approved procedures are noted in this section and site-specific deviations are explained in the Volume II Field Activities Performed sections for the individual sites.

5.1.1 Geophysical Surveys

Geophysical surveys performed at the Annex included GPR, EM ground conductivity radar, and magnetometry studies to better define the location of soil disturbances and buried material. Seismic surveys assisted in well location and established depth to bedrock, groundwater elevations, and additional stratigraphic information. The specific field work performed at each study area is described in the individual SI sections, and a more detailed geophysical report is presented in Appendix E.

5.1.1.1 Seismic Surveys

Seismic subsurface exploration works by using the basic physics of wave propagation to calculate the intensity of sound (seismic) waves reflected off or fracted by materials of different density. The components for acquiring seismic data are: the shot, defined as the energy source that generates seismic sound waves to propagate through the subsurface; the receiver, which is the instrument that converts ground motion caused by the seismic waves into an electric signal; and the recorder, which is the instrument that converts and stores the signals from the receiver into positive or negative integers of varying amplitude that correlate with the ground motion intensity and direction (up or down) at that receiver.

An ABEM MINILOC seismograph was used to collect the seismic data, following the procedure below:

- Seismic line locations were selected after consideration of surface topography, ground cover, and necessary ties with other lines in and around the sites.

- Three geophones were "planted" on the seismic line — one at each end and the third in the middle. Thirty-six shotpoints were evenly spaced between the two end geophones, with each shot recorded as a single trace in each of the three geophone records. Shot energy was created by using a 12-pound sledge hammer to strike a rubberized plastic plate, with 3 to 5 shots "stacked" at each shotpoint location.

- Data was examined by the geophysicist following completion of all shots, and if satisfactory, downloaded to a laptop computer.

- Field interpretation was run on select lines to insure data quality and check acquisition parameters, using the MINILOC built-in software.

- Final interpretation was performed using SEIS REFA, a software package from OYO Corporation.

5.1.1.2 Ground Penetrating Radar

A GSSI Model SIR-3 GPR unit was used at the Annex with 500 Mhz and 900 Mhz antennas available.

The GPR method involves transmission of an energy pulse into the subsurface by the unit's antenna. The pulse is then partially reflected back to the antenna's receiver after it is interfaced with materials of different electrical properties. The velocity of a pulse in a material is the distance it travels in that material divided by the time taken to travel that distance. This is analogous to the seismic method, in that the instrument records the time delay between energy transmission and reflection of that energy back to the receiver. The SIR-3 processes this data through gains and filters and then displays it on a graphical recorder.

To collect GPR data, a line location was selected and the endpoints of the line staked. The ground surface was then cleared to allow for the smooth travel of the antenna along the line. A fiberglass tape was laid out along the line with zero designated at one end. The antenna was then placed just beyond the beginning of the line and connected to the nearby GPR recorder. The recorder was activated and the antenna was slowly pulled along the line at a nearly constant speed. As the center of the antenna passed the tape zero, and at regular intervals thereafter, a button was pushed that caused a location marker to be plotted on the graphic display. Data from the survey are presented in Appendix E.

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5.1.1.3 Electromagnetic Conductivity Surveys

The instrument used for this EM study was the Geonics EM31 Terrain Conductivity Meter. The EM31 continuously measures the terrain conductivity of the material beneath and immediately surrounding it. The EM31 consists of a small control box with two opposing booms extending approximately 5-1/2 feet from the box. A transmitter coil is attached to the end of one boom and a receiver coil is attached to the end of the other boom. The coils are co-planar with the instrument dipole perpendicular to the ground. The depth of investigation for the EM 31 at the Annex sites was approximately 18 feet for the vertical dipole and 9 feet for the horizontal dipole. The different dipoles are obtained by rotating the instrument 90 degrees about the axis through the booms. All conductivity readings from the EM31 are in millimhos per meter (mmhos/m). Data from the survey are presented in Appendix E.

Two basic methods of conducting an EM survey were used at the Annex: a gridded survey and a reconnaissance (recon) survey. In a gridded survey, data are collected and recorded at stations that have been laid out by some form of land survey method. An EM recon survey can be considered a real-time analysis of the data, with the operator continuously watching the EM31 for any readings that deviate from background. In this type of survey, results, but not data, are usually recorded. This kind of survey was used when the exploration targets were large or shallow, highly conductive objects such as USTs or pipes.

5.1.1.4 Magnetometry Surveys

An EG & G G856 proton procession magnetometer was used in the Annex survey. This instrument provides readings that are a measurement of the Earth's total magnetic field, expressed in gammas. The presence of ferrous metals will cause anomalous readings from the local background reading, thus locating potential contaminants.

The first step in the Magnetometry Surveys was the establishment of stations (usually on a grid) where readings would be taken. A base station was established at a background location and an initial reading taken. Readings were then taken and recorded, along with the station location, with a final base station reading at the end of the day, or at survey completion. The operator periodically returned to the base station to record a new reading and the time it was taken. These base station readings were used to check against any ongoing magnetic storms or to correct the survey data for diurnal variations. Any observable metal in the survey area was logged and located so that any correlation with magnetic anomalies could be determined later.

Data were reduced, starting with diurnal variations. The base station readings were adjusted to a baseline value and these adjustment interpolated and applied to the intervening data readings. This data was then posted on a base map and contoured. Appendix E contains data from the surveys.

5.1.2 Test Pit Excavation

Test pits were excavated with a backhoe at selected sites to determine areas of possible contamination. Excavations were in areas identified by ground penetrating radar or electromagnetic surveys or where research indicated subsurface contamination might exist. An E & E geologist classified soil and collected a maximum of two samples from each test pit. Procedures followed for test pit excavations at the Annex are noted below:

- Test pits were approximately 10 feet long, 3 feet wide, and 6 to 12 feet deep. Test pit excavations were performed in Level D personal protective equipment (PPE) at all sites except Site A8, which was performed in Level B and Level C PPE. Final test pit dimensions were adjusted in the field when further digging was required to assess the extent of contamination. Refer to test pit logs in Appendix C for soil classification data.

- At each study area where test pit excavations were performed, a temporary decontamination area was constructed for steam cleaning the backhoe bucket. The decontamination water was containerized by pumping from the decontamination pad to a 55-gallon drum mounted on a flat bed truck. The drums were then transported to the main decontamination area, secured, labeled, and stored with the other drums of decontamination water.

- After completion of field investigation activities, the drums were stored in the warehouse at P13 with other drums containing investigation-derived wastes for future disposition pending the outcome of the site-specific investigations.

- Two grab samples were collected from each test pit. Volatile organics grab samples were collected first from the backhoe bucket at each of two depths sampled. Soil was then collected from the backhoe bucket with a QC-compliant, stainless-steel spoon. The remaining composite samples were collected after the soil from each interval was homogenized in aluminum pie tins.

- Each test pit was backfilled after the final soil sample was collected and the soil classification completed. All excavated material was returned to test pits during backfilling, as no material was encountered that posed an immediate hazard to the environment.

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5.1.3 Subsurface Soil Sampling

Subsurface soil samples were collected and analyzed to determine the vertical and horizontal extent of contamination in the subsurface. Presented below are the procedures followed for subsurface soil sampling at the Annex:

- Boreholes were drilled using hollow stem augers. All borings were completed to a depth just below the water table (not greater than 20 feet). Refer to bore logs in Appendix A for soil classification data.

- A 2-foot long, 2-inch diameter, stainless-steel split-spoon was driven at 5-foot intervals from the ground surface to just below the water table, using a 140-pound hammer with a 30-inch free fall. A 3-inch diameter split-spoon was used when additional soil volume was required for QC samples. If low sample recovery or split-spoon refusal was encountered, an additional split-spoon was driven within the auger hole at the same interval, at a point offset from the original split-spoon location.

- Samples for analysis were collected from one split-spoon recovered above the water table and one split-spoon recovered within the water table, at each borehole location. This was done to assess soil infiltration rates in the vadose zone and soil conductivities in the phreatic zone.

- A gasoline-fueled power auger was used to conduct subsurface soil sampling in areas that could not be reached with a drill rig or a backhoe. A 6-inch diameter, solid-stem auger was used to achieve a maximum depth of 5 feet. Samples were taken directly from the cutting collected at the 1.5 and 4.5 foot depths.

- Samples were collected with a clean stainless-steel spoon. The soil for the composite samples was homogenized in aluminum pie tins after each volatile organic grab sample was collected.

- Any rocks, twigs, leaves, or other debris that were not representative was removed from samples before homogenization.

- Sample bottles were labeled with indelible ink and sealed with custody tape. Chain-of-Custody forms were completed, and samples were placed in a temperature-controlled chest and delivered to the laboratory.

- All boreholes were backfilled with Portland cement mixed with 5% bentonite (grout). The grout was mixed by hand in a 55-gallon drum and poured into the borehole until it was level with the ground

surface. Grout in each borehole was allowed to settle overnight. After settling, additional grout was added to each hole until once again level with the ground surface. Power-auger boreholes were backfilled with drill cuttings.

5.1.4 Geotechnical Samples

USAEC requires that physical soil testing be conducted on 10 to 20 percent of the soil samples collected for lithological description and that lithological samples be collected at 5-foot intervals. Those samples not sent for analysis are retained by the installation as archive samples. The SI drilling program generated geotechnical samples which were subjected to various soil engineering tests. Procedures followed for geotechnical samples are noted below:

- Soil samples were collected for lithological description during well installation and soil borings, as described in Section 5.1.7.

- Sieve grain-size analysis was performed in most cases on one sample collected at each well location and at each sediment location and on selected surface soil samples collected at sites in each watershed. At only one borehole (E3-A12-B01) was a sample collected for sieve grain-size analysis. Samples were subsequently defined using the Unified Soil Classification System (USCS).

- Atterberg Limits analysis (ASTM D4318) was requested for all grain-size samples and performed when possible. The index of plasticity could be determined only on samples with sufficient fine-grained material to allow such a test. The laboratory made that determination at the time of testing. Appendix D provides a summary of all the geotechnical samples submitted for analysis.

5.1.5 Surface Soil Sampling

Surface soil samples were collected at Annex sites to characterize background conditions, determine the nature and extent of contamination, evaluate potential human and ecological health risks, and to assess the potential migration of contaminants. The procedures followed for surface soil sampling are presented below:

- Each location was staked and marked for future reference and sample locations were plotted on the site maps. The distance and direction from a reference point to a sampling point was also recorded.

- Personnel took care to use a new set of clean, disposable gloves when handling sample bottles.

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- Surface soil samples were collected from a depth of 0 to 6 inches at each sample location, using a disposable stainless steel spoon. Care was taken to avoid the collection of leaves, roots, sticks, and rocks.

- All samples, except those for volatile organics, were homogenized in a disposable pie tin before filling the appropriate container.

- Samples for volatile organics were collected first and immediately placed in the appropriate containers before homogenizing the sample.

- Any observed physical characteristic of the soil (e.g, color, odor, physical state) was recorded in the site log book.

- Sample bottles were labeled with indelible ink protected with clear tape. Custody seals were placed on all jars. Chain-of-custody forms were completed, and samples were packaged in a temperature-controlled chest and shipped to the laboratory.

5.1.6 Field Screening

Field screening for PCBs in subsurface and soil samples was conducted at Site A12. Field testing of surface and subsurface soil borings was conducted using the ENSYS PCB RISc Soil Test System (Ensys Inc., Research Triangle Park, NC). The system is based on an immunoassay/photometric detection method developed to qualitatively identify 95 percent of samples that are free of PCBs at concentrations greater than 1 ppm. The system control is established through the use of 1 ppm and 10 ppm standards.

The PCB screening procedure consists of three phases. Phase 1, Preparation and Extraction of the Sample, involves the weighing, extraction, and filtration of each sample to be tested. Phase 2, Sample and Standard Preparation, involves the quantitative dilution of the samples and standards to be used. Phase 3, The Immunoassay, entails incubation, enzyme addition, color development, and photometric measurement of the results. The presence of PCBs is determined by comparing the photometer reading of the standard to that of the samples at two dilution levels. Since an inverse relationship exists between PCB concentration and color intensity with this method, the lighter the color of the solution, the higher the concentration of the PCBs. Accordingly, readings of negative or zero indicate the presence of PCBs. When tested at two different solution concentrations, the relative concentration of the PCBs is determined qualitatively.

5.1.7 Monitoring Well Installation

Twenty-seven new monitoring wells were installed to monitor the groundwater at the Annex. Boreholes were nominally eight inches in diameter and wells were screened in unconsolidated material.

All wells were advanced using hollow stem augers to approximately 3 feet below the water table. The soil samples were collected at 5-foot intervals with a hammer-driven, 2-inch by 2-foot split spoon, as described in Section 5.1.3. Samples were screened with an OVA, and the soil was classified and logged by an E & E geologist. One archive sample from each split spoon was collected for storage on-site. Samples were also collected from a split spoon in the screened interval for chemical and geotechnical analyses. Analyses included Total Organic Carbon (TOC) content, grain size distribution, and Atterberg limits.

All wells were constructed with USAEC-approved materials. The well casing and screens were flush-threaded, 4-inch inside diameter (ID), schedule 40, polyvinyl chloride (PVC). All screens were No. 10 (0.010 inches) slot. No glue or solvents were used on the casing and screen. A threaded cap was placed on the bottom of each screen and expandable caps were placed on the top of each riser.

No. 10 sand was placed as a filter pack from the bottom of the well to a point not less than 5 feet above the top of the screen. Then, a 5-foot-thick, bentonite seal was placed on top of the filter pack and allowed to hydrate. A 5-percent bentonite/portland cement was placed in the well annulus by tremie pipe to the surface. A 6-inch-diameter, steel, protective surface casing was placed in the grout column and a mortar collar was then poured between the protective casing and the riser. Finally, four steel bumper posts were placed around each well. Appendix B contains well construction details for all newly installed monitoring wells. Completed bore logs and well construction logs were sent at the end of each field date to USAEC site geologists.

When conditions in the field required construction parameters to be changed, the USAEC representative was consulted prior to any deviation from the work plan. For example, groundwater was very near the surface at some locations and placement of the screen across the top of the water table required the use of an annular seal of less than 5 feet and, in some cases, a filter pack that extended 1.5 feet, as opposed to two feet above the top of the screen. Well construction details are presented in Appendix B.

Well E3-P03-M01 was drilled with an air hammer because glacial till was encountered. Also, 2-inch, inner-diameter casing and screen was substituted for 4-inch, inner diameter casing and screen. All other specifications conform to Work Plan requirements.

All drilling equipment was steam-cleaned to remove oil, grease, and other matter prior to the start of on-site drilling. Rinse water was containerized in drums. All well screens and casings were free of foreign matter and washed with approved water prior to use. Specifications for material, sand, and equipment used in monitoring well installation were USAEC approved.

5.1.8 Monitoring Well Development

Before well development, the static water level was measured from the top of the casing and recorded. Conductivity, pH, turbidity, and temperature were measured and

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recorded, before, twice during, and at completion of well development. Monitoring wells were developed between 48 hours and seven days after installation.

Well development was accomplished with a submersible pump for wells with adequate recharge or with stainless-steel, bottom-filling bailers for slow-recharging wells. The bottom-filling bailer was used to remove sediment from the wells prior to insertion of the submersible pump. All of the development equipment was decontaminated with USAEC-approved water prior to insertion in each well to avoid cross-contamination.

Each well with adequate recharge was pumped until it yielded turbid-free water or was stabilized in terms of pH, conductivity, and/or temperature. During development, water was removed throughout the entire water column by periodically lowering and raising the pump in the well. The number of linear feet of static water (difference between static water level and total depth of well) was calculated and static water volume was estimated using the following formula:

V (in gallon) = 5.8752 (conversion factor for gallons) x C^2 x H
C = Casing diameter in feet
H = Height of water column in feet

At a minimum, the standing water volume in the well was removed five times, whenever recharge rates allowed. Also, where drilling water was introduced into and lost in the well, an additional volume (five times the measured amount of lost water) was removed.

All development fluids were handled, characterized, and containerized by using the procedures outlined in Section 5.1.10 of this report.

5.1.9 Groundwater Sampling

Groundwater samples were collected to determine groundwater quality and assess the need for future groundwater remedial action. Groundwater samples were collected from a total of 62 wells -- 27 newly installed wells and 35 already-installed wells. Two rounds of groundwater sampling were performed. During the first round of sampling in August 1993, a total of 61 wells were sampled. During the second round in December 1993, a total of 32 wells were sampled (27 newly installed and 5 previously installed near Site P13). Monitoring wells and staff gauge locations at the Annex are presented in Plate 2 in a pocket at the end of this volume. As required by USAEC Geotechnical Specifications (USATHAMA 1987), the following procedures for groundwater sampling were used:

- A minimum period of two weeks was allowed between well development and sampling.

- Water-quality field instruments, such as the Horiba® U-10 Water Quality Checker, were calibrated daily before samples were drawn.

- Equipment used to measure groundwater conditions was decontaminated before the initial use and before proceeding to a new location.

- Clean plastic sheeting was spread around wells to protect the sampling equipment from ground surface contamination. New protective sheeting was used at each sampling location.

- The depth from the top of the well casing (not the protective casing) to the top of the water was measured to the nearest 0.01 feet with an electronic water level indicator and the depth was recorded in the sampling logbook.

- The depth from the top of the casing to the bottom of the sediment/water interface was measured and recorded. In cases where the well was dry, the depth of the well was measured.

- The height of the water column was obtained by subtracting the depth to top of the water from the depth to the bottom of the sediment/water interface.

- A quantity of water equal to five times the calculated volume of water in the well, including the saturated annulus, was removed from the well. The wells were purged using a 2-inch diameter submersible pump, or a stainless steel bailer, or polyethylene disposable bailers.

- Samples of groundwater were collected and measured for temperature, specific conductance, pH, and turbidity before purging, at regular intervals during purging, and after each well volume was evacuated. Purging was considered to be complete when turbidity measurements reached 50 nephelometric turbidity units (NTUs) and remained constant. It should be noted that constant measurements could be obtained when NTU measurements were still one or even two orders of magnitude greater than the EPA Region I recommended criterion of 5 to 10 NTUs (OHM 1993a).

- When a well went dry during pumping or bailing, and the recovery rate was rapid, the well was allowed to recover to its original level and evacuated a second time before sampling. If recovery was very slow, samples were obtained as soon as sufficient water was available.

- Purge water was handled and characterized in accordance with the methods and procedures described in Section 5.1.14.1.

- Samples for chemical analysis were obtained immediately after pumping or bailing was completed. For slow recovery wells, the sample was collected immediately after sufficient volume was available.

- Sample bottles were triple-rinsed with the water being sampled before filling the bottle with the sample to be analyzed. Bottles for filtered samples were rinsed with filtered sample water and bottles for unfiltered samples were rinsed with unfiltered water.

- Care was taken by personnel to use a new set of clean, disposable gloves when handling sample bottles.

- Samples were preserved in the field immediately after sampling. Samples were collected using a disposable, bottom-loading polyethylene bailer secured with nylon or polyethylene rope. Samples were poured directly from the bailer into the sample container.

- When sampling for volatile compounds, the preservative was added first and vials were filled without agitation or splashing to avoid loss of analyte. No air space was left in the vials.

- For other analyses, bottles were filled with the sample and the preservative was added. The pH of samples was ensured by filling an extra glass jar or polyethylene bottle and testing the preserved sample against pH paper. After pH testing was complete, care was taken to avoid air bubbles collecting in the sample VOA vials.

- Field logs were maintained with the site name, well number, date, time, depth to water, purge method, volume purged, sampling method, sample appearance, weather conditions, and any relevant observations.

- Sample bottles were identified with computer-generated bar code labels or with indelible ink, protected with clear tape, and then custody seals were placed over the tops of the bottles. Chain-of-custody forms were completed and samples were packaged in a temperature-controlled chest and shipped to the laboratory.

Groundwater Filtering for TAL Metals

Filtered samples were collected for metals analysis from a total of 32 wells at the Annex, using an in-iine filter and a centrifugal pump, as described below.

- The in-line filter (0.45 micron pore size) is attached to a 1-foot to two foot piece of Tygon® tubing. Prior to collecting the sample, 100 mls of 10 percent nitric acid solution are drawn through the tubing and filter. The tubing and filter are then rinsed with 1 liter of deionized water by drawing the water through the apparatus. The Tygon® tube is placed in the unfiltered container and the filter outlet is set to drain into an unrinsed, 1-liter polyethylene container. The pump is turned on and three 30-ml portions of filtrate are used to rinse the sample container. The sample is then collected by starting the pump and collecting the sample in the rinsed, 1-liter polyethylene container, The filtered sample is then preserved with nitric acid to pH <2.

5.1.10 Surface Water and Sediment Sampling

Surface water and sediment samples were collected in several areas of the Annex to determine background levels, assess potential health risks, and determine the nature and extent of contamination. Surface water and sediment locations are presented in Plate 4 in a back pocket of this volume. Dissolved oxygen, pH, temperature, and specific conductivity were measured immediately before surface water sampling with a Horiba® RU10 water quality meter. Sediment samples were collected in areas of low flow/turbulence or deposition and an effort was made to collect samples of greater than 30 percent solids by decanting excess water, as required by USAEC guidance. TOC and grain-size analyses were performed on all sediment samples. The procedures followed for surface water/sediment sampling at the Annex are noted below:

- Surface water samples were collected in conjunction with sediment samples except when the location was void of standing water.

- Before sampling, equipment was triple-rinsed with stream water downgradient from the sampling points, taking care not to disturb sediments.

- For surface water samples, the sample bottles were triple-rinsed with the water being sampled before filling the bottle with the sample to be analyzed.

- Sample collection began at the furthest downgradient location and proceeded to the upgradient locations.

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- Sample vials were only handled with a new set of clean, disposable gloves.

- At each sample location, the surface water sample was collected prior to the sediment sample.

- The surface water sample was collected by immersing the sample bottle in the surface water body, when possible. When the surface water body was too shallow to fill the sample container by immersion, a new, clean, small, glass bottle was used to fill the container. Care was taken to minimize the collection of floating debris, suspended solids, or sediment.

- Sediment samples were collected using a disposable stainless steel spoon. Volatile organics samples were taken first. All other samples were homogenized in a dedicated disposable aluminum pie tin before putting them in their appropriate containers. Care was taken to avoid the collection of leaves, roots, sticks, and rocks.

- When surface water samples for volatile organics were collected, the vials were filled without agitation or splashing to avoid loss of analyte. No air space was left in the vials.

- Surface water samples were preserved in the field immediately after sampling. Specific sample preservation and holding time requirements are presented in Section 5.1.15. For volatile organic analyses (VOA), preservatives were added to samples prior to filling the bottle. For other analyses, the bottles were filled with the sample, and then preservatives were added. The pH of samples was ensured by filling and preserving an extra bottle for each analyte before testing with pH paper.

- Physical characteristics of the sample media were recorded on the field sample collection report.

- Sample bottles were labeled with bar codes or indelible ink and protected with clear tape. A custody seal was placed over the top of the bottles. Chain-of-custody forms were completed and samples were packaged in a temperature-controlled chest and shipped to the laboratory.

- Each location was staked and marked for future reference. Sample locations were plotted on the site maps. The distance and direction from a reference point to a sampling point was also recorded.

5.1.11 Bioaccumulation Study of Puffer Pond and Ministers Pond

The bioaccumulation study of Puffer Pond at the Annex and Ministers Pond, a comparable background pond, was performed in order to determine concentrations of specific chemicals in fish at Puffer Pond, and the potential risks to humans and fish-eating wildlife of consuming fish from the pond. Field procedures, work performed, and the results of the study were developed as a stand-alone document entitled the Bioaccumulation Study at Puffer Pond. This study was issued in draft form in July 1994 (E & E 1994b).

5.1.12 Hydrogeologic Assessment

Hydrogeologic, or groundwater, assessment of the Annex involved the following activities:

- Performing slug tests on all newly installed E & E wells to derive hydraulic conductivity values for the unconfined outwash aquifers underlying the Annex;
- Surveying wells and surface water gauges and collecting water level data to derive hydraulic gradient and directions of flow;
- Collecting water quality data to evaluate natural and contaminant groundwater chemistry;
- Developing an Annex-wide groundwater elevation contour map;
- Estimating recharge, discharge, evapo-transpiration, and runoff, and incorporation of all appropriate data into an Annex-wide three-dimensional groundwater model; and
- Calibrating the model and conducting sensitivity analyses to assess the most important factors controlling groundwater hydraulics.

5.1.12.1 Hydraulic Conductivity Slug Testing

Slug testing is performed to derive a preliminary characterization of the hydraulic conductivity and/or transmissivity of the aquifer. All new wells were subjected to slug testing to determine hydraulic conductivity of the aquifer. The method used for displacing water in the wells consisted of lowering a sealed polyvinyl chloride (PVC) pipe, weighted with sand (the "slug"), into the well until the water level stabilized before rapidly withdrawing the slug. Water-level response was collected using an electronic data logger (e.g., Hermit 1000® or Hermit 2000®) manufactured by INSitu, Inc. and pressure transducer system (e.g., 10 or 20 psi transducer).

11:UC6101-3/RC1132_VJ-09/22/94-F1
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Slug test response data was analyzed using the method of Bouwer and Rice (1976), updated in 1989, or Cooper *et al.* (1967). The method selected was determined by the hydrogeological condition of the aquifer and assumptions inherent for each method.

5.1.12.2 Groundwater Elevations and Well Location Survey

Each of the 27 newly installed wells was surveyed by a licensed surveyor. The elevations of each well at ground surface, at the top of the riser, and at the top of the protective well casing were surveyed to ± 0.05 feet, and referenced to the Massachusetts State Plane Coordinator System of 1983 and the National Vertical Datum of 1983. The survey data were recorded in accordance with USAEC geotechnical requirements. Monitoring wells were located on the Annex base map. Map coordinates were transferred to the USAEC IRDMIS. The coordinates were first transformed to the former Massachusetts coordinate system of 1929, using CORPSCON (version 3.01 software) by the National Oceanographic and Atmospheric Administration (NOAA). These data supported the development of the Annex-wide groundwater elevation contour map and were used in development of the groundwater model. Groundwater monitoring well locations are presented in Plate 2 (located in a pocket at the end of this volume).

5.1.12.3 Groundwater Modeling

A detailed groundwater flow model of the Annex was developed based on the following data:

- Geologic data from the USGS geologic mapping and from E & E mapping and reports;
- All lithological data;
- Bedrock elevations from borehole and seismic results;
- Topography (digital elevation model from USGS or MDEP photography);
- Stream and river locations and stages;
- Wetland areas;
- Slug and pump testing results;
- Pumpage from on-site and nearby municipal wells; and
- Well water levels (on diskettes).

A three-dimensional groundwater flow model was set up and calibrated. The USGS MODFLOW model was used. The modeling is of two layers that encompass all of the Annex

- the unconsolidated glacial aquifer and the upper part of the bedrock aquifer. The area modeled is approximately 3 by 3.5 miles. Model sites were selected as they relate to boundary conditions, such as drainage divides and water bodies. Grid spacing is approximately 250 feet.

Hydrogeological functions simulated in the model included recharge, pumpage, and groundwater runoff to streams and ponds. Groundwater runoff in a perennial surface water stream on the Annex is simulated using the stream routing package MODFLOW. The model is calibrated using a set of monitoring-well water levels. These water-level measurement were taken on 13 September and 3 December 1993, when all wells and staff gauges were measured at one time.

A sensitivity analysis was performed using three parameters varied from their calibrated estimate (both higher and lower). A full description of the groundwater model is included as Appendix H of this report.

5.1.13 Procedures for Ecological Characterization

To identify ecological receptors, E & E conducted several field surveys throughout the Annex. In May 1993 a rapid bioassessment was conducted in a couple of streams within the Annex; in July 1993, a detailed field survey was conducted at sites P11, P13, P36, P37, and A12; and in November 1993, a bioaccumulation fish study was conducted in Puffer Pond and a comparable off-site pond. Ministers Pond, across the Assabet River in the Town of Stow, was chosen. In addition, a thorough literature study of the existing environment in the general vicinity of the remaining E & E sites within the Annex was conducted. The following provides a brief description of the procedures for these various studies.

Bioaccumulation Study of Puffer Pond

The main purpose of this study was to address concerns about Puffer Pond's suitability for public use and recreation. More specifically, the bioaccumulation study was conducted to determine whether elevated levels of contaminants are present in fish found in Puffer Pond as compared to those found in similar, off-site ponds. An E & E field team employed both active (electroshock and angling) and passive (gill netting) fish sampling techniques to collect fish from Puffer Pond. A total of 24 fish (eight pickerel, eight perch, and eight brown bullheads) representing three tropic levels (predator, forager, and bottom scavenger) were collected from six locations throughout Puffer Pond. In addition, the field team collected a surface water and a sediment sample for lab analysis from each location.

Ministers Pond, a local, off-site pond, was selected to determine the local and regional levels of metals and organics and to use as a background comparison because its water chemistry and soil species composition is similar to that of Puffer Pond. Ministers Pond, like Puffer Pond, is a shallow, mesotrophic to eutrophic waterbody with tannic waters and a comparatively low pH. The field sampling procedures used were the same as those previously described for Puffer Pond. A total of 19 fish (eight pickerel, seven perch, and

11:UC6101-3/RC1132_V1-09/22/94-F1
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four brown bullhead), and six surface water and sediment samples were collected from six different locations throughout Ministers Pond.

A full description of this study, its results, and the conclusions that may be derived from it are presented in the Draft Bioaccumulation Study at Puffer Pond issued in July 1994 (E & E 1994b).

Rapid Bioassessment

Rapid Bioassessment Protocol II (RBA II) is a method of determining, over short periods of time, with moderate field effort, the biological condition of a stream or river, and whether or not the system is impaired from its natural state. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish* (USEPA 1989a) as set forth by the EPA (EPA/444/4-89/001), was used on aquatic macroinvertebrate communities in selected streams near Sites P11, P13, P36, P37, and A12. For a full description of the RBA study conducted at the Annex, please refer to Appendix L.

Ecological Characterization of sites P11, P13, P36, P37, and A12.

In July 1993, E & E conducted a field survey to identify the vegetation cover types, wetland boundaries, and plants and animals in the general vicinity of sites P11, P13, P36, P37, and A12. Details and methodology of the survey are listed below.

- Vegetation survey: This floral survey was conducted to identify common plants in the vicinity of the sites. Also, any occurrence of Trustee species or plants on the Federal Endangered Species List and any areas displaying obvious signs of stress were noted during the survey. The methodology involved simple observation and followed the guidelines provided in the *Ecological Assessment of Hazardous Waste Sites: A Field Laboratory Reference Document* (USEPA 1989a).

- Wildlife Survey: This survey was conducted to determine the diversity of mammal, bird, reptile, and amphibian species in the general vicinity of the site. Visual observations made at the site generally followed the EPA guidelines cited above. Particular attention was paid to Trustee Species and species on the Federal Endangered Species List. In addition, a literature review was conducted so that any relevant information obtained in previous studies (Hunt 1992; Aneptek 1991; Butler 1992) could be incorporated into the report.

- Wetlands Delineation: E & E performed wetland delineations in the immediate vicinity of Sites P11, P13, P36, P37, and A12. The methodology used in this effort follows the procedures outlined in the USAEC *Wetlands Delineation Manual* (USAEC 1987) and the New

England Division of the USAEC *Wetlands Delineation Guidance* document (USAEC 1991). In general, the field survey included the following steps:

- The area of interest was located on a USGS Topographic map and the approximate site boundaries were delineated on the map. All available wetland maps, including National Wetland Inventory (sometimes referred to as USDOI maps and state wetlands maps) were reviewed.

- The Soil Conservation Service (SCS) county soil survey map, recent aerial photographs of the project area, and available site-specific information, were also reviewed prior to the field survey.

- An on-site field investigation was conducted to determine if the site fulfilled all three wetland criteria: the parameters of hydric soils, hydrophitic vegetation, and wetland hydrology.

- Finally, all wetland boundaries were flagged and identified on a site map.

Ecological Characterization of Remaining SI Sites

E & E reviewed various maps and reports to conduct the ecological characterization for the remaining sites. Details are provided below.

- Upland Vegetation: information on the dominant vegetation cover type surrounding the sites was obtained from the Forest and Land Cover Map (Leupold Forestry Service (LFS) 1983) and from observations made during a site walkover conducted in October 1993.

- Wetland Types: *The National Wetlands Inventory Map* (USDOI 1977) and *Fort Devens Annex Inventory Summary Report* (Butler 1992) were used to identify the various wetlands in the general vicinity of each site.

- Habitat Types and Wildlife Utilization: E & E evaluated the various cover types (i.e., species composition) to determine their value to wildlife: as food, cover, nesting, protection, and roosting. This information was obtained from the following sources: *The Field Guide to Wildlife Habitats of the Eastern United States* (Benyus 1989); New England Wildlife: *Habitat, Natural History, and Distribution* (DeGraaf 1992); and *American Wildlife and Plants: A Guide to Wildlife Food Habits* (Martin *et al.* 1951).

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11:UC6101-2/RC1132_V1-07/13/94-D2

- Species of Concern and Unique Habitats: E & E obtained information on species of concern and unique habitats for the general vicinity of each site from *An Environmental Inventory of Wildlife Species and their Habitats* (Aneptek 1991), *Floristic Survey with Emphasis on Rare Species of the Sudbury Annex of Fort Devens, Massachusetts* (Hunt 1992), *Fort Devens Annex Inventory Summary Report* (Butler 1992), and the *Atlas of Estimated Habitats of State-Listed Rare Wetlands Wildlife* (NHESP 1992).

5.1.14 Control and Disposal of Investigation-Derived Wastes

In the course of collecting environmental samples and conducting field work at the Annex, E & E field personnel generated different types of potentially contaminated investigation-derived wastes, including: soil cuttings, drilling muds, purged groundwater, disposable sampling equipment, and disposable PPE. Protocol for controlling and disposing of such wastes was developed by Fort Devens, USAEC, and EPA for the Fort Devens NPL Site (Fort Devens 1991), and has been adopted for application to the Annex. E & E used the procedures described below at the Annex to classify and handle its investigation-derived wastes.

5.1.14.1 Screening Procedures

The screening procedures for the Annex were as follows:

- All material (soils and waters) were screened using an OVA. Any materials exceeding background were containerized and further tested as described below.

- The OVA instrument was calibrated at once least daily in accordance with operating/calibration instructions.

- OVA readings were performed using the following headspace, field analysis procedures:

  - Samples were placed in glass containers and the container mouth was covered with aluminum foil and capped;

  - Samples were allowed to stabilize at a temperature of at least 20 degrees Celsius for at least 45 minutes;

  - The sample container was then removed, exposing the inner aluminum foil cover. The foil cover was pierced with the OVA probe to measure the total organic vapor concentration in the sample headspace.

- For well and soil borings, the sample was collected from the split-spoon samples obtained for each 5-foot auger flight interval. Auger cuttings were also examined for signs of contamination (i.e., staining or free product).

- For well development and purge water, the water was collected in 55-gallon drums. One sample for OVA evaluation was obtained from each drum.

- For decontamination liquids, at least one sample for OVA evaluation was collected from each drum of the containerization "pad" water prior to any discharge being permitted.

5.1.14.2 Material Handling

Soil and liquids exceeding background were containerized for further testing described below. Soils were consolidated in U.S. Department of Transportation (DOT)-approved, 55-gallon drums. Liquids were also consolidated in DOT-approved, 55-gallon drums.

Soils and liquids whose corresponding OVA samples were no more than background were disposed of at the site of generation. Liquids were discharged to the ground so that surface runoff was minimized.

5.1.14.3 Waste Classification Analysis

Wastes generated during the course of field work for the SI investigations were containerized following the procedures noted in the section above. These wastes are currently staged onsite at the Annex and will be classified by the U.S. Army prior to their disposal.

5.1.14.4 Waste Minimization

The principle goals of waste minimization efforts were to reduce the quantity of wastes generated, to leave wastes on site that do not require off-site disposal, and to remove wastes that do pose a threat to human health or the environment. Investigation methods that minimized the generation of wastes were used where they were feasible and not in conflict with sampling procedures required to avoid cross-contamination. The field teams limited their contact with contaminants and potentially contaminated material during sampling activities whenever possible.

Wastes that were apparently not contaminated were left on site. Soil cuttings were spread around the well location, if no levels above background were recorded after testing the cuttings with an OVA. Purged groundwater was screened with an OVA. If no readings above background levels were recorded, the water was discharged to the ground and allowed to infiltrate. PPE and disposable sampling equipment used during the investigation are being

temporarily staged in a secure location on site. Classification and disposal of wastes will be performed at a later date by the U.S. Army.

5.1.15 Sample Collection, Preservation, and Handling

During field investigative work, care was taken to adhere to the standardized sample collection protocols set forth in the E & E Sudbury Training Annex Quality Assurance Project Plan (E & E 1993). Sample collection procedures were as follows:

- Prior to mobilization to the sampling site, the appropriate number and type of precleaned containers were selected and the containers were labeled with the appropriate preprinted labels.

- Upon the sampler's arrival at the sampling location, the time, date, and sampler's initials were recorded on the preprinted label with waterproof ink and the label covered with clear tape for protection.

- Bottles to be used for water samples were then triple-rinsed with sample water to saturate the physical and chemical binding sites on the inner surfaces of the bottles to prevent these sites from removing analytes from solution. An exception to this procedure was containers used for VOCs samples, which were not triple-rinsed; they were collected prior to the rinsing of any other containers. During sampling for filtered metals, the polyethylene bottle was triple-rinsed with filtered water to insure that no suspended solids were introduced into the sample bottle.

- To prepare for preservation of VOA water samples, a separate test bottle was used to test the amount of preservation needed to lower the pH of the sample to below pH2. This was accomplished by adding an appropriate amount of preservative to the sample bottle, capping and shaking the container, and then testing with pH paper. Preservation for other samples was accomplished by using a standard of 2 mL of preservative and then checking with pH paper and adjusting as necessary.

- Samples were then collected according to the following general sample analysis priorities. For water samples: total petroleum hydrocarbons (TPHC); TCL BNAs; TCL pesticides/PCBs; herbicides; explosives; organophosphorus pesticides; anions; and TAL metals (unfiltered and filtered). For soils: TAL metals, TPHC, and TOC; explosives, TCL BNAs, and TCL pesticides/PCBs; and grain size and Atterberg limits (if applicable). This sampling scheme was also subject to the priority of the analytes of concern at the site and the standard operating procedures of the laboratory.

- After collection of each sample bottle, the appropriate amount of preservative was added to water samples, and the bottle or jar was then wiped clean and placed in an appropriate container for transport back to the field base, where each sample was placed in an ice cooler to lower the sample's temperature to 4°C or below.

5.1.16 Decontamination Program

The USAF well at the USAF Weather Science Radar Laboratory was selected as the approved water source for decontamination of equipment at the Annex. In order to satisfy USAEC requirements, the deep bedrock well was sampled in September 1993 to characterize water quality. The sampling results verified that no contaminants were introduced to the water used during decontamination. The well was analyzed for TCL organics, TAL metals, explosives, TPHC, and nitrogen as nitrites and nitrates. Samples were also collected from this well by OHM in July and November 1992, to satisfy USAEC requirements. No contaminants were detected during analysis of these samples.

Sampling methods and equipment were chosen to minimize decontamination requirements and prevent the possibility of cross-contamination. Non-disposable equipment was decontaminated between discrete sampling locations. All drilling equipment was decontaminated prior to drilling, after drilling each monitoring well or borehole, and after the completion of all monitoring wells and boreholes. Specific attention was given to the drilling assembly and augers. PVC casing and screens were kept in sealed containers and cleaned with a high-pressure washer prior to use. Drilling equipment decontamination included:

- high-pressure cleaning;
- scrubbing with brushes, if visible contamination remained on equipment; and
- high-pressure rinsing.

Split-spoon and other non-disposable sampling equipment were also decontaminated between each sampling event. Sampling equipment decontamination included:

- high-pressure cleaning (for split-spoon);
- scrubbing with brushes;
- triple rinsing with USAEC-approved water; and
- air drying.

A temporary decontamination pad was constructed by the drilling subcontractor near the E & E site trailer at the main gate. The specifications for the pad required using an approximately 12-foot by 12-foot area with a defined perimeter approximately 6 inches high,

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11:UC6101-2/RC1132_V1-07/13/94-D2
ecology and environment

lined with heavy plastic sheeting to collect decontamination waters and sediments. The primary purpose of the pad was to decontaminate heavy equipment such as augers, well casings, and screens.

5.2 ANALYTICAL PROGRAM

5.2.1 Methods, Analytes, and Detection Limits

Chemical analyses for the Annex field investigations were performed at E & E's Analytical Services Center (ASC) in accordance with the E & E Master Quality Assurance Project Plan (MQAPjP) prepared in support of analytical work under contracts for Technical Environmental Program Support (TEPS) for the USAEC (E & E 1993). Analyses performed at DataChem Laboratories and Environmental Science and Engineering Laboratories were performed in accordance with EPA validated methodologies or the methodologies previously certified for other projects. Specific methods, analytes, and detection limits are listed in Appendix F.

5.2.2 Quality Control Program

5.2.2.1 Field QC Samples

Various types of field QC samples were used to check the effectiveness of field sample-handling methods. They were analyzed in the laboratory as samples, and were used to assess whether or not the sampling and transport procedures were possible sources of sample contamination and to determine overall sampling and analytical precision. The evaluation of field QC results and the potential impact on the data usability are described in Section 5.3.3.

The field QC samples collected for each watershed are described in Volume II. A summary of the field QC results is provided in Appendix F. A general description of the type of field QC samples collected is provided below.

- ***Trip Blanks*** are field blanks that were not exposed to field conditions. Their analytical results provided the overall level of contamination from everything except ambient field conditions. Trip blanks were prepared in the field the day of sampling and shipped with the sample bottles. Trip blanks were prepared by adding organic-free water to a 40-ml VOA vial containing 2 to 3 drops of concentrated hydrochloric acid. One trip blank was used for every 10 VOA samples and shipped with each sample cooler containing the volatile samples. Each trip blank was transported to the sampling location, handled like a sample, and shipped to the laboratory for analysis without being opened in the field.

- ***Field Equipment/Rinsate Blanks*** are field blank samples designed to demonstrate that sampling equipment was contaminant-free or cleaned before field use and that cleaning procedures between

samples were sufficient to minimize cross-contamination. Rinsate blanks were prepared by passing analyte-free water over sampling equipment and analyzing the samples for all applicable parameters. One rinsate blank sample was collected per ten samples collected per matrix.

- ***Field Duplicates*** consist of a set of two samples collected independently at a sampling location during a single sampling event. Field duplicates assess the consistency of the overall sampling and analytical system. One set of duplicates was collected for every 20 samples of each type of matrix.

- ***Matrix Spike/Matrix Spike Duplicates*** (MS/MSD) are actual field samples identified by the field personnel for additional laboratory QC samples as required by the work plan. The QC samples are spiked in the laboratory to determine the potential effects of matrix interferences on sample analytical results. A set of laboratory matrix QC samples was analyzed for each type of matrix for each watershed. Extra sample volume was normally submitted by field personnel, but all other procedures were handled at the laboratory.

5.2.2.2 Laboratory Quality Procedures

Laboratory chemical analyses for the Annex were performed by E & E's ASC in Buffalo, New York, Environmental Science and Engineering, Inc. (ESE) in Gainesville, Florida, and DataChem Laboratories in Salt Lake City, Utah. All analyses were performed in accordance with the requirements of the *Quality Assurance Guidelines for Implementation of Environmental Regulation 1110-1-263 for USAEC Projects* (USAEC May 1993). The program requires approval of the method and reporting limits by the USAEC Chemistry Branch and requires control of the sample analysis and reporting by the grouping of samples into analytical lots.

Laboratory QC procedures are specified by lot for each type of analytical method. QC samples include standard matrix method blanks and standard matrix spikes at levels near both the lower and upper reporting limit. Spike recoveries are entered into USAEC-supplied software for the generation of control charts. Control charts are used to monitor the variations in the precision and accuracy of routine analyses and detect trends in these variations. Out-of-control results require immediate re-analysis or a complete justification in the weekly control chart reports submitted to the USAEC Chemistry Branch and the project QA coordinator. All data reported outside control limits was rejected or qualified as described in Section 5.3.3. Calibration procedures and other QC procedures are specified by the method. A summary of the laboratory QC results is provided in Appendix F.

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5.3 DATA MANAGEMENT PROGRAM

This section describes the data management program that was implemented to ensure that accurate and complete data were provided for the production of this report and associated electronic deliverables. The discussion below outlines the steps that E & E and the project laboratories followed to ensure the flow and quality of data from input in the field to delivery to USAEC's IRDMIS. The discussion also outlines QA/QC procedures for assessing data useability implemented as part of the analytical data review process.

5.3.1 Database Management

The overall data management program covers three interrelated categories of data, which originate from separate sources:

- map data;
- geotechnical data; and
- chemical data.

The acquisition of field data began with a site visit by E & E personnel and a scoping meeting during the project planning phase. The scoping meeting resulted in the definition of site-specific data requirements, which were incorporated into an addendum to the SI/RI Work Plan, SI/RI Field Sampling Plan, and Quality Assurance Project Plan (QAPjP). The plans provided initial requirements for sampling locations, site identifications (IDs), chemical tests, and QC sample requirements. These initial requirements were subject to review and approval by USAEC and outside regulatory agencies. Any deviations from the approved plans due to site conditions encountered during the field investigation were tracked using the Sudbury Training Annex Site Master Database maintained in E & E's USAEC Project Management Office in Arlington, Virginia. The Site Master Database includes information on the site IDs, field sample numbers, the planned analytical tests, and QC samples. The Site Master Database served as the mechanism for ensuring that samples were collected as specified in the SI/RI Work Plan, Field Sampling Plan, and QAPjP.

Map data for the field investigations were assembled prior to the start of field operations. Each map entry, or record, contains information for one sampling point at the Annex, including the site ID, description, relation to other sites in the map file, site elevation in feet AMSL, and horizontal location of the site based on the Massachusetts State Planar (STP) coordinate system. Site elevation and location were estimated for creation of the map records at first, and then updated with actual data (frequently from a licensed surveyor) after completion of field work. The map file for the Annex currently contains approximately 2,200 data items that define a variety of sample points, well locations, ground contours, etc. The map file was created prior to the start of field work because map records must be in the IRDMIS database before it will accept other data, either geotechnical or analytical.

Geotechnical data were submitted to IRDMIS: during the course of field investigative work. Three categories of geotechnical data were recorded and delivered to IRDMIS: field drilling data, monitoring well construction data, and groundwater elevation data. Field drilling data were logged by E & E geologists during the monitoring well installation and soil boring programs, and consist of descriptions of the lithology encountered during drilling. Monitoring well construction data consisted of the physical measurements of well construction, including the depths at which the well's sandpack, screen, and grout components were installed. Groundwater elevation data were recorded during discrete rounds of groundwater level measurements and were submitted to IRDMIS after the completion of the round.

E & E entered the map and geotechnical data from the standardized form into a microcomputer, using the PC Data Entry and Validation Subsystem Software (IRDMIS PC Tool; PRI 1991), and transmitted to the USAEC IRDMIS system by uploading these files over the 3COM network to the central computer.

For the chemical data, an electronic site ID file from the Site Master Database was sent to the laboratories prior to the field event. The laboratories generated preprinted labels with the appropriate IDs, analytical parameter, and preservation. E & E field personnel completed chain-of-custody (COC) records, including field information, for the laboratory to enter into IRDMIS. At the laboratory the samples were logged into the laboratory management system by comparing them to the site ID file and assigned to individual lots (i.e., analytical batches) for each chemical test. The laboratory then produced sample received reports, lot status reports, and draft data summary tables for review by the project QA chemist at various stages prior to submitting the data to IRDMIS. Discrepancies in the site IDs and assigned chemical tests between the Site Master Database, field COCs, and the laboratory were resolved by the project QA chemist, laboratory data manager, and project manager. After analysis was performed and the lot was determined to be acceptable (see Section 5.3.3), the laboratory entered raw laboratory analytical results using the IRDMIS PC Tool software and produced a transfer file. These data were subsequently group checked, submitted to the project QA chemist for approval, and then uploaded to the central USAEC computer over the 3COM network.

IRDMIS performed validation checks on the quality of these data and noted any exceptions (errors). Data for which exceptions were noted could not be made available for further processing (i.e., elevated to Level III) until the errors were corrected. Weekly error reports were provided to the E & E Project Manager by USAEC. The project QA chemist, E & E data manager, and the laboratory data manager were responsible for ensuring that the corrections were made. In some cases this required consultation with the USAEC chemist prior to approval of the data lot for acceptance at Level III IRDMIS. Once all the data for the event were processed, the IRDMIS results were downloaded into the Site Master Database for data reduction and reporting.

5.3.2 Data Reduction and Reporting

Analytical data were downloaded from IRDMIS when all data for a sample event were processed and any group or record check errors were corrected. The data were transferred to the Site Master Database, a specialized software program E & E developed in dBase III©, a relational database management system, and Clipper© (a compiler for dBase) to implement data reduction operations using E & E's in-house microcomputers.

Chemical data files were divided into two types of data files, field sample data and QC data. The field sample data file contained all required chemical tests for each sample as submitted by the laboratory. The QC data file contained field QC samples (i.e., rinsates, trip blanks, and duplicates); field and laboratory QC samples (i.e., MS/MSD); and laboratory-specific QC samples (i.e., method blanks, standard matrix spikes, and sample surrogate recoveries). Two types of reports were generated, each by site type, watershed, and by sample media: a "hits only" data summary table, and an "all data" table. The "hits only" data summary table provides summarized results for any compound detected in that sample media at each watershed. An "all data" table contains all the results for all parameters analysis for all samples. The tables were initially generated in format for review by the project QA chemist and for addition of any data usability codes, as described in Section 5.3.3. During the initial review the QA chemist also verified that the data were complete and compared them to the sampling requirements specified in the Work Plan, Field Sampling Plan, and QAPjP.

Following review and entry of data usability codes, the tables generated for the report writers and the electronic files were transferred to risk assessors and the computer-aided design (CAD) group for further processing. Because the "all data" table is extensive, it is placed in Appendix M in the form of a diskette. The data summary tables were initially screened for data determined to be usable during the QA review (see Section 5.3.3). The data were then compared against background values or ARARs as described in Section 7. The results above background or ARARs were highlighted and discussed in the Nature and Extent of Contamination for each watershed. Results were also formatted as charts to demonstrate contaminant distribution as appropriate.

5.3.3 Analytical Data Review

Analyses of the Annex samples were performed by E & E's ASC, ESE, and DataChem. Analyses included TCL VOCs, BNAs, Pest/PCBs, TAL Metals, explosives, TOC, TPHC, anions, herbicides, organophosphorus pesticides, and percent solids. A summary of the methods for each laboratory is provided in Section 5.2.2. Analytical data were reviewed at three levels by the laboratory, USAEC Chemistry Branch, and the project QA coordinator.

At laboratory level, analytical data were first evaluated by comparing standard matrix spike recoveries to method-specific control limits. The evaluation was submitted in weekly control chart summaries to the USAEC Chemistry Branch for approval and to the project QA chemist for review. The USAEC Chemistry Branch reviewed all method control charts and

determined acceptability for submission to IRDMIS. The laboratory also notified the project QA chemist if any results might be requested because they were outside control limits, and when re-analysis would be beyond holding times. When possible, these samples were recollected for the specific analysis if approved by the project manager and USAEC project officer. Any other results were qualified as described below.

As a standard of practice, the laboratory assigns a flagging code to designate spike recoveries outside limits, results outside the method linear range, compounds also detected in the method blank, and other analytical concerns. The USAEC Chemistry Branch assigns a data qualifier in IRDMIS based on their review of the control chart submission. It is then the responsibility of the project QA chemists to review both the flagging codes and data qualifiers along with the field quality control results, and to assign a single code indicating data usability. Data usability codes appear on the data summary tables and are described as follows:

- "B" — Sample result is less than five times the result in the associated method blank, rinsate, or trip blank and should be considered not site-related but attributable to background contamination. For common laboratory contaminants, the result is flagged if it is less than 10 times the method blank.

- "J" — Sample result is estimated due to calibration or QC problems, but usable for evaluating site-related contamination. The estimated flag is also used if results are reported below the method detection limit but above the instrument detection limit.

- "K" — Sample result is biased high due to interference, background contamination, or high spike recovery, but usable for evaluating site-related contamination.

- "L" — Sample result is biased low due to low spike recovery, but usable for evaluating site-related contamination.

- "R" — Sample result is rejected and data is not usable for evaluating site-related contamination.

- "U" — Sample result is not confirmed on a second column and, therefore, the compound is not present.

- "C" — Sample result is confirmed on a second column and, therefore, the compound is likely to be present.

Any result qualified with a "B", "U", or "R" was not used for evaluating site-related contamination. Any result with a "J", "K", and "L" was used for evaluating site-related contamination, but any comparison of the values to ARARs was considered questionable.

As discussed in Section 5.2.2.1, several types of field QC samples were taken throughout the investigation. The QC sample results were reviewed and used to qualify analytical data presented for each site as described above. All field QC sample results are presented in Appendix F and discussed briefly below. Specific field QC samples applicable to each watershed are discussed in the Analytical Data Qualification sections for each watershed in Volume II.

Field duplicates were taken for each of the watersheds to assess overall sampling and analytical precision for various matrices. For each duplicate pair, a RPD was calculated for all detected compounds and presented on summary tables in Appendix G. In general, duplicates with high RPDs outside of the EPA Region I criteria of 30 percent for waters and 50 percent for soils against work plan (QAPjP) indicate non-homogeneous sample matrices, or poor sampling or analytical precision, and related sample results are qualified as estimated.

Field blank rinsates were collected throughout the investigation at various sites. The results for all detected compounds are summarized in Appendix F. The rinsates for groundwater were collected from disposable bailers and analyzed for all parameters of concern at that site to evaluate potential residual contamination. Rinsates for groundwater were also collected from the filtering apparatus and analyzed for TAL metals to evaluate potential cross-contamination permitted despite decontamination procedures. The rinsate results are directly comparable to groundwater sample results, and any sample results less than five times the blank level was attributed to background contamination. No rinsates were collected for surface water samples, since no sampling equipment is used in their collection other than the sample bottles themselves. For soils and sediments, reinstates were collected from split-spoon augers and disposable aluminum pie tins used to composite samples. These rinsate results were converted to units of $\mu g/g$, using the final sample volume and the amount of soil used in the comparable soil method, and the sample results were qualified if they were less than five times the converted rinsate values.

Trip blanks were sent with sample shipments throughout the investigation and analyzed for VOCs to assess potential contamination during transport. Generally, all the VOC samples for the day were combined in a single cooler and shipped with a trip blank. The results for detected compounds only are summarized in Appendix F. If the sample results were not qualified from the method blank, the sample result was qualified if it was less than five times the trip blank levels for the day it was shipped.

Samples were also collected for MS/MSD for explosive compounds, pesticides/PCBs analysis and for inorganics analysis. These samples were designated by field personnel as representative matrices for each watershed throughout the Annex. The MS/MSD results are summarized in Appendix F. Both percent recovery and RPD were calculated and compared to EPA Region I criteria for the CLP. If the lot QC spike samples were within control limits, but the MS/MSD results were outside limits, matrix interferences were suspected and the sample results were qualified as estimated.

In addition to the chemical data file, the laboratory produces a hard copy data package with all calibration information, raw data, and a case narrative describing any

problems. All data packages were reviewed by the laboratory QA coordinator. Approximately 10 percent of the packages were reviewed by project QA chemists to ensure that USAEC requirements specified in the QAPjP were followed. The review focused on data packages containing data that exhibited suspect results due to apparent values outside of acceptable limits. For TCL organics and TAL metals, additional lot packages were reviewed to evaluate how the data compare to EPA CLP requirements. All the results were comparable and no effect on data usability was determined.

5.4 HEALTH AND SAFETY PLAN FIELD PROCEDURES

5.4.1 Health and Safety Plan

The Health and Safety Plan Addendum (HASP), (E & E 1993c), developed for field activities at the Annex was designed to ensure that E & E and subcontractor personnel comply with all applicable Federal, State, and local safety and health regulations. The HASP describes specific responsibilities, training requirements, medical and environmental surveillance, hazard communication, protective and emergency equipment, environmental monitoring, and safe operating procedures to be followed at each site.

The Corporate Health and Safety Officer (CHSO) at E & E is responsible to the Program Manager for the overall development of the HASP, based on an analysis of activities planned at the site. The Health and Safety Advisory Committee serves to coordinate the medial and exposure monitoring of field personnel. The Project Manager for the Task Order coordinates implementation of and accessibility to the HASP. The Site Manager and Field Safety Coordinators are responsible for implementing the HASP in the field, and all field personnel (E & E and subcontractor) are required to review and comply with the HASP.

5.4.2 Health and Safety Plan Field Procedures

Prior to any field activities, all field personnel are trained in health and safety requirements. Specialized training is provided, as mandated by site conditions or by activities anticipated during the field work. Site personnel are not authorized for field work unless all health and safety base requirements are met. A Health and Safety Plan containing specific information pertinent to the site is developed for each site. If the plan needs to be amended, a "Site Safety Plan Addendum Form" is completed and submitted to the CHSD for approval. All personnel are required to follow the HASP.

Daily health and safety briefings are conducted prior to field entry to ensure that any concerns related to planned activities are covered and are understood by all team members. Sign-off sheets document attendance and discussions. In addition, teams are required to keep daily logs of all field activities performed, including the daily briefings, other *ad hoc* briefings, significant events, or noteworthy changes in field conditions. The site log is the responsibility of each team leader and is meant to provide a defensible record of the day's activities and field conditions. Past investigation briefings are held after field work is completed in order to review site activities and field conditions and any changes expected for either in subsequent efforts.

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Two types of field equipment are available for use as required. PPE is selected based on an analysis of site conditions and planned activities. Requirements can be revised by the Field Safety Coordinator on an "as needed" basis to meet changing site conditions. Level D was used for most of the site work, except at Site A8, where Level B was used. Environmental monitoring equipment is issued for personnel safety monitoring and is selected to monitor for possible site emergencies or unexpected conditions. Emergency equipment is provided to meet site emergencies.

Communication equipment was provided to field personnel, and information on emergency procedures and the available emergency services was provided to all field teams. It was ascertained that all personnel understood how to respond to an emergency and the correct procedures for reporting an incident or an accident.

6. FACILITY-WIDE INVESTIGATIONS

6.1 WATERSHED APPROACH TO ANNEX INVESTIGATIONS

The size of the Annex and the number of suspected contaminated sites (70 sites Annex-wide) require an overall approach to assessing the Annex's total possible impact on the surrounding environment, in order to complement site investigations tailored for the specific sites.

The nature of the materials used and possibly disposed of at the Annex during its history as a Federal facility is extremely varied. Materials used, spilled, and possibly disposed of could include explosives, solvents, pesticides, herbicides, PCBs, heavy metals, petroleum fuels, oils and lubricants, and even very limited quantities of decontaminated material resulting from testing the permeability of a clothing to a chemical warfare agent (mustard agent). The general public, institutions such as the Massachusetts Fire Fighting Academy, and others have probably also added to potential sources of pollution on and adjoining the site. The question of overall impact is therefore best addressed by asking which media (soil, air, groundwater, surface water, and sediment) are contaminated, and which could represent a hazard to human health or the environment.

Very little evidence has been acquired, during extensive investigations, of any current generalized significant high levels of contamination at the Annex. Sources of contamination that do exist are probably highly localized and directly associated with activities at a specific site. The watershed approach to Annex characterization provides a more specific review of possible contamination linked to sub-zones within the Annex and a further level of detail and a new reference measure for the possible impacts of the Annex on the surrounding environment or risks to human health because of Annex accessibility to the public.

By "watershed approach," the Army means the division of the facility into areas draining to particular streams or surface water bodies, both by surface runoff (minimal at the Annex), and by groundwater flow. Within each watershed, the individual sites are potential sources of contaminants and the surface water and sediments are potential receptors or sinks for contaminants.

At individual sites, soil is generally of concern because it may provide contaminated dust particles to create air pollution, or contaminants may be absorbed or ingested as the result of direct contact. These are local, site-specific concerns, and must be addressed as such.

The most important mobile material at the Annex is water, and this is the medium that may carry contamination offsite and transport contaminants within the Annex from soil to groundwater, from soil to surface water, from groundwater to surface water, and from within a specific site to more widely exposed populations and to the environment.

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The climate, geology, and hydrology of the Annex, while not studied in exhaustive detail, are all well enough known to permit considerable confidence in determining overall flux of water within the Annex, its volume, its origins, and its destination. This permits the selection of a strategy to characterize the impact of individual sites and determine which sites may have joint cumulative impacts on any specific body of water, such as a stream, pond, or river.

The climate of the Annex is humid, with average annual rainfall of approximately 40 to 45 inches. This translates into over three billion gallons of water per year falling on the Annex. Much of this water falls upon vegetation and evaporates before reaching the ground. More reaches the soil surface and is evaporated, or enters the soil and then evaporates or is transpired by plants. All of the remaining precipitation either falls directly into surface water (in swamps, ponds, or streams) or passes through soil down to the underlying water table. This last water is that part of the precipitation (between one-third and one-half) known as infiltration, which can most readily come into contact with hazardous materials in the ground. This can mobilize the hazardous material to create groundwater contamination and, consequently, surface water and sediment contamination, and can cause the most serious harm to people and to the environment.

Although the underlying geology of the Annex is complex, in assessing groundwater flow it can be understood as a relatively simple, three-layer system. The lowest layer, the bedrock, is a complex assemblage of igneous and metamorphic rocks, all of which have extremely low permeability when unfractured or unweathered. They tend to have a weathered or fractured layer within their uppermost levels on which glacial sediments rest, and they tend to be progressively less permeable the deeper they are. These rocks form the areas of the hills on the Annex, so that topographically high points also tend to be high points on the bedrock.

The second layer is till, a heterogeneous mixture of rock fragments, sand, silt, and clay, laid down by an ice sheet. This layer is also of low permeability, and tends to form hills. In between the hills is a complex of glacial outwash deposits, primarily sand and gravel, of higher permeability and of greater surface extent than either bedrock or till.

The lower permeabilities of the bedrock and till hills result in lower rates of infiltration and of groundwater flow, as well as steeper hydraulic gradients needed to sustain the flow. The result is that groundwater flow is almost entirely in the same direction as the slopes of the surface topography, and flow into the outwash deposits surrounding the hills.

The outwash deposits, because of their low surface slopes and sandy, well-drained soils, allow high rates of infiltration, which adds to the water coming off the hills and discharging to the swamps, streams, and ponds on or adjoining the Annex. Much of this flow passes through sediment layers in swamps, streams, and ponds. These sediment layers are often organic-rich, with high TOC, and can adsorb contaminants occurring in the groundwater before it reaches surface water.

The result of the movement of water through the Annex and the discharge of groundwater to surface water is that contaminants move from the soil to groundwater and then to surface water and sediments. Any persistent toxics present in the groundwater discharge can accumulate in sediments and in biota living in the streams and ponds, if the toxics bioaccummulate. The result is that the cumulative impacts of all the sites within a given watershed tend to be concentrated in the sediments and surface waters which drain the watershed. This can affect the health and diversity of the biota living in the surface water, compared to appropriate background locations.

The Annex's irregular topography of isolated hills divided by swamps and streams can be divided into approximately seven watersheds. The largest of these is Taylor Brook, which has several tributaries, including Honey Brook, that originate within the Annex or on land formerly within the Annex. To simplify the investigation of Taylor Brook's drainage basin, its catchment area is divided into two separate watersheds; 1A — Upper Taylor Brook and 1B — Lower Taylor Brook. Other individual watersheds are Hop Brook and its tributaries, which drain most of the detached portion of the Annex south of Hudson Road; Willis Pond and Crystal Lake, southeast of the main part of the Annex; the White Pond/Boons Pond drainage, which receives flow from the west side of the Annex; and two unnamed tributaries of the Assabet, which drain the remaining northern portion of the Annex. Hop Brook and Willis Pond drain to the Sudbury River, and the others all discharge to the Assabet River.

Groundwater monitoring wells have been placed downgradient of many individual sites to assess the impact of those sites on the groundwater before it reaches surface water, or in some locations, before it passes off the Annex or approaches areas where groundwater is being used. These wells can indicate what the probable impacts on surface water or sediment may be and what off-site groundwater may be at risk.

The Army will attempt to discover where discharges from specific sites enter the surface water pathway by taking a number of sediment or surface water samples along a given drainage, and to ascertain what the cumulative impacts of that watershed may be by sampling at the point where the drainage leaves the site or joins a larger stream.

The combination of individual site studies, sediment and surface water studies of individual watersheds, and an integration of individual watershed impacts is being used by the Army to:

- Assess local site impacts;
- Integrate local, adjoining site impacts and migration of contaminants by watershed; and
- Combine individual watershed impacts to define the overall Annex impacts on the Assabet and Sudbury River drainages.

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The total effects on these watersheds will necessarily include those from any hypothetical undiscovered sites, or those from sites within each watershed that appear innocuous and have not been studied in depth.

6.2 E & E BACKGROUND

The results of previous background and facility-wide sampling conducted by OHM, Dames and Moore, and other USAEC contractors, are not presented or discussed in Chapter 6. Previous facility-wide sampling locations and analytical results are used, however, during the analysis of each watershed in Volume II to comparatively assess watershed conditions. Past results provide supporting data for the recommended conclusions also discussed in Section 8 of Volume I. The following sections discuss the background samples E & E collected during the field investigations in 1993. The surface water, sediment, and surface soil samples E & E collected profile natural or background conditions at the Annex. Three surface water and sediment samples were also collected at the Annex or at the exit points or drainages off the Annex to characterize water quality. These samples are discussed under their appropriate watershed and the data are presented at the end of the appropriate watershed assessment.

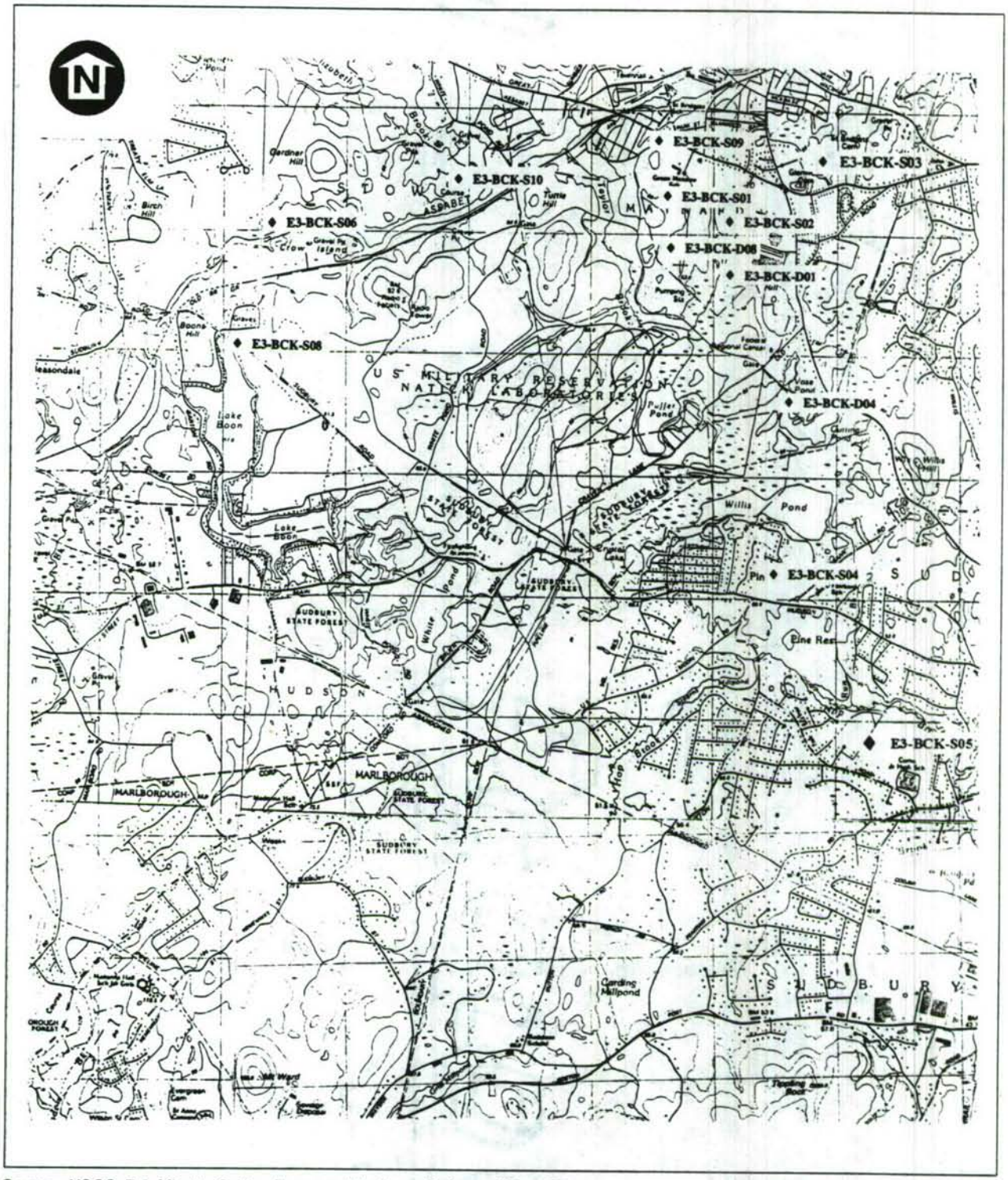
6.2.1 Background Surface Soil Sampling Locations

Ten background surface soil locations, E3-BCK-S01 through E3-BCK-S10, were chosen after consultation with four town representatives of Families Organized to Clean-Up Sites (FOCUS), MDEP, EPA, Fort Devens EMO, and USAEC representatives. The locations were selected to represent the natural regional soil conditions (background conditions) and were used to assess the impact, if any, of sites at the Annex on the local surface soils. During the collection of the initial background surface soil samples, representatives from the EPA and Fort Devens EMO were present to witness the choice of specific locations and the sampling procedures. Surface soil sample locations are included on Figure 6-1.

Sample Locations

- The first sample (at E3-BCK-S01) was collected on 21 September 1993, near Green Meadow School just north of the Annex in Maynard. The sample was collected 30 feet east of a footpath in a forested area approximately 300 feet southwest of the school buildings.

- The second sample (at E3-BCK-S02) was collected on 21 September 1993, near Maynard High School located northeast of the Annex. The sample was taken from a forested area west of the school building and west of a soccer field.



Source: USGS 7.5 Minute Series Topographic Map, Hudson, MA, 1983; Framingham, MA, 1987; Marlborough, MA, 1988; Maynard, MA, 1988.

Approximate Scale in Feet

5000 0 5000

Figure 6-1 BACKGROUND SOIL, STREAM SEDIMENT, AND STREAM WATER SAMPLE LOCATIONS AT THE SUDBURY ANNEX

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- The third sample (at E3-BCK-S03) was collected on 21 September 1993, within the property line of the Maynard Town Cemetery northeast of the Annex. The sample was taken in an relatively undisturbed area in the southern part of the Cemetery.

- The fourth sample (at E3-BCK-S04) was collected on 21 September 1993, near the Sudbury-Atkinson Pool and Recreation Center southeast of the Annex. The sample was taken from a forested area approximately 1,200 feet north of Hudson Road.

- The fifth sample (at E3-BCK-S05) was collected on 21 September 1993, east of the Annex near Hop Brook, on the Curtis Middle School grounds. The sample was taken in a forest area located approximately 400 feet north of the school's baseball field.

- The sixth sample (at E3-BCK-S06) was collected on 22 September 1993, northwest of the Annex at the Crow Island Glider Field. The sample was taken from a forested area in the southwestern edge of the island.

- The seventh sample (at E3-BCK-S07) was collected on 23 September 1993, in the Marlborough State Forest in Marlborough. The sample was taken in a forested area approximately 400 feet southeast of Concord Road, across from the Marlborough Country Club golf course.

- The eighth sample (at E3-BCK-S08) was collected on 23 September 1993, near Pine Bluff's Beach within a public park west of the Annex. The sample was taken approximately 700 feet south of the dirt access road and 400 feet east of Lake Boon.

- The ninth sample (at E3-BCK-S09) was collected on 23 September 1993, near the John A. Crow Maynard Town Park located north of the Annex in Maynard. The sample was taken in a forested area located approximately 500 feet north of a soccer field and tennis courts.

- The tenth sample (at E3-BCK-S10) was collected on 23 September 1993, from an area within the Stow Away Public Golf Course located north of the Annex across the Assabet River. The sample was taken from a relatively undisturbed and forested area located north of the Assabet and approximately 400 feet west of the green for Hole No. 9.

Summary of Background Soil Sample Analysis

Background soil samples were analyzed for pesticides/PCBs, TAL metals, herbicides, and organophosphates. Analysis of the ten background soil samples showed consistent levels of metals. Low concentrations of pesticides were found in many of the soil samples, including α–benzenehexachloride (BHC), α-chlordane, β-BHC, β-endosulfan, Δ-BHC, dieldrin, endrin, endrin aldehyde, endosulfan sulfate, γ-chlordane, heptachlor epoxide, lindane, and dichlorodiphenyltrichloroethane (DDT) and its degradation products, dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE). The detection of these pesticides in background soils is in accordance with general pest management practices in the past involving the applications of pesticides in the communities surrounding the Annex, and the pesticide ranges were considered to be valid "background" levels. The sample results for inorganic analytes were statistically analyzed to remove any outliers. The only outlier removed was an arsenic concentration found in one sample at 17 μg/g. The background soil results for inorganic analytes were also compared to concentration ranges for uncontaminated soil of the eastern United States and all inorganics were found within the ranges, usually toward the low end. This suggests that comparing analytes in site soil samples to the highest of the background levels is a sensitive method for identifying site-related contaminations. The results for inorganic and organic analytes in background soil sample were screened against soil screening values (see Section 7 for a description of screening methodology and sources of screening values) used to identify potential concerns at sites at the Annex. The only compound found above soil screening levels was beryllium (up to 0.446 μg/g), which was found in two out of ten samples at concentrations slightly above the most conservative soil screening value of 0.4 μg/g (Massachusetts Contingency Plan (MCP) GW–1/S–1 soil value). Since the beryllium concentrations found in background soil samples were at the low end of the range for soil in the caterminous United States, these detections were still considered valid background levels (Shacklette and Boerngen 1984). Table 6-1 lists the highest concentrations of each analyte found in background surface soils. A discussion of the statistical analysis of background soil data for the Annex is presented in Appendix J, along with the full background soil sample data, and a table of concentrations ranges for inorganic analytes for soil in the eastern United States.

6.2.2 Background Surface Water and Sediment Sampling

Three background surface water samples were collected in streams that drain onto the Annex in order to characterize natural background surface water levels for comparison with surface water sampling results at the Annex. Three sediment samples were collected in conjunction with each surface water sample to characterize background sediment conditions for streams at the Annex. These sample locations are noted on Figure 6-1, and are described below:

- The first surface water/sediment sample (at E3-BCK-D01) was collected on 15 September 1993, from the headwaters of a stream south of the parking lot located at the DEC facility in Maynard.

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Table 6-1

**BACKGROUND SOIL SAMPLES
MAXIMUM ANALYTE CONCENTRATIONS**

Analytes	Concentration (μg/g)
TAL Metals	
Aluminum	10,400
Antimony	<0.500
Arsenic	10
Barium	25.1
Beryllium	0.446
Cadmium	<0.500
Calcium	1,170
Chromium (total)	14.2
Cobalt	6.13
Copper	10.7
Iron	12,300
Lead	150
Magnesium	2,310
Manganese	95.8
Mercury	0.318
Nickel	10.7
Potassium	617
Selenium	0.571
Sodium	<200
Vanadium	33
Zinc	44.6

Table 6-1 (continued)

BACKGROUND SOIL SAMPLES
MAXIMUM ANALYTE CONCENTRATIONS

Analytes	Concentration (µg/g)
Pesticides/PCBs	
alpha-BHC	0.004
alpha-Chlordane	0.004
beta-BHC	0.002
beta-Endosulfan	0.004
delta-BHC	0.010
Dieldrin	0.023
Endrin	0.008
Endrin Aldehyde	0.011
Endosulfan sulfate	0.008
gamma-Chlordane	0.005
Heptachlor Epoxide	0.006
Lindane	0.001
DDD	0.063
DDE	0.139
DDT	0.230

Source: Ecology and Environment, Inc. 1994.

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Subsequent analytical results indicated that this sample contained elevated levels of polynuclear aromatic hydrocarbons (PAHs) and lead, likely from the runoff from the parking lot. Consequently, the samples collected at this location were not used to establish background levels for the Annex.

- The second surface water/sediment sample (at E3-BCK-D04) was collected on 17 September 1993, from the outlet of Cutting Pond at the eastern boundary of the Annex. This stream drains onto the Annex, and ultimately enters Puffer Pond.

- The third surface water/sediment sample (at E3-BCK-D08) was collected on 21 September 1993, from an unnamed tributary to Taylor Brook located near the northeastern boundary of the Annex and east of Site P45. Although located inside the Annex boundary, this location is upgradient of any sites or any identified area of activity at the Annex.

Summary of Background Surface Water Analysis

Background surface water samples were analyzed for TCL volatile organics, TCL BNAs, TCL pesticides/PCBs, TAL metals, explosives, TPHC, and phosphate. As noted above, the background samples taken in the drainage located downstream of the DEC facility were not used to establish background surface water or sediment levels for the Annex. The higher of the results of laboratory analysis for the other two surface water samples was used as a screening tool to evaluate potential contamination of surface waters at the Annex. Given that there were only two background surface water samples considered, no statistical analysis was performed to remove outliers. The background surface water results were also compared to screening levels used in the analysis of sites at the Annex. Arsenic (up to 3.15 μg/L), iron (up to 4,810 μg/L), and lead (up to 10.3 μg/L) were found in background surface water samples in concentrations above screening levels. Since these samples were taken upstream of any potential sites at the Annex, the arsenic, iron, and lead levels are considered to be naturally occurring. Thus, arsenic, iron, and lead results in surface water samples collected at sites at the Annex were considered to be potential concerns only when they were found above both the screening and the background levels. The only other result of note in the background surface water samples was the detection of low levels of tetrachloroethene (PCE) (1.90 μg/L, estimated) and trichloroethene (TCE) (1.80 μg/L, estimated) at levels below the reporting limit in one of the background streams (at E3-BCK-D08). While these compounds were not found in trip blanks in the field or in method blanks, it is unlikely that there is a source of these compounds in this stream, and they are considered to be laboratory artifacts. The results for PCE and TCE were not used to establish background surface water levels for the Annex. The highest levels of compounds found in background surface water samples (except PCE and TCE) are listed in Table 6-2. The complete data for background surface water samples is presented in Appendix J.

Summary of Background Sediment Analysis

Background sediment samples were analyzed for TCL VOC, TCL BNAs, TCL pesticides/PCBs, TAL metals, explosives, TPHC, and TOC. Given that there were only two sediment samples considered appropriate to establish background sediment levels, no statistical analysis was performed to remove outliers. Analytical results from the two sediment samples, indicated no metals present at concentrations above sediment screening values used for assessing potential concerns at sites on the Annex. One pesticide, aldrin (0.007 μg/g) was found at a concentration above sediment screening values. Lindane (0.001 μg/g and endosulfan sulfate (0.001 μg/k) were also found in background sediment samples but were below screening levels. These pesticide concentrations, like in the background surface soils, probably reflect general pesticide use in past in the general area, and were considered valid "background" levels for comparison purposes. TPHC (16.6 μg/g) were found in the sediment sample taken from the Cutting Pond outlet, probably indicating some low-level runoff from the surrounding off-Annex area. The highest concentrations of analytes found in background sediment samples are listed below in Table 6-2. The complete data for background sediment samples is presented in Appendix J.

6.2.3 Background Pond Surface Water and Sediment Sampling

In order to establish baseline data for the study of site-related contamination in Puffer Pond, a background study was conducted at Ministers Pond. The selection of Ministers Pond as background was based on the criteria established by the MDEP, specifically, the reference location should have no or minimal potential for impacts; a central Massachusetts location; and similar morphology. Both Puffer Pond and Ministers Pond are shallow, mesotrophic to eutrophic ponds with tannic waters, a comparatively low pH, and extensive wetlands adjacent to them. The ponds have similar drainage and are part of the Assabet River drainage. Ministers Pond is located in the town of Stow, approximately one mile northwest of the Annex. The study was designed to determine background levels of pesticides and metals in the area. Therefore, sediment samples were analyzed for pesticides, organophosphorus pesticides, TAL metals, and TOC. Surface water samples were analyzed for pesticides, organophosphorus pesticides and TAL metals. Samples were collected on 9 November 1993, using a sample container for the surface water and a dredge for sediment. Six of each were collected. The locations are designated as E3-OFF-D01 through E3-OFF-D06.

Summary of Background Pond Surface Water and Sediment Analysis

Background pond surface water samples were analyzed for TCL pesticides and TAL metals. Background pond sediment samples were analyzed for TCL pesticides, TAL metals, and TOC. Inorganic analytes in Ministers Pond surface water and sediment samples were statistically analyzed to remove any outliers. The analytical results from surface water sampling were also compared with screening values that were used in this report to assess potential contamination in surface waters at the Annex. Iron (up to 1,110 μg/L) in three of six samples, was found in concentrations slightly above the screening level of 1,000 μg/L. The iron concentrations found in the surface water samples were consistent, ranging from 954 μg/L to 1,110 μg/L, and are considered to reflect naturally occurring levels of iron in

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Table 6-2

**BACKGROUND STREAM SAMPLES
MAXIMUM ANALYTE CONCENTRATIONS**

Analyte	Sediment (µg/g)	Water (µg/L)
TAL Metals		
Aluminum	5,020	400
Antimony	<0.5	<5
Arsenic	2.03	3.15
Barium	23.9	10.4
Beryllium	0.18	<5
Cadmium	<0.5	<5
Calcium	562	8,520
Chromium (total)	9.66	3.16
Cobalt	3.74	4.79
Copper	6.33	<10
Iron	7,590	4,810
Lead	4.48	10.3
Magnesium	2,140	1,890
Manganese	70.5	156
Nickel	5.92	<10
Potassium	1,520	2,060
Selenium	0.2	<2
Sodium	R	14,000
Thallium	0.195	ND
Vanadium	17	4.72
Zinc	20.8	13.3
TPHC Total Petroleum Hydrocarbons	16.6	ND
Pesticides/PCBs		
Aldrin	0.007	ND
Endosulfan sulfate	0.001	ND
Lindane	0.001	ND
Phosphorus	NA	280

Key: ND = Note Detected
NA - Not analyzed
R = Result rejected

Source: Ecology and Environment, Inc. 1994.

Minsters Pond. In sediment samples from Ministers Pond, arsenic (9.56 μg/g) in one sample, lead in three samples (up to 49.4 μg/g), DDE in two samples (up to 0.074 μg/g), and DDD in all six samples (up to 0.390 μg/g) were found in concentrations above sediment screening values used in evaluation of sediment sampling at sites at the Annex. The arsenic and lead concentrations are both within concentration ranges for mid-basin bottom sediment collected from remote New England lakes, and are considered to be naturally occurring. The DDD and DDE concentrations probably reflect past pesticide applications in the vicinity or upstream of Ministers Pond. The highest concentrations of analytes in Ministers Pond sediments were used as comparison levels for the surface water and sediment results from Puffer Pond and are listed in Table 6-3. The complete data for sediment sampling at Ministers Pond are presented in Appendix J along with comparison data for sediment in remote New England Lakes.

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Table 6-3

**BACKGROUND POND SAMPLES (MINISTERS POND)
MAXIMUM ANALYTE CONCENTRATIONS**

Analyte	Sediment (µg/g)	Water (µg/L)
TAL Metals		
Aluminum	5,740	69.2
Antimony	<0.5	<5
Arsenic	9.56	<2
Barium	55.3	14
Beryllium	<0.5	<5
Cadmium	2.06	<5
Calcium	4,550	8,730
Chromium (total)	12.8	<10
Cobalt	11.4	2.32
Copper	10.9	<10
Iron	16,300	1,110
Lead	49.4	3.02
Magnesium	1,480	2,250
Manganese	74.1	26.6
Nickel	23.2	11.3
Potassium	900	3,640
Selenium	<0.2	<2
Silver	0.879	ND
Sodium	778	18,000
Thallium	<0.5	ND
Vanadium	21.8	10
Zinc	55.3	67.8
Pesticides/PCBs		
DDD	0.39	ND
DDE	0.074	ND
DDT	<0.01	ND

Key: ND = Not Detected

Source: Ecology and Environment, Inc. 1994.

7. PRELIMINARY SCREENING METHODOLOGY FOR SITE INVESTIGATIONS

7.1 METHODOLOGY

A preliminary screening was conducted as part of the SI for each site at the Annex to assist in determining whether the results of environmental investigation will require one of the following:

- no further action (NFA);
- removal action (with/without proposal for NFA);
- supplemental site investigation (SI); or
- remedial investigation/feasibility study (RI/FS).

During the preliminary screening, the concentration of each contaminant found in each sample was compared to background levels and to available human health and ecological standards or guidelines. For contaminants detected in soil, sediment, and surface waters, the concentrations were compared to the highest concentration found in background soils, sediments, and surface waters. The rationale for the background levels is discussed in Section 6 of this report and the data and calculations used to establish background levels are presented in Appendix J.

In the human health screening, contaminants detected in groundwater, soils, sediments, and surface waters were compared to human health-oriented guidelines and standards. In the ecological screening, contaminants detected in surface waters and sediments were compared to ecological benchmarks. Where available, draft ARARs or To Be Considered (TBC) guidance identified by Oak Ridge National Laboratory were used as screening values. The Oak Ridge report is included with this report as Appendix I. Exceedances of background levels and/or screening levels have been noted in the text discussing the results of each SI (Volume II).

This screening approach puts the focus for decision-makers on the contaminants that may be of human health or ecological concern, and helps to determine if further action or study is required. It does not assess total cumulative site risks. Contaminants without published human health or ecological criteria are noted in the preliminary screening section for each site, but are not included in the site evaluation. Thus, this approach is only useful for a preliminary assessment of sites, and cannot be used to determine when and if actual human health or ecological effects will occur. A more definitive conclusion regarding site risks cannot be made without a full quantitative risk assessment, using appropriate exposure scenarios and assumptions.

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7.2 HUMAN HEALTH PRELIMINARY SCREENING

For the human health preliminary screening, screening values were chosen based on conservative assumptions regarding present conditions and future development. These assumptions are not intended as judgments or conclusions on the actual or likely future conditions at the Annex, but rather only as a means of focusing on potential contaminants of concern at Annex sites for further action. Human health screening values were based on the assumption that groundwater will be used in the future and that the Annex will be used for residential purposes. For example, the groundwater screening values used are those related to drinking water supplies, such as the Massachusetts Contingency Plan GW-1 groundwater category standard and the EPA and Massachusetts Maximum Contaminant Levels (MCLs) for drinking water.

At some sites, sampling results were also compared to other comparison values that exist for particular compounds. These values were often based on different assumptions from those used in choosing the screening values. For example, groundwater results from sites with low-yield aquifers were also compared to the Massachusetts GW-3 groundwater category standard for groundwater not used as a drinking water source. Similarly, for soils, EPA Region III Risk-Based Concentrations (RBCs) for commercial/industrial soil were occasionally used as a means of comparison at selected sites.

The sources of the values used in the human health preliminary screening of sites at the Annex are described in the sections below, and the screening and comparison values are presented in Tables 7-1 through Table 7-4 at the end of this section.

7.2.1 Groundwater Criteria for Human Health Preliminary Screening

Screening Values

These screening values were used for groundwater that may be used for drinking water:

- Lowest of Draft Applicable Requirements (MCP Category GW-1 Standards), EPA, and Massachusetts MCLs; or
- Lowest of Draft Relevant and Appropriate Requirements, if no applicable levels available; or
- Lowest of TBC Guidance, if no draft ARARs are available.

Additional Comparison Values

The following additional comparison value was used at some sites when groundwater was not likely to be used as a drinking water source:

- MCP Category GW-3 Standards

7.2.1.1 Draft Applicable Requirements for Cleanup of Groundwater

Oak Ridge National Laboratory has identified the following standards as draft applicable, chemical-specific requirements for the cleanup of groundwater used as drinking water at the Annex (these ARARs are tentative and need to be reviewed by the regulatory community prior to any use):

- EPA Safe Drinking Water Act Maximum Contaminant Level (SDWA MCLs) (Safe Drinking Water Act Phase II National Primary Water Regulations, effective July 30, 1992): These standards are promulgated by the EPA's Office of Drinking Water. MCLs are enforceable standards that apply to contaminants found in public water systems that have at least 15 service connections or serve an average of at least 25 people daily at least 60 days of the year. MCLs are enforceable standards that take into consideration human health effects, available treatment technologies, and costs of treatment. MCLs would be legally applicable to remediation of any Zone II groundwater or of groundwater that serves a public water supply well at the Annex. MCLs are set as close as feasible to Maximum Contaminant Level Goal (MCLG), which are non-enforceable, health-based goals at which no known or anticipated adverse effects on health will occur, that disregard cost or treatment feasibility. The MCLGs are not legally enforceable, but would be relevant and appropriate for cleanup of groundwater at the Annex.

- Massachusetts Maximum Contaminant Level (MMCL) (310 CMR 10, effective November 20, 1992): The Commonwealth of Massachusetts has adopted Drinking Water Standards and Guideline, expressed in terms of maximum levels of contaminants allowable in drinking water. Oak Ridge National Laboratory identified the MMCLs as applicable requirements for remediation of medium-to-high yield groundwater that could be a potential source of drinking water supply. The MMCLs are identical to the SDWA MCLs, with the exception of chlordane, for which the SDWA MCL of 2 μg/L is stricter than the MMCL of 5 μg/L. Massachusetts Secondary MCLs have been promulgated as well, pursuant to 310 CMR Section 22 (effective November 20, 1992), and are legally enforceable and relevant and appropriate for cleanup of groundwater at the Annex.

- Massachusetts Contingency Plan (MCP) (310 CMR 40, October 1, 1993): The Commonwealth of Massachusetts has also established Groundwater Standards in the Massachusetts Contingency Plan. These standards apply to the cleanup of disposal sites and are developed using a Method 1 risk characterization approach (310 CMR 40.0970), which compares the current and reasonably foreseeable use of the groundwater at the disposal site to promulgated

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standards. Category GW-1 groundwater is defined as one of the following: within a Zone II area; within a Wellhead Protection Area; within a potentially productive aquifer; within Zone A of a Class A surface water body; within 500 feet or more of a public water system distribution pipeline; or within 500 feet of a private water supply well. Based on these definitions, certain areas of groundwater at the Annex would be in Category GW-1. Consequently, the MCP Method 1 groundwater standards provided for the GW-1 category would be considered applicable requirements for cleanup of these areas of contaminated groundwater at the Annex. GW-3 groundwater category standards would be applicable requirements for remediation of groundwater at the Annex that potentially discharges to surface waters that are not a current or potential source of drinking water. The GW-3 category standards are used as comparison values at sites where, due to low yield, groundwater is not likely to be developed in the future.

7.2.1.2 Draft Relevant and Appropriate Requirements for Cleanup of Groundwater

Oak Ridge National Laboratory has identified the following standards as draft relevant and appropriate requirements for the cleanup of groundwater used as drinking water at the Annex:

- Safe Drinking Water Act Maximum Contaminant Level Goal (MCLG): See discussions for Safe Drinking Water Act MCL above.

- Massachusetts Secondary Maximum Contaminant Level (MA SMCL): See discussion above for Massachusetts MCL.

7.2.1.3 Draft TBC Guidance for Cleanup of Groundwater

Oak Ridge National Laboratory has identified the following standards as TBC guidance for the cleanup of groundwater used as drinking water at the Annex:

- Safe Drinking Water Act Secondary Maximum Contaminant Level (SMCLs, 40 CFR Part 143): National Secondary Drinking Water Regulations are levels established to regulate the aesthetic qualities related to public acceptance of drinking water. These Federal regulations are not enforceable, but rather are intended to serve as guidelines for the states.

- Drinking Water Health Advisory (HA): The EPA has published Lifetime Health Advisories based on 10^{-6} cancer risk levels (USEPA 1993). These values are calculated assuming that individuals receive 80 percent of their exposure from sources other than consumption of drinking water.

- Massachusetts Office of Research and Standards Guidance (MA ORSG): The MDEP Office of Research and Standards issues guidance for chemicals for which Massachusetts State MCLs have not been promulgated. These guidelines apply to non-chlorinated water supplies and represent a level at or below which adverse, non-cancer health effects are unlikely to occur. The ORSG are based on an excess lifetime cancer risk of less than or equal to one in one million. SDWA MCLs that have been promulgated by EPA but are not yet effective are listed as ORSG.

7.2.2 Soil Criteria for Human Health Screening

Screening Values

These screening values were used for soil in areas that might be used for residential purposes:

- Background levels for inorganic analytes at the Annex, *and* MCP GW-1/S-1 soil category standards; or
- EPA Region III Risk-Based Concentration (RBCs) for Residential Soil; or
- RCRA Action level (for endosulfan sulfate only).

Other Comparison Values

These other comparison values were used for cases where land use is expected to be commercial or industrial:

- MCP GW-3/S-3 soil category standards; or
- EPA Region III RBCs for Commercial/Industrial Soil.

Massachusetts Contingency Plan (MCP)

Categories of groundwater and soil have been established by the MDEP as part of the Massachusetts Contingency Plan for risk characterization. The MCP uses both groundwater and soil categorization to establish risk characterization levels for soils. The most conservative soil standards are for areas where groundwater is used for drinking water (category GW-1) and where the soil is accessible, the frequency or intensity of a child's use of the soil is considered to be high, or the frequency and intensity of an adult's use of the soil is considered to be high (category S-1). This level (GW-1/S-1) has been used as the most conservative screening value based on a future residential use of the Annex. As a comparison value, the GW-3/S-3 soil category standards, which assume that groundwater is not used for drinking water supplies and that the accessibility of the soil and the frequency and intensity of use by children or adults is considered to be low, were also used.

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EPA Region III Risk-Based Concentration (RBC) Table

EPA Region III has developed risk-based soil concentrations based on published reference doses, cancer potency slopes, "standard" exposure scenarios (*i.e.*, an adult body weight of 70 kg, a child body weight of 15 kg for ages 1 to 6, and a daily soil ingestion rate of 100 mg for adults and 200 mg for children). The concentrations reported correspond to a hazard quotient of 1, indicating either no risk of non-carcinogenic effects, or a lifetime cancer risk of one in 1 million, whichever is lower. The table is designed as a screening tool, and "has no official status as either regulation or guidance, and should be used only as a predicator of generic-single-contaminant health risk estimates." EPA Region III publishes RBCs for both residential and commercial/industrial soils.

RCRA Action Levels (Proposed)

EPA has proposed criteria for establishing action levels for soil, assuming exposure through consumption of soil contaminated with hazardous constituents. These levels assume a residential use pattern, with long-term direct contact and soil ingestion by children. Action levels for soil are typically relevant only to the upper two feet of surface soil. These levels were first proposed in 1990, and correspond to a hazard index of 0.2.

7.2.3 Surface Water Criteria for Human Health Screening

Massachusetts/Clean Water Act (MA/CWA) Water Quality Criteria (WQC) are the screening values used for protection of human health from risks of water and fish consumption.

MA/CWA WQC are the comparison values used for protection of human health from fish consumption only. MA/CWA WQC can be found at 314 CMR Section 4.05(5)(e)/57 FR 60848.

Massachusetts has adopted the Clean Water Act (CWA) Water Quality Criteria (WQC) as the Massachusetts WQC. The Massachusetts WQC could be considered applicable for the remediation of contamination in the on-site surface water bodies of the Concord River Basin, which are considered Class B waters. The CWA WQC are relevant and appropriate requirements for remediation of these water bodies. The EPA has developed WQC for the protection of human health and aquatic life. The WQC for protection of aquatic life are discussed in the section below on ecological screening. WQC for the protection of human health are divided into two separate categories: one for the protection of human health from risks due to water and fish consumption, and a second for the protection of human health from risks due solely to the consumption of fish. WQC for the protection of human health from risks due both to water and fish consumption can be several orders of magnitude lower than those for the protection from risks of fish consumption alone. The more conservative levels for consumption of both water and fish have been used as the screening value. The WQC for fish consumption alone have been used as a comparison value. WQC for human health are based on a 10^{-6} risk level.

7.2.4 Sediment Criteria for Human Health Screening

There are no current standards or benchmarks for screening potential risks to human health from contaminated sediments. Thus, for the human health screening at the Annex, contaminants positively detected in levels above background have been compared to the screening levels established for Annex soils. The rationale for using the soil screening values is that the likely exposure routes of dermal contact or ingestion for soil and sediment at the Annex are likely to be quite similar. Given that the soil criteria was not developed for the sediment media, this screening can only be a very rough estimate of areas of potential risk related to contaminated sediments. The exposure route of consumption of fish that may have come in contact with contaminants in sediment is being addressed through the related bioaccumulation study of Puffer Pond (which will be completed in May 1994). Surface water samples were taken in conjunction with all sediment samples taken at the Annex, and any contaminants identified in surface waters were screened against water quality criteria for the consumption of water and fish by humans.

7.3 ECOLOGICAL PRELIMINARY SCREENING

Volume II of this report includes ecological characterizations for each site which identify habitat type, sensitive environments, and wildlife potentially exposed to contamination. This ecological characterization provides the background for a screening of ecological risks through the use of ecological benchmarks. Section 2.7 of this report provides an overall profile of the regional ecology, vegetative cover types, and ecosystems at the Annex, based on a review of scientific literature, site-specific reports and records, and observations made during site inspections. The presence of any rare and endangered flora and fauna at the Annex, as well as information regarding any other critical ecological receptors (i.e., wetlands, surface water bodies, etc.) is also reviewed in Section 2.0. Information regarding rare and endangered species at individual sites has been presented in the SIs, as available.

When conducting an ecological screening of the sites at the Annex, three pathways of contamination, soil, surface water and sediment, are considered. However, no state or Federal standards or guidelines exist for the exposure of ecological receptors to surface soil contaminants. Consequently, this pathway could not be analyzed through comparison of concentrations of contaminants found at the Annex with ecological benchmarks. Screening of potential exposure to aquatic and wetland receptors has been conducted through direct comparison of maximum concentrations in Annex surface waters and sediments to background levels and to state, Federal, and other criteria and guidance values. The criteria and guidelines used for ecological screening are described below and the screening and comparison values used are presented in Tables 7-5 through 7-7 at the end of this section.

7.3.1 Surface Water Criteria for Ecological Screening

Surface water criteria for ecological screening are:

- Background levels in surface water at the Annex, and

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- MA/CWA WQC for the protection of aquatic life.

As noted above, Massachusetts has adopted the Clean Water Act (CWA) Water Quality Criteria (WQC) as Massachusetts Water Quality Criteria. EPA has developed WQC for the protection of all life stages of aquatic animals and plants. The most recent updating of the WQC was in 1992 (57 FR 60848, December 22, 1992). These criteria specify the contaminant concentration in ambient surface water that, if not exceeded, should protect most species of aquatic life. The chronic criterion represents the contaminant concentration that should not be exceeded by the four-day average chemical concentration more than once every three years. In developing a chronic WQC, EPA estimates protective contaminant levels based on chronic toxicological data for animals, plants and on residue level in aquatic organism. The acute criteria represents the level that should not be exceeded by the one-hour average concentration more than once every three years. For the purpose of ecological screening of Annex sites, the chronic WQC was used as screening values.

The EPA Ambient Water Quality Criteria (AWQC) for aluminum, as it affects aquatic life, was purposely excluded from consideration for screening purposes at Sudbury Annex. The criterion is valid only for a pH range of 6.5 to 9, which is above the pH range of most water at Sudbury. At lower pH levels, there are no quantitative criteria for evaluating the toxicity of aluminum. Even within the applicable pH ranges the aluminum criterion is frequently exceeded in pristine water where the biota are unimpaired. This is because the toxicity of aluminum is affected by a number of other factors than pH, including the presence of organic acids and complexing ligands, and the concentrations of dissolved silicon.

The EPA considers the aluminum AWQC to be a poor predictor of aquatic effects (Ken Potts, USEPA Ecological Risks Branch, personal communication, to Steven Peterson, E & E, July 1993). In any case, at Sudbury it is highly unlikely that aluminum, which is abundant in bedrock, soil, and sediment minerals, is an indication of contamination from site activities. In surface water, the presence of elevated aluminum is probably a reflection of suspended sediment, and reflects the high aluminum content of the clay and silt in the water.

7.3.2 Sediment Criteria for Ecological Screening

Sediment criteria for ecological screening are:

- Background levels in sediments at the Annex, and
- The lower of NOAA Effects Range-Low (ERL) criteria, and
- Ontario Ministry of the Environment (Ontario MOE) Lowest Effect Level.

Other comparison values are:

- NOAA Effects Range-Median (ERM) criteria, and

- EPA and New York State Department of Environmental Conservation (NYSDEC) Sediment Quality Criteria (SQC) adjusted on a sample-specific basis related to total organic content (TOC).

National Oceanographic and Atmospheric Administration Sediment Threshold Values

Long and Morgan (1991) have developed biological effects-based criteria for evaluating sediment contaminant data. Although this NOAA study was designed primarily for evaluating the toxicity of marine and estuarine sediment, EPA has suggested that the Long and Morgan criteria may also be used as a source of information for the evaluation of freshwater sediments at hazardous waste sites. The Effects Range-Median (ERM) criteria represent the 50th percentile concentration of contamination in estuarine sediments with observed (or predicted) effects. The Effects Range-Low (ERL) represent the 10th percentile concentration of contamination in estuarine sediments with observed (or predicted) effects. The NOAA criteria were either developed on a dry-weight basis, or were for the most part, converted to a dry-weight basis by Long and Morgan based on an assumption of 1 percent TOC content. Thus, the NOAA criteria, when used for ecological screening, are not carbon-normalized. Noting that the TOC content of sediments at Annex sites may vary from the 1 percent TOC assumption of the NOAA values, the NOAA ERLs and ERMs may not be strictly comparable criteria to the other sediment values.

Lowest Effect Level, Ontario Ministry of the Environment

Sitzhko (1989, revised 1991), with the Ontario MOE has developed criteria for evaluating sediment contaminant data. The criteria define the chronic long-term effects of sediment contamination on benthic organisms. The LEL describes a level of sediment contamination that can be tolerated by most benthic organisms.

EPA Sediment Quality Criteria (SQC)

SQCs for several hydrophobic organic compounds have been developed and published by the EPA (1988). No EPA SQC are available to evaluate the effects of inorganic constituents on aquatic life. The SQC are intended to protect benthic organisms which are primarily impacted by contaminants in the interstitial water between sediment particles. EPA developed SQC using an equilibrium partitioning approach to identify sediment concentrations which could be associated with interstitial water concentrations equal to chronic federal ambient water quality criteria. For non-polar hydrophobic compounds, such as PCBs, the degree to which compounds are released from sediment particles into interstitial water is strongly influenced by their low solubility and strong binding affinity to organic carbon within the sediment particle. The higher the TOC of the sediments, the lower the potential for contaminant release to the interstitial water. Therefore, the toxicity of sediments containing hydrophobic compounds varies on a site-specific basis in an inverse relationship with the fraction of sediment that is organic carbon. For this reason, when appropriate, sediment toxicity threshold criteria for organic compounds were TOC normalized by multiplying the TOC content of sediment samples by the appropriate SQC. These adjusted values were then

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compared with sediment analytical data. When available, EPA SQC were preferentially chosen as a comparison value for preliminary screening on a sample-specific criteria basis.

New York State Department of Environmental Conservation (NYSDEC) Sediment Quality Criteria

The NYSDEC Bureau of Environmental Protection, Division of Fish and Wildlife has published a document entitled, *"Sediment Criteria — November 1993"* (NYSDEC 1993). This report is a guidance document, not a standard or policy. The NYSDEC SQC document contains a methodology for developing sediment criteria, a description of the use of these criteria in risk management decision-making processes, and a table of sediment criteria derived for various human-and ecological receptors. Organic contaminant sediment criteria are based on the TOC equilibrium partitioning approach. The guidance document contains recommended criteria for several organic and inorganic constituents. As described above for the EPA SQC, the NYSDEC criteria for organic compounds were carbon normalized. When EPA SQC were unavailable, the NYSDEC freshwater criteria were used as comparison values for sediment on a sample-specific criteria basis.

Table 7-1: Groundwater Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/L (a)	GW (App.) SDWA MCLs ug/L (b)	GW(App.) Mass. MCLs ug/L (c)	GW (App.) MCP GW-1 Standards ug/L (d)	GW(R & A) MA SMCL ug/L (e)	GW(TBC) EPA Drinking Water HAs ug/L (b)
METALS						
Aluminum	50	50(1)			**50/200**	
Antimony	6	**6**	6(2)	6		3
Arsenic	50	50(10)	**50**	50		2(6)
Barium	2000	**2000**	2000			2000
Beryllium	4	**4**	4(2)	4		0.8(6)
Cadmium	5	**5**	5	5		5
Chromium (total)	100	**100**	100	100		100
Chromium (III)	100			100		
Chromium (VI)	50			**50**		
Cyanide	200	200 (5)		**200**		
Copper	1300	1000(1)	**1,300(4)**		1000	
Iron	300	300(1)			**300**	
Lead	15	**15(4)**	15(4)	15		
Manganese	50	50(1)			**50**	
Mercury	2	**2**	2	2		
Nickel	100	**100**	100(2)	100		100
Selenium	50	**50**	50	50		
Silver	40	100(1)	50	**40**	100	100
Sodium	20000		28,000(2)			**20000 (7)**
Thallium	2	**2**		2		0.4
Zinc	2000	5000(1)		**2000**	5000	2000
VOLATILE ORGANICS						
Acetone	3000		3,000(2)	**3000**		
Benzene	5	**5**	5	5		100 (6)
Bromodichloromethane	5			**5**		60(6)
Bromoform	5	100		**5**		400 (6)
Bromomethane	10			**10**		10
Carbon Tetrachloride	5	**5**		5		30 (6)
Chlorobenzene	100	**100**	100	100		
Chloroform	5	100	50(2)	**5**		600(6)
Chloromethane	3					**3**
Dibromochloromethane	5			**5**		
1,1-Dichloroethane	70			**70**		
1,2-Dichloroethane	5	**5**	5	5		40(6)
1,1-Dichloroethylene	7	**7**	7	7		7
CIS-1,2-Dichloroethylene	70	**70**		70		70
Trans-1,2-Dichloroethylene	100	**100**		100		100
1,2-Dichloropropane	5	**5**		5		
1,3-Dichloropropene	0.5			**0.5**		
1,3-Dimethylbenzene	10000		**10000**			
Ethylbenzene	700	**700**	700	700		700
Ethylene Dibromide	0.05	**0.05**		**0.2**		0.04(6)
Methylene chloride	5	**5**	5(2)	5		
Methyl ethyl ketone	350		350(2)	**350**		
Methyl isobutyl ketone	350		350(2)	**350**		
Methyl Mercury	2			**2**		
Methyl t-Butyl Ether	700			**700**		40
Styrene	100	**100**	100	100		100

Key At End of Table

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Table 7-1: Groundwater Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/L (a)	GW (App.) SDWA MCLs ug/L (b)	GW(App.) Mass. MCLs ug/L (c)	GW (App.) MCP GW-1 Standards ug/L (d)	GW(R & A) MA SMCL ug/L (e)	GW(TBC) EPA Drinking Water HAs ug/L (b)
VOLATILE ORGANICS						
1,1,1,2-Tetrachloroethane	5			**5**		70
1,1,2,2,-Tetrachloroethane	2			**2**		
Tetrachloroethylene(PCE)	5	**5**	5	5		70(6)
Toluene	1000	**1000**	1000	1000		1000
1,1,1-Trichloroethane	200	**200**	200	200		200
1,1,2-Trichloroethane	5	**5**	5(2)	5		3
Trichloroethylene(TCE)	5	**5**	5	5		300(6)
Vinyl Chloride	2	**2**		2		1.5(6)
Total Xylenes	10000	**10000**	10000	10000		10000
TPHC						
Tot. Petroleum Hydrocarbons	1000			**1000**		
PESTICIDES/PCBS						
alpha-Chlordane	2	**2(8)**	5	5		3(6,8)
alpha-Endosulfan	0.4			**0.4 (11)**		
Aldrin	0.5			**0.5**		0.2 (6)
beta-Endosulfan	0.4			**0.4(11)**		
Chlordane	2	**2**	5	5		3(6)
DDD	0.1	0.5		**0.1**		
DDE	0.1	0.5		**0.1**		
DDT	0.3	0.5		**0.3**		
Dieldrin	0.1			**0.1**		0.2(6)
gamma-Chlordane	2	**2 (8)**	5	5		3(6,8)
gamma-BHC (Lindane)	0.2	**0.2**	0.2	0.2		0.2
Endosulfan	0.4			**0.4**		
Endrin	2	**2**	2	2		2
Endrin aldehyde	2			**2**		
Heptachlor	0.4	**0.4**	0.4	0.4		0.8(6)
Heptachlor epoxide	0.2	**0.2**	0.2	0.2		0.4(6)
Methoxychlor	40	**40**		40		40
PCBs	0.5	**0.5**	0.5	0.5		0.5(6)
Toxaphene	3	**3**				
HERBICIDES						
Dacthal(DCPA)	4000					**4000**
Silvex	50	**50**	50			
EXPLOSIVES						
Cyclonite(RDX)	2					**2**
Cyclotetramethylenetetramine	400					**400**
1,3-Dinitrobenzene	1					**1**
2,4-Dinitrotoluene	30			**30**		30(9)
2,4,6-Trinitrotoluene	2					**2**

Key At End of Table

Table 7-1: Groundwater Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/L (a)	GW (App.) SDWA MCLs ug/L (b)	GW(App.) Mass. MCLs ug/L (c)	GW (App.) MCP GW-1 Standards ug/L (d)	GW(R & A) MA SMCL ug/L (e)	GW(TBC) EPA Drinking Water HAs ug/L (b)
BNAS						
Acenapthene	20			**20**		
Acenapthylene	300			**300**		
Anthracene	600			**600**		
Benzo[A]anthracene	0.1	**0.1 (3)**		0.2		
Benzo[A]pyrene	0.2	0.2(3)	0.2(2)	**0.2**		
Benzo[B]flouranthene	0.2	0.2(3)		**0.2**		
Benzo[G,H,I]perylene	0.5			**0.5**		
Benzo[K]fluoranthene	0.2	0.2(3)		**0.2**		
1,1-Biphenyl (Dipehnyl)	400			**400**		
Bis(2-Chloroethyl)Ether	30			**30**		
Bis(2-Chloroisopropyl)Ether	30			**30**		
Bis(2-ethylhexyl)phthalate	6	**6**	6(2)	6		300
4-Chloroaniline	30			**30**		
2-Chlorophenol	10			**10**		40
Chrysene	0.2	0.2(3)		**0.2**		
Dibenzo(a,h)Anthracene	0.2	0.3(3)		**0.2**		
1,2-Dichlorobenzene	600	**600**		600		600
1,3-Dichlorobenzene	600	**600**		600		600
1,4-Dichlorobenzene	5	75		**5**		75
3,3-Dichlorobenzidine	80			**80**		
2,4-Dichlorophenol	2			**2**		20
Diethyl Phthalate	6000	5(3)		**6000**		500
2,4-Dimethylphenol	100			**100**		
2,4-Dinitrophenol	100			**100**		
Dimethyl Phthalate	50000			**50000**		
Dioxin	0.00003	**0.00003**		0.00003		
Fluoranthene	100			**100**		
Fluorene	300			**300**		
Hexachlorobenzene	1	**1**		1		2 (6)
Hexachlorobutadiene	0.6			**0.6**		1
Hexachloroethane	8			**8**		1
Indeno[1,2,3-C,D]pyrene	0.2	0.4(3)		**0.2**		
2-Methylnapthalene	10			**10**		
Napthalene	20			**20**		20
Pentachlorophenol	1	**1**		1		30(6)
Phenanthrene	300			**300**		
Phenol	4000			**4000**		4000
Pyrene	80			**80**		
1,2,4-Trichlorobenzene	70	**70**		70		70
2,4,5-Trichlorophenol	200			**200**		
2,4,6-Trichlorophenol	10			**10**		300(6)
ANIONS						
Chloride	250000	**250000**			250000	
Fluoride	2000	**2000(10)**			2000	
Nitrate	10000	**10000**				
Nitrite	1000	**1000**				
Sulfate	250000	**250000**			**250000**	

Key At End of Table

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Table 7-1: Groundwater Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used	GW (App.) SDWA MCLs	GW(App.) Mass. MCLs	GW (App.) MCP GW-1 Standards	GW(R & A) MA SMCL	GW(TBC) EPA Drinking Water HAs
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
	(a)	(b)	(c)	(d)	(e)	(b)

Key

(a) Groundwater screening values were chosen from the values identified by Oak Ridge National Laboratories. When Oak Ridge did not identify a value, the lowest available ARAR or TBC value was used. Sources are in bold.
(b) USEPA Drinking Water Regulations and Health Advisories (May, 1994) SMCLs noted with (1) Health Advisories based on lifetime risk level for 70 kg adult, unless otherwise noted
(c) Massachusetts Drinking Water Standards and Guidelines (Massachusetts, 1992) 310 CMR 22
(d) Massachusetts Contingency Plan 310 CMR 40.0974 and 40.0975, July 30, 1993, effective October 1, 1993
(e) Secondary Maximum Contaminant Goal, Code of Massachusetts Regulations, Title 310 Section 22, Effective 11/20/199
(1) Secondary standard
(2) Mass. Guidance value
(3) Proposed standard
(4) Action Level
(5) Total trihalomenthanes (tentative)
(6) 10-4 Cancer Risk, 70 kg Adult
(7) DWEL (Drinking Water Equivalent Level) , 70 kg adult
(8) As Chlordane
(9) Longer-term level for 10 kg child
(10) under review
(11) As Endosulfan

Source: Ecology & Environment, Inc. 1994

Table 7-2: Soil Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/g (a)	ARAR MCP GW-1/S-1 ug/g (b)	TBC Reg III RBC Residential ug/g (c)	TBC RCRA Action Levels ug/g (d)
METALS				
Antimony	10	**10**	31	6
Arsenic	30	**30**	23	80
Barium	5500		**5500**	800
Beryllium	0.4	**0.4**	0.15	0.2
Cadmium	30	**30**	39	8
Chromium (total)	1000	**1000**		80
Chromium (III)	1000	**1000**	78000	
Chromium (VI)	200	**200**	390	
Cyanide	100	**100**		
Copper	2900		**2900**	
Lead	300	**300**		
Manganese	390		**390**	1600(1)
Mercury	10	**10**	23	4(inorg)
Nickel	300	**300**	1600	4000
Selenium	300	**300**	390	40-80
Silver	100	**100**	390	40
Thallium	8	**8**		1.2
Vanadium	550		**550**	120(1)
Zinc	2500	**2500**	23000	3200(1)
VOLATILE ORGANICS				
Acetone	3	**3**	7800	1600
Acrolein	1600		**1600**	
Acrylonitrile	1.2		**1.2**	
Benzene	10	**10**	22	
Benzoic Acid	310000		**310000**	60,000(1)
Bromodichloromethane	0.1	**0.1**	10	
Bromoform	0.1	**0.1**	81	
Bromomethane	10	**10**	110	
Carbon Disulfide	7800		**7800**	
Carbon Tetrachloride	1	**1**	4.9	
Chlorobenzene	8	**8**	1600	
Chloroform	0.1	**0.1**	100	
Chloromethane	49		**49**	
Dibromochloromethane	0.09	**0.09**	7.6	
1,1-Dichloroethane	3	**3**	7800	
1,2-Dichloroethane	0.05	**0.05**	7	
1,1-Dichloroethylene	0.7	**0.7**	1.1	
CIS-1,2-Dichloroethylene	2	**2**	780	
Trans-1,2-Dichloroethylene	4	**4**	1600	
1,2-Dichloropropane	0.1	**0.1**	9.4	
1,3-Dichloropropene	0.01	**0.01**	3.7	
Ethylbenzene	80	**80**	7800	2000
Ethylene Dibromide	0.005	**0.005**		
Methylene chloride	0.1	**0.1**	85	90
Methyl ethyl ketone	0.3	**0.3**	47000	
Methyl isobutyl ketone	0.5	**0.5**	6300	

Key at end of Table

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Table 7-2: Soil Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/g (a)	ARAR MCP GW-1/S-1 ug/g (b)	TBC Reg III RBC Residential ug/g (c)	TBC RCRA Action Levels ug/g (d)
Methyl Mercury	7	**7**	23	
Methyl t-Butyl Ether	3	**3**	390	
Styrene	2	**2**	16000	
1,1,1,2-Tetrachloroethane	0.4	**0.4**	25	
1,1,2,2,-Tetrachloroethane	0.02	**0.02**	3.2	
Tetrachloroethylene(PCE)	0.5	**0.5**	12	
Toluene	90	**90**	16000	4000
1,1,1-Trichloroethane	30	**30**	7000	
1,1,2-Trichloroethane	0.3	**0.3**	11	
Trichloroethylene(TCE)	0.4	**0.4**	58	
Trichlorofluoromethane	23000		**23000**	
Vinyl Chloride	0.3	**0.3**	0.34	
Total Xylenes	500	**500**	160000	
TPHC				
Tot. Petroleum Hydrocarbons	500	**500**		
PESTICIDES/PCBS				
alpha-BHC	0.1		**0.1**	0.1
alpha-Chlordane	1			
alpha-Endosulfan	0.2			
Aldrin	0.03	**0.03**	0.038	
beta-BHC	**0.35**		**0.35**	
beta-Endosulfan	0.2			
Chlordane	1	**1**	0.49	
DDD	2	**2**	2.7	3
DDE	2	**2**	1.9	2
DDT	2	**2**	1.9	2
Dieldrin	0.03	**0.03**	0.04	0.04
gamma-Chlordane	1			
gamma-BHC (Lindane)	0.1	**0.1**	0.49	0.5
Endosulfan	0.2	**0.2**	470	
Endosulfan sulfate	0.8			**0.8**
Endrin	0.6	**0.6**	23	4
Endrin aldehyde	0.6			
Heptachlor	0.1	**0.1**	0.14	
Heptachlor epoxide	0.06	**0.06**	0.07	
Methoxychlor	100	**100**	390	
PCBs	2	**2**	0.083	0.09
Toxaphene	0.58		**0.58**	
HERBICIDES				
Dacthal(DCPA)	39000		**39000**	
Silvex	630		**630**	
EXPLOSIVES				
Cyclonite(RDX)	5.8		**5.8**	60(1)

Key at end of Table

Table 7-2: Soil Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/g (a)	ARAR MCP GW-1/S-1 ug/g (b)	TBC Reg III RBC Residential ug/g (c)	TBC RCRA Action Levels ug/g (d)
HMX	3900		**3900**	800(1)
1,3-Dinitrobenzene	7.8		**7.8**	1.6
2,4-Dinitrotoluene	0.7	**0.7**	160	
2,6-Dinitrotoluene	78		**78**	
Nitrobenzene	39		**39**	
3-Nitrotoluene	780		**780**	
1,3,5-Trinitrobenzene	3.9		**3.9**	0.8(1)
BNAS				
Acenapthene	20	**20**	4700	
Acenapthylene	100	**100**		
Anthracene	1000	**1000**	230000	
Benzidine	0.0028		**0.0028**	
Benzo[A]anthracene	0.7	**0.7**	0.88	
Benzo[A]pyrene	0.7	**0.7**	0.088	
Benzo[B]flouranthene	0.7	**0.7**	0.88	
Benzo[G,H,I]perylene	100	**100**		
Benzo[K]fluoranthene	0.7	**0.7**	8.8	
1,1-Biphenyl (Dipehnyl)	1	**1**	3900	
Bis(2-Chloroethyl)Ether	0.7	**0.7**	0.58	
Bis(2-Chloroisopropyl)Ether	0.7	**0.7**	9.1	
Bis(2-ethylhexyl)phthalate	100	**100**	46	50
Carbazole	32		**32**	
4-Chloroaniline	1	**1**	310	
2-Chlorophenol	0.7	**0.7**	390	
Chrysene	0.7	**0.7**	88	
Dibenzo(a,h)Anthracene	0.7	**0.7**	0.088	
1,2-Dichlorobenzene	100	**100**	7000	
1,3-Dichlorobenzene	100	**100**	7000	
1,4-Dichlorobenzene	2	**2**	27	
3,3-Dichlorobenzidine	1	**1**	1.4	
2,4-Dichlorophenol	10	**10**	230	
Diethyl Phthalate	100	**100**	63000	12000
2,4-Dimethylphenol	0.7	**0.7**	1600	
2,4-Dinitrophenol	3	**3**	160	
Dimethyl Phthalate	30	**30**	780000	
Di-N-octyl phthalate	1600		**1600**	
1,2-Diphenyl hydrazine	0.8		**0.8**	
Dioxin	4.000000E-06	**4.000000E-06**	4.100000E-06	
Fluoranthene	600	**600**	3100	
Fluorene	400	**400**	3100	
Hexachlorobenzene	0.7	**0.7**	0.4	
Hexachlorobutadiene	3	**3**	8.2	
Hexachloroethane	6	**6**	46	
Hexachlorocyclopentadiene	550		**550**	
Indeno[1,2,3-C,D]pyrene	0.7	**0.7**	0.88	
Isophorone	670		**670**	
2-Methylnapthalene	0.7	**0.7**	-	
4-Methylphenol	390		**390**	800

Key at end of Table

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Table 7-2: Soil Values for Human Health Screening

Source of Screening Value Used in Bold	Screening Value Used ug/g (a)	ARAR MCP GW-1/S-1 ug/g (b)	TBC Reg III RBC Residential ug/g (c)	TBC RCRA Action Levels ug/g (d)
Napthalene	4	**4**	3100	
N-Nitrosodi-N-propylamine	0.091		**0.091**	
N-Nitrosodiphenylamine	130		**130**	
Pentachlorophenol	5	**5**	5.3	
Phenanthrene	700	**700**	2300	
Phenol	60	**60**	47000	
Pyrene	500	**500**	2300	
1,2,4-Trichlorobenzene	100	**100**	780	
2,4,5-Trichlorophenol	3	**3**	7800	
2,4,6-Trichlorophenol	3	**3**	58	
ANIONS				
Fluoride	4700		**4700**	
Nitrate	130000		**130000**	
Nitrite	7800		**7800**	

Key
(a) The soil screening value used was the MCP Method 1 GW-1/S-1 values, if available
If no MCP value existed, then a Region III RBC was used. If no RBC existed, then a RCRA Action level was used.
(b) Massachusetts Contingency Plan 310 CMR 40.0974 and 40.0975, July 30, 1993, effective October 1, 1993
(c) USEPA Region III Risk-Based Concentration Table , Values for Residential Soil (USEPA, 1994, Third Quarter)
(d) RCRA Action level, Proposed Rule: RCRA Corrective Measures Study Action level (FR:55; 27 July, 1990) corresponding to a hazard index of 0.2 in compliance with MDEP
(1) Proposed standard

Source: Ecology & Environment, Inc., 1994

Key at end of Table

Table 7-3: Surface Water Values for Human Health Screening (ug/L)

METALS	
Antimony	14
Arsenic	0.018(1)
Cyanide	700
Mercury	0.14
Nickel	610
VOLATILE ORGANICS	
Acetone	
Acrolein	320
Acrylonitrile	0.059
Benzene	1.2
Bromodichloromethane	0.27
Bromoform	4.3
Carbon Tetrachloride	0.25
Chlorobenzene	680
Chloroform	5.7
Dibromochloromethane	0.41
1,2-Dichloroethane	0.38
1,1-Dichloroethylene	0.057
1,3-Dichloropropene	10
Ethylbenzene	3100
Methylene chloride	4.7
1,1,2,2,-Tetrachloroethane	0.17
Tetrachloroethylene(PCE)	0.8
Toluene	6800
1,1,2-Trichloroethane	0.6
Trichloroethylene(TCE)	2.7
Vinyl Chloride	2
PESTICIDES/PCBS	
alpha-Benzenehexachloride	0.0039
alpha-Chlordane	0.00057
alpha-Endosulfan	0.93
Aldrin	0.00013
beta-Benzenehexachloride	0.014
beta-Endosulfan	0.93
Chlordane	0.00057
DDD	0.00083
DDE	0.00059
DDT	0.00059
Dieldrin	0.00014
gamma-Chlordane	0.00057
gamma-BHC (Lindane)	0.019
Endosulfan sulfate	0.93
Endrin	0.76
Endrin aldehyde	0.76
Heptachlor	0.00021
Heptachlor epoxide	0.0001
PCB1242	0.000044
PCB1248	0.000044

PESTICIDES/PCBS, cont.	
PCB1254	0.000044
PCB1260	0.000044
Toxaphene	0.00073
EXPLOSIVES	
2,4-Dinitrotoluene	0.11
Nitrobenzene	17
BNAS	
Anthracene	9600
Benzidine	0.00012
Benzo[A]anthracene	0.0028
Benzo[A]pyrene	0.0028
Benzo[B]flouranthene	0.0028
Bis(2-Chloroisopropyl)Ether	1400
Bis(2-ethylhexyl)phthalate	1.8
Chrysene	0.0028
Dibenzo(a,h)Anthracene	0.0028
1,2-Dichlorobenzene	2700
1,3-Dichlorobenzene	400
1,4-Dichlorobenzene	400
3,3-Dichlorobenzidine	0.04
2,4-Dichlorophenol	93
Diethyl Phthalate	23000
2,4-Dinitrophenol	70
Dimethyl Phthalate	313000
Di-N-butyl phthalate	2700
1,2-Diphenyl hydrazine	0.04
Dioxin	1.30000000E-08
Fluoranthene	300
Fluorene	1300
Hexachlorobenzene	0.00075
Hexachlorobutadiene	0.44
Hexachloroethane	1.9
Hexachlorocyclopentadiene	240
Indeno[1,2,3-C,D]pyrene	0.0028
Isophorone	8.4
2-Methyl-4,6-dinitrophenol	13.4
N-Nitrosodiphenylamine	5
Pentachlorophenol	0.28
Phenol	21000
Pyrene	960
2,4,6-Trichlorophenol	2.1

Notes

(a) Water Quality Criteria from CMR 314, Section 4.05 (c)/ U.S. EPA, 57 FR 60848, December 22, 1992. Mass/CWA WQC for consumption of water and aquatic organisms; Chronic values used; Human health levels based on 10 -6 risk

(1) Value for inorganic form only

Source: Ecology & Environment, Inc. 1994

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Table 7-4: Other Comparison Values for Human Health Screening

Medium	Groundwater	Soil	Soil	Surf. Water
Source	MCP GW-3	MCP GW-3/S-3	Reg III RBC Comm./Indust.	Mass/CWA AWQC For Cons. of Fish Only
Units	ug/L (a)	ug/g (a)	ug/g (b)	ug/L (c)
METALS				
Aluminum			1000000	
Antimony	300	40	410	4300
Arsenic	400	30	310	0.14
Barium			72000	
Beryllium	50	3	0.67	
Cadmium	10	80	510	
Chromium (total)	2000	5000		
Chromium (III)	2000	5000	1000000	
Chromium (VI)	100	1000	5100	
Cyanide	10	400		22000
Copper			38000	
Iron				
Lead	30	600		
Manganese			5100	
Mercury	1	60	310	0.15
Nickel	80	700	20000	4600
Selenium	80	2500	5100	
Silver	7	200	5100	
Sodium				
Thallium	400	100		
Vanadium			7200	
Zinc	900	5000	310000	
VOLATILE ORGANICS				
Acetone	50000	60	100000	-
Acrolein			20000	780
Acrylonitrile			5.3	0.66
Benzene	7000	200	99	71
Benzoic Acid			1000000	
Bromodichloromethane	50000	90	46	22
Bromoform	50000	700	360	360
Bromomethane	50000	700	1400	
Carbon Disulfide			100000	
Carbon Tetrachloride	50000	40	22	4.4
Chlorobenzene	500	40	20000	21000
Chloroform	10000	300	470	470
Chloromethane			220	
Dibromochloromethane	50000	70	34	34
1,1-Dichloroethane	50000	500	100000	
1,2-Dichloroethane	50000	60	31	99
1,1-Dichloroethylene	50000	9	4.8	3.2
CIS-1,2-Dichloroethylene	50000	500	10000	
Trans-1,2-Dichloroethylene	50000	2000	20000	
1,2-Dichloropropane	30000	40	42	
1,3-Dichloropropene	2000	20	16	1700
Ethylbenzene	4000	500	100000	29000
Ethylene Dibromide	50000	0.07		
Methylene chloride	50000	700	380	1600
Methyl ethyl ketone	50000	40	610000	
Methyl isobutyl ketone	50000	70	51000	
Methyl Mercury	0.1	20	310	
Methyl t-Butyl Ether	50000	200	5100	
Styrene	50000	100	200000	
1,1,1,2-Tetrachloroethane	50000	20	110	
1,1,2,2,-Tetrachloroethane	20000	2	14	11
Tetrachloroethylene(PCE)	5000	500	55	8.85
Toluene	50000	2500	200000	200000
1,1,1-Trichloroethane	50000	500	92000	

Key at end of Table

Table 7-4: Other Comparison Values for Human Health Screening

Medium	Groundwater	Soil	Soil	Surf. Water
Source	MCP GW-3	MCP GW-3/S-3	Reg III RBC Comm./Indust.	Mass/CWA AWQC For Cons. of Fish Only
Units	ug/L (a)	ug/g (a)	ug/g (b)	ug/L (c)
1,1,2-Trichloroethane	50000	10	50	42
Trichloroethylene(TCE)	20000	500	260	81
Trichlorofluoromethane			310000	
Vinyl Chloride	600	2	1.5	525
Total Xylenes	50000	2500	1000000	
TPHC	50000	5000		
PESTICIDES/PCBS				
alpha-Benzenehexachloride			0.45	0.011
Aldrin	9	0.1	0.17	0.00014
beta-Benzenehexachloride			1.6	0.037
Chlordane	2	5	2.2	0.00059
DDD	6	10	12	0.00084
DDE	20	9	8.4	0.00059
DDT	0.3	9	8.4	0.00059
Dieldrin	0.1	0.1	0.18	0.00014
gamma-BHC (Lindane)	0.8	0.5	2.2	0.052
Endosulfan	0.1	0.05	6100	
Endrin	5	1	310	0.81
Heptachlor	1	0.7	0.64	0.00021
Heptachlor epoxide	2	0.3	0.31	0.00011
Methoxychlor	2	30	5100	
PCBs	0.3	2	0.37	0.000045
Toxaphene			2.6	0.00075
HERBICIDES				
Dacthal(DCPA)			510000	
Silvex			8200	
EXPLOSIVES				
Cyclonite(RDX)			26	
Cyclotetramethylenetetramine			51000	
1,3-Dinitrobenzene			100	
2,4-Dinitrotoluene	2000	7	2000	9.1
2,6-Dinitrotoluene			1000	
Nitrobenzene			510	1900
3-Nitrotoluene			1000	
1,3,5-Trinitrobenzene			5.1	
BNAS				
Acenapthene	2000	2000		
Acenapthylene	2000	800		
Anthracene	600	1000		110000
Benzidine			0.012	0.00054
Benzo[A]anthracene	5	0.7		0.031
Benzo[A]pyrene	2	0.7		0.031
Benzo[B]flouranthene	7	0.7		0.031
Benzo[G,H,I]perylene	0.1	30		
Benzo[K]fluoranthene	0.4	0.7		
1,1-Biphenyl (Dipehnyl)	4000	10	51000	
Bis(2-Chloroethyl)Ether	50000	0.7	2.6	
Bis(2-Chloroisopropyl)Ether	50000	9	41	170000
Bis(2-ethylhexyl)phthalate	30	500	200	5.9
Carbazole			140	
4-Chloroaniline	50000	30	4100	
2-Chlorophenol	40000	20	5100	
Chrysene	3	0.7		0.031
Dibenzo(a,h)Anthracene	0.3	0.8		0.031

Key at end of Table

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Table 7-4: Other Comparison Values for Human Health Screening

Medium	Groundwater	Soil	Soil	Surf. Water
Source	MCP GW-3	MCP	Reg III RBC	Mass/CWA AWQC
		GW-3/S-3	Comm./Indust.	For Cons. of Fish Only
Units	ug/L	ug/g	ug/g	ug/L
	(a)	(a)	(b)	(c)
1,2-Dichlorobenzene	8000	500	92000	17000
1,3-Dichlorobenzene	8000	500	91000	2600
1,4-Dichlorobenzene	8000	200	120	2600
3,3-Dichlorobenzidine	2000	3	6.4	0.077
2,4-Dichlorophenol	4000	90	3100	790
Diethyl Phthalate	30	0.7	820000	120000
2,4-Dimethylphenol	20000	10	20000	
2,4-Dinitrophenol	20000	6	2000	14000
Dimethyl Phthalate	30	0.7	1000000	2900000
Di-N-butyl phthalate				12000
Di-N-octyl phthalate			20000	
1,2-Diphenyl hydrazine			3.6	0.54
Dioxin	0.0001	0.00002	0.000019	1.40000000000E-08
Fluoranthene	100	600		370
Fluorene	1000	1000		14000
Hexachlorobenzene	40	3	1.8	0.00077
Hexachlorobutadiene	90	40	37	50
Hexachloroethane	5000	50	200	8.9
Hexachlorocyclopentadiene			7200	17000
Indeno[1,2,3-C,D]pyrene	0.3	0.7		0.031
Isophorone			3000	600
2-Methylnapthalene	3000	7		
4-Methylphenol			5100	
Napthalene	6000	1000		
N-Nitrosodi-N-propylamine			0.41	
N-Nitrosodiphenylamine			580	16
Pentachlorophenol	80	40	24	8.2
Phenanthrene	50	100		
Phenol	30000	500	610000	4600000
Pyrene	80	500		11000
1,2,4-Trichlorobenzene	500	800	10000	
2,4,5-Trichlorophenol	100	2	100000	
2,4,6-Trichlorophenol	10000	200	260	6.5
ANIONS				
Fluoride			61000	
Nitrate			1000000	
Nitrite			10000	
Sulfate				

Key
(a) Massachusetts Contingency Plan 310 CMR 40.0974 and 40.0975, July 30, 1993
(b) USEPA Region III Risk-Based Concentration Table (USEPA, 1993, Fourth Quarter)
(c) Water Quality Criteria from Code of Massachusetts Regulation, Title 314, Section 4.05 (c)/
U.S. Environmental Protection Agency, 57 FR 60848, December 22, 1992
Chronic values used; Human Health levels based on 10 -6 risk levels

Source: Ecology & Environment, Inc., 1994

Key at end of Table

Table 7-5: Surface Water Values for Ecological Screening

Source of Screening Value Used is In Bold	Screening Value Used ug/L (a)	Mass/CWA AWQC Aquatic Life ug/L (b)	LOEL Chronic ug/L (c)
METALS			
Antimony	30	**30(1)**	1,600(2)
Arsenic	190	**190(3)**	
Beryllium	5.3		**5.3**
Cadmium	1.1	**1.1(4)**	
Chromium (III)	210	**210(4)**	
Chromium (VI)	11	**11**	
Cyanide	5.2	**5.2**	
Copper	12	**12(4)**	
Iron	1000	**1000**	
Lead	3.2	**3.2(4)**	
Mercury	0.012	**0.012**	
Nickel	160	**160(4)**	
Selenium	5	**5**	
Silver	4.1	**4.1(5)**	
Zinc	110	**110(4)**	
VOLATILE ORGANICS			
Chlorobenzene	50	**50**	
Chloroform	1240	**1240**	
Methylene chloride	11000		**11,000(5)**
1,1,1,2-Tetrachloroethane	2400		**2400**
1,1,2,2,-Tetrachloroethane	2400		**2400**
Tetrachloroethylene(PCE)	840		**840**
Toluene	840	**840**	17,500(5)
1,1,2-Trichloroethane	9400	**9400**	
Trichloroethylene(TCE)	21900	**21900**	21900
Trichlorofluoromethane			
PESTICIDES/PCBS			
alpha-Chlordane	0.0043		
alpha-Endosulfan	0.056	**0.056(6)**	
Aldrin	3	**3(7)**	
beta-Endosulfan	0.056	**0.056(6)**	
Chlordane	0.0043	**0.0043(6)**	
DDT	0.001	**0.001(6)**	
Dieldrin	0.0019	**0.0019**	
gamma-Chlordane	0.0043	**0.0043(6)**	
gamma-BHC (Lindane)	0.08	**0.08**	
Endrin	0.0023	**0.0023(6)**	
Endrin aldehyde	0.0023		
Heptachlor	0.0038	**0.0038**	
Heptachlor epoxide	0.0038		
PCBs	0.014	**0.014(8)**	
Total PCBs	0.014	**0.014(8)**	
Toxaphene	0.0002	**0.0002**	
BNAS			
Napthalene	620		**620**

Key at end of Table

Table 7-5: Surface Water Values for Ecological Screening

Source of Screening Value Used is In Bold	Screening Value Used ug/L (a)	Mass/CWA AWQC Aquatic Life ug/L (b)	LOEL Chronic ug/L (c)
Phenanthrene	6.3	**6.3(1)**	
ANIONS			
Chloride	230000	**230000**	

Key
(a) SW Screening Values used were MA/CWA WQC chronic values for protection of aquatic life and LOEL levels when no WQC was available.
(b) Water Quality Criteria from Code of Massachusetts Regulation, Title 314, Section 4.05 (e)/ U.S. Environmental ProtectionAgency, 57 FR 60848, December 22, 1992, Chronic values listed
(c) Lowest Observed Effect Level (LOEL) for aquatic life. Chronic value listed.
(1) Proposed standard
(2) Fresh Water Acute Criterion/Fresh Water Chronic Criterion
(3) Arsenic III value
(4) Hardness dependent, assumed hardness value of 100 mg/l as CaC03
(5) Fresh Water Acute Criterion
(6) 24-hour average
(7) Criteria based on Final Acute Value, instantaneous value
(8) Total PCBs

Source: Ecology & Environment, Inc., 1994

Key at end of Table

Table 7-6: Sediment Values for Ecological Screening

Source of Screening Value Used Is in Bold	Screening Value Used ug/g (a)	NOAA Effects Range Low (ERL) ug/g (b)	Ontario MOE LOEL ug/g (c)
METALS			
Antimony	**2**	**2**	
Arsenic	6	33	**6**
Cadmium	0.6	5	**0.6**
Chromium (total)	26	80	**26**
Cobalt	50		**50**
Cyanide	0.1		**0.1**
Copper	16	70	**16**
Iron	20000		**20000**
Lead	31	35	**31**
Manganese	460		**460**
Mercury	0.15	**0.15**	0.2
Nickel	16	30	**16**
Silver	0.5	1	**0.5**
Zinc	120	**120**	120
TPHC	**2**		**2**
PESTICIDES/PCBS			
Aldrin	0.002		**0.002**
alpha-Chlordane	0.0005		
Chlordane	0.0005	**0.0005**	0.007
DDD	0.002	**0.002**	0.008
DDE	0.002	**0.002**	0.005
DDT	0.001	**0.001**	
DDT (Total)	0.003	**0.003**	0.007
Dieldrin	0.00002	**0.00002**	0.002
gamma-BHC (Lindane)	0.003		**0.003**
gamma-Chlordane	0.0005		
Endrin	0.00002	**0.00002**	0.003
Endrin aldehyde	0.00002		
Heptachlor epoxide	0.005		**0.005**
Total PCBs	0.05	**0.05**	
PCB1248	0.03		**0.03**
PCB1254	0.06		**0.06**
PCB1260	0.005		**0.005**
Total PCBs	0.07		**0.07**
BNAS			
Acenapthene	0.15	**0.15**	
Anthracene	0.085	**0.085**	
Benzo[A]anthracene	0.23	**0.23**	
Benzo[A]pyrene	0.4	**0.4**	
Chrysene	0.4	**0.4**	
Fluoranthene	0.6	**0.6**	
Fluorene	0.35	**0.035**	
Hexachlorobutadiene	0.02		**0.02**
2-Methylnapthalene	0.065	**0.065**	
Napthalene	0.34	**0.34**	

Key at end of Table

Table 7-6: Sediment Values for Ecological Screening

Source of Screening Value Used Is in Bold	Screening Value Used ug/g (a)	NOAA Effects Range Low (ERL) ug/g (b)	Ontario MOE LOEL ug/g (c)
Total PAHs	0.4	**0.4**	
Phenanthrene	0.225	**0.225**	
Pyrene	0.35	**0.35**	

Key

(a) Screening values chosen as the lower of the NOAA ERL and the Ontario MOE LOEL

(b) The potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trend Program, Long and Morgan, 1990. NOAA Technical Memorandum NOS OMA52 (1990) Effects Range -Low Values expressed on dry wt. basis, carbon-normalized on 1% TOC assumption

(c) Lowest Observed Effect Level, "Criteria for Contaminated Soil/Sediment Cleanup" J. Sitzhko, Ontario Ministry of Environment, 1989

Source: Ecology & Environment, Inc., 1994

Key at end of Table

Table 7-7: Other Sediment Comparison Values for Ecological Screening

	NOAA Effects Range-Median (ERM) ug/g (a)	NYSDEC SQC-chronic ug/gOC (b)	EPA SQC ug/gOC (c)
METALS			
Antimony	25		
Arsenic	85		
Cadmium	9		
Chromium (total)	145		
Copper	390		
Lead	110		
Mercury	1.3		
Nickel	50		
Silver	2.2		
Zinc	270		
VOLATILE ORGANICS			
Chlorobenzene		3.5	
PESTICIDES/PCBS			
alpha-Endosulfan		0.03	
beta-Benzenehexachloride		0.06	
beta-Endosulfan		0.03	
Chlordane	0.006	0.03	
DDD	0.02		
DDE	0.015		
DDT	0.007	1	0.828(1)
DDT (Total)	0.35		
Dieldrin	0.008	9	0.13(1)
gamma-BHC (Lindane)		0.06	0.157(2
Endosulfan		0.03	
Endrin	0.045	4	0.0533(1)
Heptachlor		0.1	0.11(1)
Methoxychlor		0.6	
PCB1254			19.5(1)
Total PCBs	0.4	19.3	
Toxaphene		0.01	
BNAS			
Acenapthene	0.65	140	732(2)
Anthracene	0.96		
Benzidine		0.003	
Benzo[A]anthracene	1.6		1317
Benzo[A]pyrene	2.5		1063
Bis(2-ethylhexyl)phthalate		199.5	
Chrysene	2.8		
Dibenzo(a,h)Anthracene	0.26		
1,2-Dichlorobenzene		12	
1,3-Dichlorobenzene		12	
1,4-Dichlorobenzene		12	
Fluoranthene	3.6	1020	1883
Fluorene	0.64		
Hexachlorobenzene		5570	
Hexachlorobutadiene		5.5	
Hexachlorocyclopentadiene		4.4	
2-Methylnapthalene	0.67		

Key at end of Table

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Table 7-7: Other Sediment Comparison Values for Ecological Screening

	NOAA Effects Range-Median (ERM) ug/g (a)	NYSDEC SQC-chronic ug/gOC (b)	EPA SQC ug/gOC (c)
Napthalene	2.1		
Total PAHs	35		
Pentachlorophenol		40	
Phenanthrene	1.38	120	139(2)
Pyrene	2.2		1311

Key

(a) The potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trend Program, Long and Morgan, 1990. NOAA Technical Memorandum NOS OMA52 (1990) Effects Range -Low Values expressed on dry wt. basis, carbon-normalized on 1% TOC assumption

(b) New York State Department of Environmental Conservation, "Technical Guidance for Screening Contaminated Sediments, 1993, organics as ug/gOC, organic criteria must be adjusted on TOC content

(c) "Interim Sediment Criteria Values for Nonpolar Hydrophobic Organic Contaminants"; USEPA, 1988 organics as ug/gOC, organic criteria must be adjusted on TOC content

(1) Interim Criteria value based on the Final Residue Value (FRV) conc. protecting aquatic life

(2) Interim Criteria value based on the Final Chronic Value (FCV) conc. protecting uses of aquatic life

Source: Ecology & Environment, Inc. 1994

Key at end of Table

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 GENERAL ANNEX-WIDE CONCLUSIONS

The overall results of the study of 33 sites in Sudbury Annex have identified or confirmed minor effects from former Annex activities. Although every effort was made by E & E to sample every part of the Annex and to sample at those sites having the greatest evidence of past spills, leaks, discharges, or dumping, the overall impact of site activities appears to be low. It should be noted that three other sites (investigated by OHM, Inc.) were evaluated to have concerns warranting Feasibility Studies (Sites A4, A7, and A9) and these sites will be remediated, and that five other sites (P11, P13, P36, P37, and A12) are currently undergoing remedial investigations (by E & E).

The conclusion of the Bioaccumulation Study conducted for fish in Puffer Pond (E & E 1994b) indicated that the residual metals and pesticides in fish tissue in species caught in Puffer Pond were statistically similar to concentrations found in fish caught in the background pond, Ministers Pond. The implication of this study is that the risk of eating fish from Puffer Pond is similar to that of eating fish from the background pond. However, because a single fish sample from Puffer Pond contained mercury in excess of the FDA action level of 1 ppm, the Army stated at a Technical Review Committee meeting on 4 August 1994, that it would continue its catch and release policy in Puffer Pond to avoid any potential risk related to fish consumption. The average concentration of mercury in fish from Puffer Pond was below the FDA action level.

The most widespread indication of former site activities is the almost ubiquitous presence at almost all sites of low levels (generally less than 1μg/g) of chlorinated pesticides in soils, particularly DDT and its breakdown products DDE and DDD. One bunker (Bunker 303) registered a concentration of DDT (59 μg/g) high enough to suggest a spill or discharge requiring further investigation, but otherwise the levels found were consistent with historic pest management practices, which included the formulation and use of oil-based pesticide mixtures that were applied by spraying, fogging, or direct application to surface waters.

Lead was found to be elevated in soils, sediments, and surface water in a number of isolated instances both on- and off-site, but not above levels typically found in many urban areas. Several localized "hot spots" exist where relatively high lead levels were found at former drum locations at Sites P23 and P31. At one site (Site P23), high levels of petroleum hydrocarbons were found in soil, suggesting that a limited removal action might be appropriate. At another site (Site A5) known to be affected by perchloroethene (PCE) disposal, one monitoring well continued to show a slight exceedance of the drinking water standard for PCE.

The only widespread subject of concern identified at the Annex is the element arsenic. It has been found in levels elevated well above background at a number of locations. In

11:UC6101-3/RC1132_V1-09/22/94-F1
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Watershed 1A, arsenic was found at several of the bunkers in soil (with the highest concentrations at Bunker 302), in sediments in Puffer Pond and Taylor Brook, and in soil at Site P27, the former pyrotechnics test area. In Watershed 1B, arsenic was found in surface water and sediments in Honey Brook alongside the bunker area, in Taylor Brook, and in an unnamed tributary to Taylor Brook at Site P45. In Watershed 2, high concentrations of arsenic were found in soils at Site P28, the railroad classification yard ("rocket range"), Site P38, the former railroad inspection pit, and at Site A10, the railroad maintenance pit. Marlboro Brook, downgradient of Sites P28 and P38, also had elevated arsenic in sediments and surface water. In Watershed 3, arsenic was found in high concentrations in soil samples at Site P9. In Watershed 5, arsenic was found in a filtered sample from one monitoring well at Site P31 at a level above drinking water standards, and also in surface water and sediments at Sites P31 and P58 along Sudbury Road.

Taylor Brook and its tributaries, including Puffer Pond, have shown elevated arsenic in sediment samples (12 of 26), but the sample taken at the exit point of Taylor Brook from the Annex shows a level close to background. Neither of the other smaller streams entering the Assabet River from the Annex show evidence of elevated levels of arsenic at their entry point to the river. The high levels of arsenic found in Assabet River sediments by OHM appear to be related mainly to upstream sources.

Two sites close to Boons Pond, Site P31, and Site P58 in Watershed 5, appear to be contributing some elevated levels of arsenic, mercury, and lead to surface water and sediments. Although this area is no longer entirely on Annex property, and appears to contain general refuse probably unrelated to Annex activities, the sites are on land formerly part of the Annex. The elevated levels of metals in sediments and surface water do not extend as far as Boons Pond.

Site P31 showed arsenic slightly above drinking water standards in filtered samples from one well and the adjoining Site P58 had elevated arsenic in groundwater also. Because of their locations close to off-site private wells, this is the only instance where arsenic is of possible concern for human health at this time.

Arsenic is present in natural levels in background soils and sediments, and in wells unaffected by site activities. Its presence in elevated levels could be due to a number of possible factors. It could be due to naturally elevated levels, particularly in till and bedrock areas. It is present in coal and often in ballast used by railroads on their rail beds, so that its presence could represent impacts from the railroads that traversed the site. It could be related to chemicals used in pyrotechnics, and to arsenical pesticides, herbicides, and rodenticides that have a long history of use in agriculture and weed control, and as rat poison within New England and probably at the Annex.

A recent study (Puls *et al.* 1994) has shown that natural arsenic can be mobilized by increased alkalinity (rising pH) and reducing conditions. While anoxic (reducing) conditions may prevail as the result of decaying vegetation in wetlands around the Annex, this is typically accompanied by acidic (low pH) conditions. The overall effects of activities at the

Annex do not appear to lead to either an increased pH level in environmental media or the creation of reducing conditions.

To gain an understanding of arsenic exposure and risks at the Annex, it should be noted that arsenic is naturally present in soils and waters, and humans are exposed to arsenic in food, air, and water on a daily basis. Therefore, to put the potential site-related exposures and risks in perspective, it is important to be aware of the routine, daily exposures to arsenic that everyone is exposed to and the risks that could be associated with those exposures.

The general population of the United States is estimated to be exposed to 25 to 50 μg of arsenic per day, primarily in food and drinking water (ATSDR 1993; WHO 1981). For a 70-kg adult, these intake rates correspond to estimated cancer risks of 6×10^{-4} to 1×10^{-3} and an estimated hazard index of 1.2 to 2.4 for noncarcinogenic effects. The federal MCL for arsenic in drinking water is 50 μg/L. Using EPA's standard default drinking water exposure factors, the MCL concentration would correspond to an estimated cancer risk of 2.5×10^{-3} and an estimated hazard index of 4.8. (A hazard index greater than 1 indicates that adverse effects may be possible while a value less than 1 means that adverse effects would not be expected. The higher the hazard index is above 1, the more likely it is that adverse effects could occur.) The very conservative, health-protective nature of EPA's toxicity assessment process is shown by the fact that the majority of the United States population does not appear to be suffering adverse effects from arsenic despite the risks estimated by this process to be incurred by everyday arsenic exposure.

Again, it must be stated that, despite every effort to sample from areas most likely to be affected by historic activities at the Annex, the results of the investigations conducted by E & E during the Phase II efforts, have shown that no areas have widespread or intense contamination, except those areas with arsenic concerns. The ongoing RI/FS sites, (Sites A4, A7, and A9), currently being investigated by OHM, Inc. are of separate concern. All the data that show elevated levels of any element or compound, other than arsenic, have come from isolated, spotty, or very limited areas and have shown no obvious pattern of distribution. Data on the sediments or surface waters leaving the Annex do show an impact of past Annex activities on Marlboro Brook, which flows into Hop Brook just at the upstream end of Stearns Millpond. However, it first passes through a small pond just south of Marlboro Road (Moore Road) that will act as a trap for sediments.

8.2 RECOMMENDATIONS

E & E has presented recommendations for each site evaluated as part of this Phase II effort, in the site discussions presented in Volume II of this report. These recommendations have been summarized as Table 8-1 for ease of reference. There are five categories of recommendations. The sites are categorized into the following groups and are discussed briefly in this section.

- Group 1: No further action necessary and a NFADD is recommended. This group consists of the following 12 sites (Sites A8 and P10 are counted as two individual sites; Site P43A/P43B is

11:UC6101-3/RC1132_V1-09/22/94-F1
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one site): A6, A8/P10, P3, P26, P40, P42, P43A/B, P48, P52, P56, and P57.

- Group 2: Further action pending results of other investigations at the Annex. This group includes the following four sites: A10, A11, P1, and P6.

- Group 3: Further action recommended in the form of a non-CERCLA removal of debris and/or contaminated soil in the area. This group consists of the following five sites: A1, A2, P2, P22, and P39.

- Group 4: Supplemental Site Investigations are recommended for the following 12 sites: A5, P9, P16, P23, P27, P28, P31, P38, P41, P45, P54, and P58.

- Group 5: Remedial Investigations are currently underway at Sites P11 and P13 and also at Sites P36, A12, and P37. No recommendations are made concerning these five sites in this report. Recommendations will be made once the RIs are completed.

It is recommended that 12 sites be proposed for NFA because the SI sampling results show no contaminant concentrations at levels which pose a threat to human health or the environment. It is recommended that NFADDs be initiated for the following sites: A6, A8/P10, P3, P26, P40, P42, P43A/B, P48, P52, P56, and P57.

Three sites are proposed for further action, due to the presence of a limited amount of arsenic contamination. However, no field work has been proposed at this time. The scope of any field work at these sites should be determined after the results of arsenic studies at the Annex are completed. The three sites in this group are Sites A10, P1, and P6. Site A11 is also proposed for further action pending other investigations at the Annex. Sediments and surface water contaminated with metals were found in Marlboro Brook near Site A11, but not in soils or groundwater at the site. Further action regarding Site A11 should be taken after the SSIs at Sites P28 and P38 are completed, which may identify a source of the contaminants in Marlboro Brook unrelated to Site A11.

Five sites are recommended for further action in the form of a non-CERCLA removal action and the focus of the potential removal actions are as follows: Site A1, one drum and lead in soils; Site A2, explosives, lead, metals in soils; Site P2, pesticides in soils; Site P22, PAHs in soils; and Site P39, metals and debris in soils and sediments.

Two sites (P31 and P58) were identified as warranting a combined SSI. This recommendation is based on arsenic in the groundwater and lead and other metals in sediments. It is recommended that an SSI be performed to assess the impact of Sites P58 and P31 on surface water, sediments, and groundwater off the Annex boundary. The SSI should include sampling of off-site private wells to assess if any migration of contaminants may have occurred.

A number of other sites were identified where a limited field and sampling effort or SSI would determine whether the extent of the contamination justifies an RI, or whether a NFA recommendation is appropriate. A total of 12 sites as listed in Table 8-1 are identified for further field sampling. These include: Sites P9, P16, P27, P28/P38, and P45 to address arsenic concerns; Site A5 continued monitoring because of PCE exceeding the MCL in one well; Site P23 to address elevated TPHC and lead in soils; and Site P41 to investigate elevated pesticides. Site P54 is recommended for SSI status, but has no recommended field work pending the arsenic investigation at Site P16.

Two remedial investigations are currently underway, one for Sites P11 and P13, and the second at Sites P36/A12/P37. Conclusions regarding these sites will be made following the completion of the RIs for these sites.

11:UC6101-3/RC1132_V1-09/22/94-F1
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Table 8-1
RECOMMENDED STATUS OF SITES AND PROPOSED ACTIONS

Watershed	NFADD Sites	RI Sites (Currently Underway)	Proposed Fieldwork for SSI and Further Action Sites				
			SSI Sites	Further Action (Removal) Sites	Further Action Pending Sites	Primary Concern(s)	Field Work[a]
1A	P43A/43B P52 P56		P16 P27 P41 P54		P6	Arsenic Arsenic Arsenic Pesticides Arsenic	Pending arsenic studies at P16, P54 Soil, groundwater, wipe sampling Soil, groundwater, sw/sed sampling Soil, groundwater, wipe sampling Pending P16 investigation
1B	P26 P42	P11/P13	P23 P45	A1 A2		Lead Explosives, Metals TPHC, lead Arsenic	Drum/soil removal, confirmatory sampling Soil removal, confirmatory sampling Soil sampling and removal Soil removal, sw/sed sampling
2	P48	A12/P36/P37	P28/P38	P39	A10 A11	Arsenic Metals	Pending arsenic study at P28/P38 Pending study of Marlboro Brook (P28/P38) Soil, groundwater, sw/sed sampling Soil/debris removal, confirmatory sampling
3	A8/P10 P57		P9			Arsenic	Soil sampling
4	A6			P22			Soil removal, confirmatory sampling
5	P40		A5 P31/P58			PCE Arsenic, other metals	Continued groundwater monitoring Groundwater, sw/sed sampling
6	P3			P2	P1	Arsenic Pesticides	Pending arsenic studies at Annex Soil removal, confirmatory sampling

[a]Indicates media to be sampled or removed.
Source: Ecology and Environment, Inc. 1994.

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STOWAWAY GOLF CLUB

ASSABET

P12

A9

A8 & P10

P8 P9

A7

LOWER ASSABET RIVER 3

P57

P11

P13

CROW ISLAND GLIDER PORT

ROAD

TRACK

USAF WEATHER SCIENCE RADAR LABORATORY

THICKET CIRCLE

WILDWOOD ROAD

UPPER ASSABET RIVER 4

A6

P25

P26

P24

P22

P21

LAKEWOOD ROAD

POND ROAD

WHITE

HONE BROOK

LAKE BOON

PARKER ROAD

P51

P30

SUDBURY

KINGLAND RD.

RICE POINT ROAD

A5

LAKE BOON 5

P40

E 665,000

E 670,000

N 2,980,000

N 2,975,000

NEWTON DR.

ROUTE 117

SUDBURY ST.

PARK ST.

WINTER ST.

WHITE AVE.

DRISCOLL AVE.

CLAMORE AVE.

ESPIE AVE.

MAYNARD C.P.W.

GREEN MEADOW SCHOOL

TAYLOR BROOK

PATROL ROAD

LOWER TAYLOR BROOK 1B

UPPER TAYLOR BROOK 1A

REGION ONE FEMA OPERATIONS CENTER

DIGITAL

OLD MARLBORO ROAD

ROUTE 27

EAST GATE

VOSE POND

PUFFER ROAD

PUFFER POND

CUTTING POND

MAYNARD SUDBURY

CRANBERRY BOGS

CRAVEN LN.

P6 P11 P13 P14 P16 P18 P19 P20 P23 P24 P25 P26 P27 P29 P30 P41 P42 P43A P43B P44A P44B P45 P46 P47 P49 P50 P51 P52 P53 P54 P55 P56

A1 A2 A3 A4 P5

SITE NUMBE
A3
A4
P5
P6
P14
P16
P18
P27
P41
P43A/B
P44A/B
P46
P47
P49
P50
P52
P54
P55
P56

SITE NUMBE
A1
A2
P4
P11
P13
P19
P20
P23
P24
P25
P26
P29
P30
P42
P45
P51

WATERSHED 1A SITES – UPPER TAYLOR BROOK	
R	SITE NAME
	GENERAL DUMP
	WASTE DUMP
	DRUM STORAGE AREA
	PUFFER POND POSSIBLE DUMP AREA
	EAST GATE BURIAL DUMP
	CHEMICAL AND WASTE STORAGE BUNKERS 302, 306, AND 309
	CLOTH BURIAL AREA
	PYROTECHNICS TEST AREA
	BUNKER 303 PESTICIDE/HERBICIDE STORAGE
	DISTURBED AREA/STAINED SOILS AND STRESSED VEGETATION
	CLEARING WITH STAINS AND WHITE OBJECTS
	CLEARED BURNED AREA AND DEAD TREES
	DAMAGED VEGETATION
	TWO DRUMS NEAR ROAD AND BUNKER 323
	ONE DRUM NEAR ROAD AND BUNKER 325
	POSSIBLE DUMP AREA NEAR FEMA PROPERTY
	BUNKERS 305, 307, 314, AND SUPPLEMENTAL BUNKERS 301, 304, 311, 312, AND 318
	CLEARED AREA SOUTH OF BUNKER 301
	CLEARED AREA SOUTH OF BUNKER 313

WATERSHED 1B SITES – LOWER TAYLOR BROOK	
R	SITE NAME
	DECONTAMINATED MUSTARD AREA
	DEMOLITION GROUND 1
	BUNKER DRUM AREA
	BUILDING T405 DUMP AREA
	MASSACHUSETTS FIRE FIGHTING ACADEMY
	CLEARING AND TRACKED AREA
	BURNED AREA AND DRUM
	BUILDING T465 (DRUMS)
	CLEARED AREA
	TEST CHAMBER BUILDING T463
	AIR DROP ZONE CLEARING
	STATIC ROCKET FIRING
	PROPOSED TEST AREA
	OFFSITE DUMP
	BURNED AREA BY OUTSIDE FENCE
	ONE DRUM NEAR WHITE POND ROAD

LEGEND:

- APPROXIMATE WATERSHED BOUNDARY
- BUILDING/STRUCTURE
- PAVED ROAD
- UNIMPROVED ROAD
- WATER BODY
- STREAM
- RAILROAD
- FENCE
- INSTALLATION BOUNDARY
- 200 CONTOUR (25' INTERVAL)
- WETLAND
- P26 **E&E SITE NUMBER IN BOLD**
- P12 OHM SITE NUMBER
- E&E SUPPLEMENTAL SAMPLING LOCATIONS

WATERSHED 5 SITES – LAKE BOON	
SITE NUMBER	SITE NAME
A5	SOLVENT/WASTE DUMP
P7	PATROL ROAD DUMP AREA
P31/P58	OLD DUMP/SUDBURY ROAD DUMP
P40	BUILDING T452 AREA

WATERSHED 6 SITES – WILLIS POND & CRYSTAL LAKE	
SITE NUMBER	SITE NAME
P1	UST ACROSS FROM BUILDING T223
P2	BUILDING T267 FUEL SPILLS
P3	BUILDING T209 UST
P17	BUILDING T206 CLOTH BURIAL AREA
P33	GROUND SCAR
P34	VEGETATION STRESS AT MAIN GATE
P35	MAIN GATE GUARD SHACK
P53	BUILDING T210 UST



Plotted: 03/11/94

WILLIS POND & CRYSTAL LAKE 6

WILLIS POND

CRYSTAL LAKE

HOP BROOK 2

N 2,970,000

N 2,965,000

P55 P3 P2 P1 P17 P35 P34 P28 P33 A11 P36 A12 P37

LAKESHORE DR. BIRCHWOOD AVE. BASSWOOD AVE. PARKWOOD AVE. BEECHWOOD AVE. PINEWOOD AVE. MAPLEWOOD AVE. GREAT LAKE DR. ORCHARD LAKE DR. INTERVALE RD. HARMES LANE BUTLER PL. LOUISE AVE. BUTLER RD. BARBARA RD. RICHARD RD. MIDDLE RD. STEARNS RD. PINECUT LAKE MOORE RD. SIBLEY LN. PONDVIEW RD. PARTRIDGE LN. BARTON DR. BRENT BROOK RD. MILL POND RD. HUDSON STREET MARLBORO ROAD STOW SUDBURY ROAD B & M RAILROAD (ABANDONED) HOP BROOK

SITE NUMBE
A10
A11
A12
P15
P28
P32
P36
P37
P38
P39
P48

SITE NUMBE
A7/P8
A8/P10
A9/P12
P9
P57

SITE NUMBE
A6
P21
P22

ecolog
International

DESIGNED BY
A. RAWA

DRAWN BY
R. BIDELL

NO.	DATE	DWN	APP'D	DESCRIPTION
REVISIONS				

WATERSHED 2 SITES - HOP BROOK	
R	SITE NAME
	RAILROAD PIT/UST AREA
	LEACHING FIELD
	PCB SPILL REMEDIATION AREA
	NAVY BURNING GROUND
	ROCKET RANGE
	ROAD AND RAILROAD INTERSECTION
	FORMER RAYTHEON BUILDING T104
	BUILDING T106 UST
	FORMER RAILROAD INSPECTION PIT
	DUMP AREA
	FUEL BLADDER AREA

WATERSHED 3 SITES - LOWER ASSABET RIVER	
R	SITE NAME
	OLD GRAVEL PIT LANDFILL/POSSIBLE TRANSFORMER DISPOSAL
	FOOD BURIAL AREA/CONFIDENCE COURSE DUMP AREA
	POL BURN AREA / ABANDONED UST
	STREAM DUMP AREA BETWEEN SITES A7 AND A9
	FORMER BUILDING S449

WATERSHED 4 SITES - UPPER ASSABET RIVER	
R	SITE NAME
	DEMOLITION GROUND II
	POSSIBLE DUMP AREA
	OLD GRAVEL PIT

REFERENCES:

1. TOPOGRAPHIC MAPPING INITIALLY DEVELOPED BY BIONETICS CORPORATION FROM APRIL 1992 AERIAL PHOTOGRAPHY WITH REVISIONS AND FINALIZATION CONDUCTED BY OHM CORPORATION.
2. GROUND CONTROL FOR AERIAL MAPPING ESTABLISHED BY T. F. MORAN.
3. STATE PLAN COORDINATE SYSTEM OF NORTH AMERICAN DATUM (NAD 1983).



y and environment, inc.
Specialists in the Environment

CHECKED BY
H. ALDIS

APPROVED BY
B. KING

SUDBURY TRAINING ANNEX
MIDDLESEX COUNTY, MASSACHUSETTS

SITES AT THE SUDBURY ANNEX
PLATE 1

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1"=800'	3/15/94	UC6S0280	UC6101 - 1	0

N

E 655,000

E 660,000

ELIZABETH BROOK

OHM-A7-10
OHM-A7-11
OHM-A7-12
SG-6

EHA2
OHM-A7-9
OHM-A7-8
OHM-A7-46
OHM-A7-45

DM8
OHM-
DM9A
OHM-
P12
OHM-A9-47
DM10
A9
OHM-A8-
OHM-
A8 &
P10
A7
P8
OHM-A7-7A
P9
OHM-A8-15
SG-9

ASSABET

OHM-A7-13
E3-P13-M01-
EHA3
OHM-P11-34
SG-8
E3-P57-M01
P57
P11
E3-P11-M01
OHM-P11-33

USAF WEATHER-SCIENCE RADAR LABORATORY

SG-18
P25
P2
E3-P26-
E3-P26-M01
P24
E3-A6-M01
A6
SG-7
E3-P22-M01
P22
P21
P51
SG-2
P30
LAKE BOON
SG-10
A5
OHM-A5-44
DM6
OHM-A5-24
P40
E3-A5-M01
OHM-P40-39
EHA1
OHM-P40-38

E 665,000

E 670,000

N 2,980,000

N 2,975,000

MAYNARD D.P.W.

GREEN MEADOW SCHOOL

TAYLOR

ROOT

MAYNARD TOWN WELL #3

DIGITAL

REGION ONE FEMA OPERATIONS CENTER

CRANBERRY BOG

EAST GATE

YOSE POND

PUFFER POND

CUTTING POND

MAYNARD

SUDBURY

P42 P43A P43B P44A P44B P45 P46 P47 P18 P19 P20 P23 P27 P52 P54 P56 P6 P4 P5 P14 P29 P50 P49 P16 P41

A1 A2 A3 A4

EHA4 EHA5 EHA6 EHA7

DM1 DM3 DM4 DM5

SG-17 SG-16 SG-15 SG-14 SG-13 SG-12 SG-11 SG-5 SG-4 SG-3

GZA-MW1 GZA-MW2 GZA-MW3

TW-14

E3-A2-MO1 E3-P13-M03 E3-P13-M02 E3-P13-M04 E3-P23-M01

OHM-P6-25 OHM-P6-27 OHM-P6-26

OHM-A3-1 OHM-A3-3 OHM-A4-4 OHM-A4-5 OHM-A4-50

A9-17 A9-18 A9-16 A9-49

SITE NUM
A3
A4
P5
P6
P14
P16
P18
P27
P41
P43A/
P44A/B
P46
P47
P49
P50
P52
P54
P55
P56

SITE NUME
A1
A2
P4
P11
P13
P19
P20
P23
P24
P25
P26
P29
P30
P42
P45
P51

WATERSHED 1A SITES – UPPER TAYLOR BROOK	
NBER	SITE NAME
	GENERAL DUMP
	WASTE DUMP
	DRUM STORAGE AREA
	PUFFER POND POSSIBLE DUMP AREA
	EAST GATE BURIAL DUMP
	CHEMICAL AND WASTE STORAGE BUNKERS 302, 306, AND 309
	CLOTH BURIAL AREA
	PYROTECHNICS TEST AREA
	BUNKER 303 PESTICIDE/HERBICIDE STORAGE
B	DISTURBED AREA/STAINED SOILS AND STRESSED VEGETATION
	CLEARING WITH STAINS AND WHITE OBJECTS
	CLEARED BURNED AREA AND DEAD TREES
	DAMAGED VEGETATION
	TWO DRUMS NEAR ROAD AND BUNKER 323
	ONE DRUM NEAR ROAD AND BUNKER 325
	POSSIBLE DUMP AREA NEAR FEMA PROPERTY
	BUNKERS 305, 307, 314, AND SUPPLEMENTAL BUNKERS 301, 304, 311, 312, AND 318
	CLEARED AREA SOUTH OF BUNKER 301
	CLEARED AREA SOUTH OF BUNKER 313

WATERSHED 1B SITES – LOWER TAYLOR BROOK	
BER	SITE NAME
	DECONTAMINATED MUSTARD AREA
	DEMOLITION GROUND 1
	BUNKER DRUM AREA
	BUILDING T405 DUMP AREA
	MASSACHUSETTS FIRE FIGHTING ACADEMY
	CLEARING AND TRACKED AREA
	BURNED AREA AND DRUM
T	BUILDING T465 (DRUMS)
	CLEARED AREA
	TEST CHAMBER BUILDING T463
	AIR DROP ZONE CLEARING
	STATIC ROCKET FIRING
	PROPOSED TEST AREA
	OFFSITE DUMP
	BURNED AREA BY OUTSIDE FENCE
	ONE DRUM NEAR WHITE POND ROAD

LEGEND:

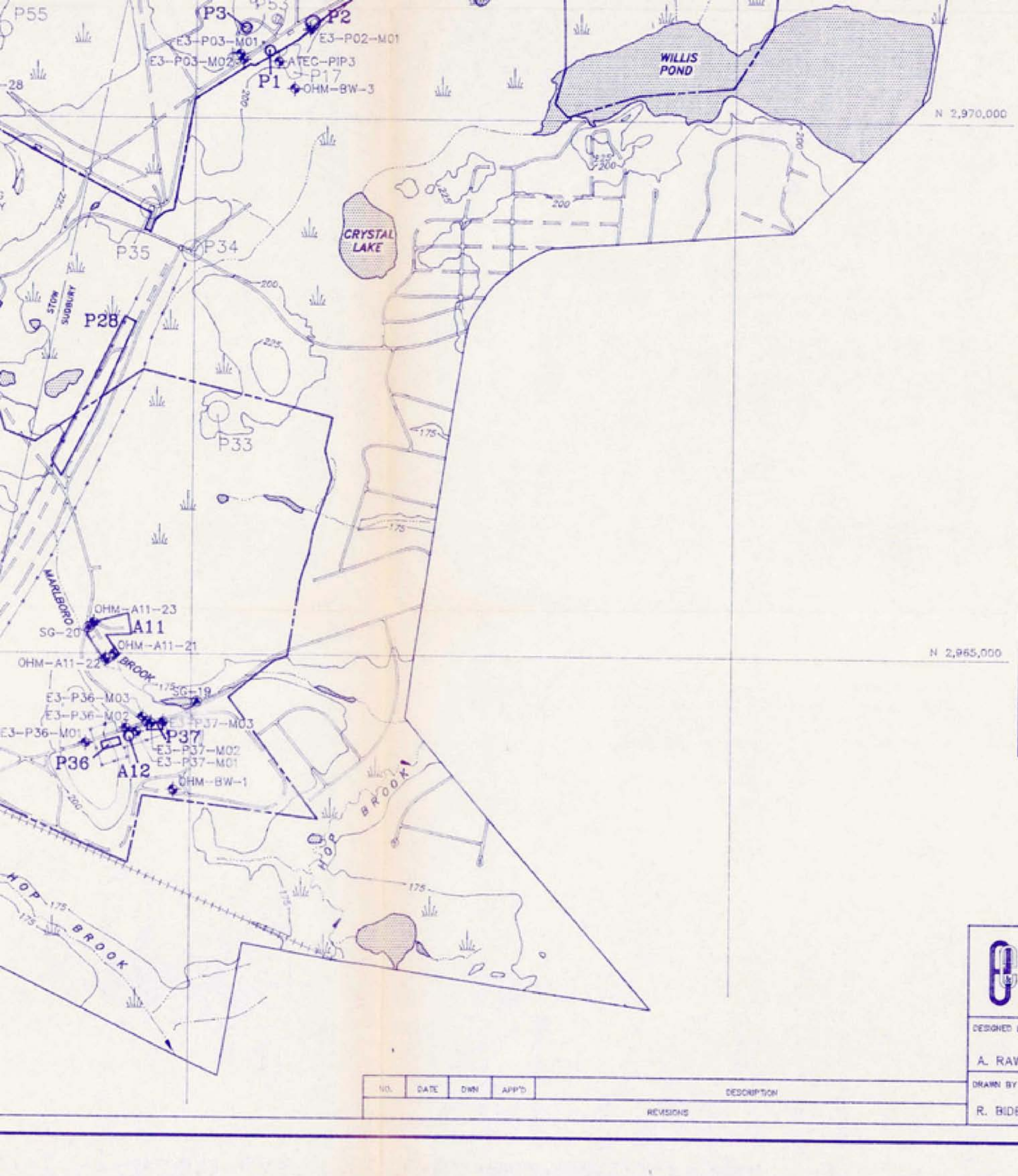
- BUILDING/STRUCTURE
- PAVED ROAD
- UNIMPROVED ROAD
- WATER BODY
- STREAM
- RAILROAD
- FENCE
- INSTALLATION BOUNDARY
- 200 — CONTOUR (25' INTERVAL)
- WETLAND
- **P26** — **E&E SITE NUMBER IN BOLD**
- P12 — OHM SITE NUMBER
- E&E SUPPLEMENTAL SAMPLING LOCATIONS
- MONITORING WELL LOCATION
- STAFF GAUGE LOCATION

WATERSHED 5 SITES – LAKE BOON	
SITE NUMBER	SITE NAME
A5	SOLVENT/WASTE DUMP
P7	PATROL ROAD DUMP AREA
P31/P58	OLD DUMP/SUDBURY ROAD DUMP
P40	BUILDING T452 AREA

WATERSHED 6 SITES – WILLIS POND & CRYSTAL LAKE	
SITE NUMBER	SITE NAME
P1	UST ACROSS FROM BUILDING T223
P2	BUILDING T267 FUEL SPILLS
P3	BUILDING T209 UST
P17	BUILDING T206 CLOTH BURIAL AREA
P33	GROUND SCAR
P34	VEGETATION STRESS AT MAIN GATE
P35	MAIN GATE GUARD SHACK



Plotted: 03/15/94



SITE NUMBE
A10
A11
A12
P15
P28
P32
P36
P37
P38
P39
P48

SITE NUMBE
A7/P8
A8/P10
A9/P12
P9
P57

SITE NUMBE
A6
P21
P22

ecology
International S

DESIGNED BY
A. RAWA

DRAWN BY
R. BIDELL

NO.	DATE	DWN	APP'D	DESCRIPTION

REVISIONS

P53	BUILDING T210 UST

WATERSHED 2 SITES – HOP BROOK	
ER	SITE NAME
	RAILROAD PIT/UST AREA
	LEACHING FIELD
	PCB SPILL REMEDIATION AREA
	NAVY BURNING GROUND
	ROCKET RANGE
	ROAD AND RAILROAD INTERSECTION
	FORMER RAYTHEON BUILDING T104
	BUILDING T106 UST
	FORMER RAILROAD INSPECTION PIT
	DUMP AREA
	FUEL BLADDER AREA

WATERSHED 3 SITES – LOWER ASSABET RIVER	
ER	SITE NAME
	OLD GRAVEL PIT LANDFILL/POSSIBLE TRANSFORMER DISPOSAL
	FOOD BURIAL AREA/CONFIDENCE COURSE DUMP AREA
	POL BURN AREA / ABANDONED UST
	STREAM DUMP AREA BETWEEN SITES A7 AND A9
	FORMER BUILDING S449

WATERSHED 4 SITES – UPPER ASSABET RIVER	
R	SITE NAME
	DEMOLITION GROUND II
	POSSIBLE DUMP AREA
	OLD GRAVEL PIT

REFERENCES:

1. TOPOGRAPHIC MAPPING INITIALLY DEVELOPED BY BIONETICS CORPORATION FROM APRIL 1992 AERIAL PHOTOGRAPHY WITH REVISIONS AND FINALIZATION CONDUCTED BY OHM CORPORATION.
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3. STATE PLAN COORDINATE SYSTEM OF NORTH AMERICAN DATUM (NAD 1983).
4. ECOLOGY AND ENVIRONMENT INC. WATER LEVEL SURVEY CONDUCTED IN SEPTEMBER 1993.



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	CHECKED BY H. ALDIS
	APPROVED BY B. KING

SUDBURY TRAINING ANNEX
MIDDLESEX COUNTY, MASSACHUSETTS

MONITORING WELL AND STAFF GAUGE LOCATIONS AT THE SUDBURY ANNEX
PLATE 2

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1"=800'	3/15/94	UC6S029D	UC6101 – 2	0

E 655,000

E 660,000

ELIZABETH BROOK

SG-6

176

ASSABET

180

190

200

220

210

230

P12

A9

A8 & P10

P57

P11

P13

SG-18

P26

A6

P24

SG-7

P22

P21

P51

SG-2

LAKE BOON

186

P30

SG-10

A5

P40

E 669,000

E 670,000

N 2,980,000

N 2,975,000

MAYNARD O.P.W.

GREEN MEADOW SCHOOL

DIGITAL

MAYNARD TOWN WELL #3

REGION ONE FEMA OPERATIONS CENTER

CRANBERRY EDGE

PUFFER POND

178

CUTTING POND

191

VOSE POND

EAST GATE

MAYNARD SUDBURY

P42 P45 P43A P43B P44A P44B P23 P27 P52 P54 P56 P6 P46 P16 P41 P50 A1 A2 A3 P4 P5 P14

SG-1 SG-2 SG-3 SG-4 SG-5 SG-6 SG-11 SG-12 SG-13 SG-14 SG-15

176 180 190 200 210 220 230

SITE NUMBE
A3
A4
P5
P6
P14
P16
P18
P27
P41
P43A/B
P44A/B
P46
P47
P49
P50
P52
P54
P55
P56

SITE NUMBE
A1
A2
P4
P11
P13
P19
P20
P23
P24
P25
P26
P29
P30
P42
P45
P51

WATERSHED 1A SITES – UPPER TAYLOR BROOK	
ER	SITE NAME
	GENERAL DUMP
	WASTE DUMP
	DRUM STORAGE AREA
	PUFFER POND POSSIBLE DUMP AREA
	EAST GATE BURIAL DUMP
	CHEMICAL AND WASTE STORAGE BUNKERS 302, 306, AND 309
	CLOTH BURIAL AREA
	PYROTECHNICS TEST AREA
	BUNKER 303 PESTICIDE/HERBICIDE STORAGE
	DISTURBED AREA/STAINED SOILS AND STRESSED VEGETATION
	CLEARING WITH STAINS AND WHITE OBJECTS
	CLEARED BURNED AREA AND DEAD TREES
	DAMAGED VEGETATION
	TWO DRUMS NEAR ROAD AND BUNKER 323
	ONE DRUM NEAR ROAD AND BUNKER 325
	POSSIBLE DUMP AREA NEAR FEMA PROPERTY
	BUNKERS 305, 307, 314, AND SUPPLEMENTAL BUNKERS 301, 304, 311, 312, AND 318
	CLEARED AREA SOUTH OF BUNKER 301
	CLEARED AREA SOUTH OF BUNKER 313

WATERSHED 1B SITES – LOWER TAYLOR BROOK	
R	SITE NAME
	DECONTAMINATED MUSTARD AREA
	DEMOLITION GROUND 1
	BUNKER DRUM AREA
	BUILDING T405 DUMP AREA
	MASSACHUSETTS FIRE FIGHTING ACADEMY
	CLEARING AND TRACKED AREA
	BURNED AREA AND DRUM
	BUILDING T465 (DRUMS)
	CLEARED AREA
	TEST CHAMBER BUILDING T463
	AIR DROP ZONE CLEARING
	STATIC ROCKET FIRING
	PROPOSED TEST AREA
	OFFSITE DUMP
	BURNED AREA BY OUTSIDE FENCE
	ONE DRUM NEAR WHITE POND ROAD

LEGEND:

- APPROXIMATE GROUNDWATER CONTOUR (FEET ABOVE MEAN SEA LEVEL)
- BUILDING/STRUCTURE
- PAVED ROAD
- UNIMPROVED ROAD
- WATER BODY
- STREAM
- RAILROAD
- FENCE
- INSTALLATION BOUNDARY
- 200 CONTOUR (25' INTERVAL)
- WETLAND
- **P26** **E&E SITE NUMBER IN BOLD**
- P12 OHM SITE NUMBER
- E&E SUPPLEMENTAL SAMPLING LOCATIONS
- MONITORING WELL LOCATION
- STAFF GAUGE LOCATION

WATERSHED 5 SITES – LAKE BOON	
SITE NUMBER	SITE NAME
A5	SOLVENT/WASTE DUMP
P7	PATROL ROAD DUMP AREA
P31/P58	OLD DUMP/SUDBURY ROAD DUMP
P40	BUILDING T452 AREA

WATERSHED 6 SITES – WILLIS POND & CRYSTAL LAKE	
SITE NUMBER	SITE NAME
P1	UST ACROSS FROM BUILDING T223
P2	BUILDING T267 FUEL SPILLS
P3	BUILDING T209 UST
P17	BUILDING T206 CLOTH BURIAL AREA
P33	GROUND SCAR
P34	VEGETATION STRESS AT MAIN GATE



Plotted: 03/15/94

SITE NUMBE
A10
A11
A12
P15
P28
P32
P36
P37
P38
P39
P48

SITE NUMBE
A7/P8
A8/P10
A9/P12
P9
P57

SITE NUMBER
A6
P21
P22

P3 P2 P1 P17 P35 P34 P33 P28 P37 P36 A11 A12

190 210 200 180 170 175

WILLIS POND 183 185 CRYSTAL LAKE

STOW SUDBURY MARLBORO SG-20 SG-19 BROOK HOP BROOK

N 2,970,000 N 2,965,000

ecology
International S

NO.	DATE	DWN	APP'D	DESCRIPTION
REVISIONS				

DESIGNED BY
A. RAWA

DRAWN BY
R. BIDELL

P35	MAIN GATE GUARD SHACK
P53	BUILDING T210 UST

WATERSHED 2 SITES – HOP BROOK	
R	SITE NAME
	RAILROAD PIT/UST AREA
	LEACHING FIELD
	PCB SPILL REMEDIATION AREA
	NAVY BURNING GROUND
	ROCKET RANGE
	ROAD AND RAILROAD INTERSECTION
	FORMER RAYTHEON BUILDING T104
	BUILDING T106 UST
	FORMER RAILROAD INSPECTION PIT
	DUMP AREA
	FUEL BLADDER AREA

WATERSHED 3 SITES – LOWER ASSABET RIVER	
A	SITE NAME
	OLD GRAVEL PIT LANDFILL/POSSIBLE TRANSFORMER DISPOSAL
	FOOD BURIAL AREA/CONFIDENCE COURSE DUMP AREA
	POL BURN AREA / ABANDONED UST
	STREAM DUMP AREA BETWEEN SITES A7 AND A9
	FORMER BUILDING S449

WATERSHED 4 SITES – UPPER ASSABET RIVER	
R	SITE NAME
	DEMOLITION GROUND II
	POSSIBLE DUMP AREA
	OLD GRAVEL PIT

REFERENCES:

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2. GROUND CONTROL FOR AERIAL MAPPING ESTABLISHED BY T. F. MORAN.
3. STATE PLAN COORDINATE SYSTEM OF NORTH AMERICAN DATUM (NAD 1983).
4. ECOLOGY AND ENVIRONMENT INC. WATER LEVEL SURVEY CONDUCTED IN SEPTEMBER 1993.

SCALE

800 0 800 1600 FEET

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CHECKED BY
H. ALDIS

APPROVED BY
B. KING

SUDBURY TRAINING ANNEX
MIDDLESEX COUNTY, MASSACHUSETTS

SITE-WIDE INTERPRETATION OF GROUNDWATER CONTOURS PLATE 3

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1"=800'	3/15/94	UC6S030D	UC6101 – 3	0

N

E 655,000

E 660,000

STOWAWAY GOLF CLUB

ELIZABETH BROOK

FWSD15

ASSABET

E3-BCK-003

A9

A7SD/SW2

A7SD/SW1

SW/SED8

P8

P9

A7

P9SD/SW1

P9SD/SW2

P9SD/SW4

SW/SED7

FWSD14

CROW ISLAND GLIDER PORT

ROAD

TRACK

E3-BCK-002

LOWER ASSABET RIVER 3

E3-P11-D04

E3-P57-D01

P57

E3-A05-D01

E3-P11-D01

WEATHER SCIENCE RADAR LABORATORY

THICKET CIRCLE

WILDWOOD

ROAD

P25

FWSD17

A6

E3-A06-D02

E3-A06-D01

UPPER ASSABET RIVER 4

A6SD/SW1

E3-P26-D03

P24

LAKEWOOD ROAD

P22

P21

RBA-HI

E3-BCK-S08

WHITE POND

HONE

P51

PARKER

LAKE BOON

P30

SUDBURY

KINGLAND RD.

ROAD

A5

LAKE BOON 5

P40

E3-A5-

E 665,000

E 670,000

N 2,980,000

N 2,975,000

RIVER

MAYNARD D.P.W.

NEWTON DR

ROUTE 117

PARK ST

MINUTEMAN

WHITE AVE

DRISCOLL

ESPIE AVE

MOORE AVE

E3-BCK-S09

E3-P42-D01

P42

E3-BCK-S01

GREEN MEADOW SCHOOL

TAYLOR

SW/SED1

FWSD10

ROAD

A1SD/SW3

E3-BCK-D08

P12

NORTH GATE

P19

PATROL

A2

A1

P45

P43A

A1SD/SW2

E3-P45-D01

A1SD/SW1

LOWER TAYLOR BROOK 1B

P29

BUFFER

DIGITAL

RBA-TB

E3-BCK-D01

P43B

E3-P13-D02

E3-P13-D03

P13

E3-P13-D01

E3-P11-D02

SW/SED3

E3-BCK-D05

P44A

E3-P13-D04

REGION ONE FEMA OPERATIONS CENTER

P44B

E3-P13-D04

E3-P13-D05

P20

ROAD

FWSD8

P26

E3-P11-D03

P23

FWSD9

SW/SED5

SW/SED2

P27

P52

E3-P26-D01

P4

FWSD12

A3SD/SW1

P54

CRANBERRY BOGS

P6SD/SW1

UPPER TAYLOR BROOK 1A

A3

P5

A4

EAST GATE

VOSE POND

E3-P26-D02

E3-P26-D04

P54

P6SD/SW2

FWSD13

P6SD/SW3

P6

P56

P5SD/SW1

A4SD/SW1

P14

P14SD/SW1

FWSD2

A4SD/SW3

A4SD/SW2

P6SD/SW4

FWSD3

E3-PUF-D08

E3-PUF-D01

SW/SED11

E3-BCK-D04

PUFFER ROAD

MAYNARD STORM

P50

P49

P46

P54

P54

PUFFER POND

FWSD1

FWSD7

E3-PUF-D03

E3-PUF-D04

FWSD6

MAYNARD SUDBURY

P16

P54

FWSD4

E3-PUF-D05

CUTTING POND

FWSD5

E3-PUF-D06

PATRIOT ROAD

P41

P54

P54

P18

CRAVEN

SITE NUMBER
A3
A4
P5
P6
P14
P16
P18
P27
P41
P43A/B
P44A/B
P46
P47
P49
P50
P52
P54
P55
P56

SITE NUMBER
A1
A2
P4
P11
P13
P19
P20
P23
P24
P25
P26
P29
P30
P42
P45
P51

WATERSHED 1A SITES - UPPER TAYLOR BROOK	
R	SITE NAME
	GENERAL DUMP
	WASTE DUMP
	DRUM STORAGE AREA
	PUFFER POND POSSIBLE DUMP AREA
	EAST GATE BURIAL DUMP
	CHEMICAL AND WASTE STORAGE BUNKERS 302, 306, AND 309
	CLOTH BURIAL AREA
	PYROTECHNICS TEST AREA
	BUNKER 303 PESTICIDE/HERBICIDE STORAGE
	DISTURBED AREA/STAINED SOILS AND STRESSED VEGETATION
	CLEARING WITH STAINS AND WHITE OBJECTS
	CLEARED BURNED AREA AND DEAD TREES
	DAMAGED VEGETATION
	TWO DRUMS NEAR ROAD AND BUNKER 323
	ONE DRUM NEAR ROAD AND BUNKER 325
	POSSIBLE DUMP AREA NEAR FEMA PROPERTY
	BUNKERS 305, 307, 314, AND SUPPLEMENTAL BUNKERS 301, 304, 311, 312, AND 318
	CLEARED AREA SOUTH OF BUNKER 301
	CLEARED AREA SOUTH OF BUNKER 313

WATERSHED 1B SITES - LOWER TAYLOR BROOK	
R	SITE NAME
	DECONTAMINATED MUSTARD AREA
	DEMOLITION GROUND 1
	BUNKER DRUM AREA
	BUILDING T405 DUMP AREA
	MASSACHUSETTS FIRE FIGHTING ACADEMY
	CLEARING AND TRACKED AREA
	BURNED AREA AND DRUM
	BUILDING T465 (DRUMS)
	CLEARED AREA
	TEST CHAMBER BUILDING T463
	AIR DROP ZONE CLEARING
	STATIC ROCKET FIRING
	PROPOSED TEST AREA
	OFFSITE DUMP
	BURNED AREA BY OUTSIDE FENCE
	ONE DRUM NEAR WHITE POND ROAD

LEGEND:

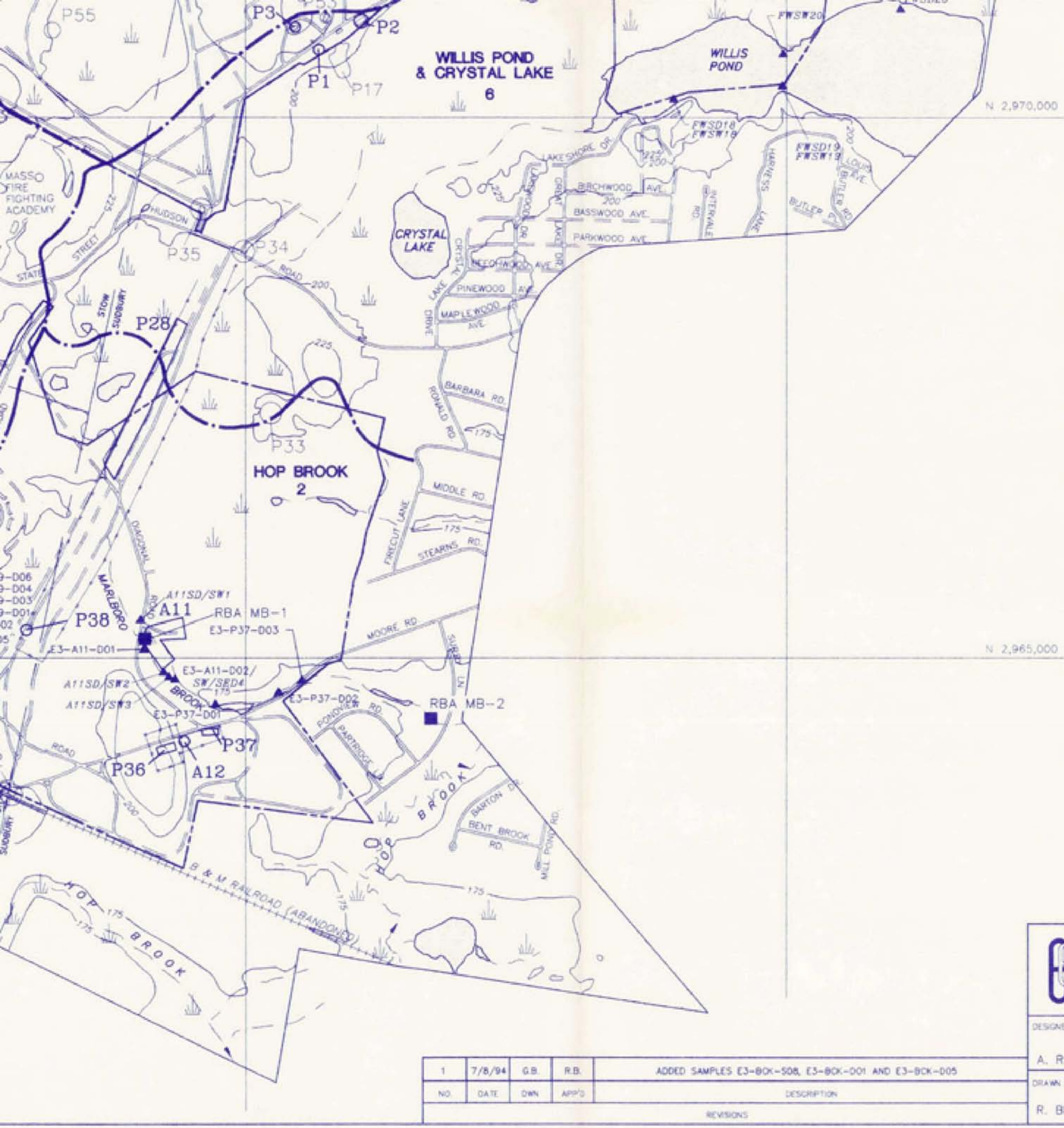
	APPROXIMATE WATERSHED BOUNDARY
	BUILDING/STRUCTURE
	PAVED ROAD
	UNIMPROVED ROAD
	WATER BODY
	STREAM
	RAILROAD
	FENCE
	INSTALLATION BOUNDARY
200	CONTOUR (25' INTERVAL)
	WETLAND
P26	**E&E SITE NUMBER IN BOLD**
P12	OHM SITE NUMBER
	E&E SUPPLEMENTAL SAMPLING LOCATIONS
FWSW20	NON E&E SAMPLES ITALICIZED
▲	SURFACE WATER AND SEDIMENT LOCATION
■	RBA STATION

WATERSHED 5 SITES - LAKE BOON	
SITE NUMBER	SITE NAME
A5	SOLVENT/WASTE DUMP
P7	PATROL ROAD DUMP AREA
P31/P58	OLD DUMP/SUDBURY ROAD DUMP
P40	BUILDING T452 AREA

WATERSHED 6 SITES - WILLIS POND & CRYSTAL LAKE	
SITE NUMBER	SITE NAME
P1	UST ACROSS FROM BUILDING T223
P2	BUILDING T267 FUEL SPILLS
P3	BUILDING T209 UST
P17	BUILDING T206 CLOTH BURIAL AREA
P33	GROUND SCAR



Plotted: 07/12/94



SITE NUMBE
A10
A11
A12
P15
P28
P32
P36
P37
P38
P39
P48

SITE NUMBE
A7/P8
A8/P10
A9/P12
P9
P57

SITE NUMBE
A6
P21
P22

NO.	DATE	DWN	APP'D	DESCRIPTION
1	7/8/94	G.B.	R.B.	ADDED SAMPLES E3-BOK-508, E3-BOK-001 AND E3-BOK-005

REVISIONS

ecology
International

DESIGNED BY
A. RAWA

DRAWN BY
R. BIDELL

WATERSHED 2 SITES – HOP BROOK	
R	SITE NAME
	RAILROAD PIT/UST AREA
	LEACHING FIELD
	PCB SPILL REMEDIATION AREA
	NAVY BURNING GROUND
	ROCKET RANGE
	ROAD AND RAILROAD INTERSECTION
	FORMER RAYTHEON BUILDING T104
	BUILDING T106 UST
	FORMER RAILROAD INSPECTION PIT
	DUMP AREA
	FUEL BLADDER AREA

WATERSHED 3 SITES – LOWER ASSABET RIVER	
R	SITE NAME
	OLD GRAVEL PIT LANDFILL/POSSIBLE TRANSFORMER DISPOSAL
	FOOD BURIAL AREA/CONFIDENCE COURSE DUMP AREA
	POL BURN AREA / ABANDONED UST
	STREAM DUMP AREA BETWEEN SITES A7 AND A9
	FORMER BUILDING S449

WATERSHED 4 SITES – UPPER ASSABET RIVER	
R	SITE NAME
	DEMOLITION GROUND II
	POSSIBLE DUMP AREA
	OLD GRAVEL PIT

P34	VEGETATION STRESS AT MAIN GATE
P35	MAIN GATE GUARD SHACK
P53	BUILDING T210 UST

REFERENCES:

1. TOPOGRAPHIC MAPPING INITIALLY DEVELOPED BY BIONETICS CORPORATION FROM APRIL 1992 AERIAL PHOTOGRAPHY WITH REVISIONS AND FINALIZATION CONDUCTED BY OHM CORPORATION.
2. GROUND CONTROL FOR AERIAL MAPPING ESTABLISHED BY T. F. MORAN.
3. STATE PLAN COORDINATE SYSTEM OF NORTH AMERICAN DATUM (NAD 1983).

SCALE

800 0 800 1600 FEET

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Specialists in the Environment

CHECKED BY
H. ALDIS

APPROVED BY
B. KING

SUDBURY TRAINING ANNEX
MIDDLESEX COUNTY, MASSACHUSETTS

SURFACE WATER, SEDIMENT, AND RBA SAMPLE LOCATIONS AT THE SUDBURY ANNEX PLATE 4

SCALE	DATE ISSUED	C.A.D. FILE NO.	DRAWING NO.	REV.
1"=800'	7/13/94	UC6S0390	UC6101 – 4	1