UC2081/RC424

PHASE I REMEDIAL INVESTIGATIONS REPORT FOR AREAS OF CONTAMINATION 4, 5, 18, 40

FORT DEVENS, MASSACHUSETTS

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

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LIST OF ACRONYMS AND ABBREVIATIONS

ABS	Absorption Factor
ACGIH	American Conference of Government Industrial Hygienists
ADL	Arthur D. Little, Inc.
AF	Adherence Factor
AIHA	American Industrial Hygiene Association
ANL	Argonne National Laboratory
AOC	Area of Contamination
APR	Air Purifying Respirator
ARAR	Applicable or Relevant and Appropriate Requirement
ASC	Analytical Services Center
ASTM	American Society for Testing and Materials
AT	Average Time
AVS	Acid Volatile Sulfide
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factor
B(a)P	benzo(a)pyrene
BW	Body Weight
CAA	Clean Air Act
CASAC	Clean Air Science Advisory Committee
CDC	Centers for Disease Control
CDI	Chronic Daily Intakes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHSO	Corporate Health and Safety Officer
CLP	Contract Laboratory Program
CMR	Code of Massachusetts Regulations
CNS	Central Nervous System
COC	Chain-of-Custody
COPC	Contaminants of Potential Concern
COR	Contracting Officer's Representative

CPR	Cardio-Pulmonary Resuscitation
CRC	Community Relations Coordinator
CRL	Certified Reporting Limit
CRP	Community Relations Plan
CRQL	Contract Required Quantitation Limit
CVAA	Cold Vapor Atomic Absorption
CWA	Clean Water Act
2,4-D	2,4-dichlororophenoxyacetic acid
CV	Cold Vapor
CX	Categorical Exclusion
dBA	Decibels
dbh	Diameter at Breast Height
DCA	dichloroethane
DCE	dichloroethylene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEH	Directorate of Engineering and Housing
DERA	Defense Environmental Restoration Account
DIO	Directorate of Industrial Operations
DNB	Dinitrobenzene
DO	Dissolved Oxygen
DOD	United States Department of Defense
DOE	United States Department of Energy
DOT	United States Department of Transportation
DPCA	Directorate of Personnel and Community Activities
DQO	Data Quality Objectives
DRMO	Defense Reutilization and Marketing Office
ECD	Electron Capture Detector
ED	Exposure Duration
E & E	Ecology and Environment, Inc.
EE	Estimated Exposure
EE&G	Environmental Engineering and Geotechnics, Inc.
EF	Exposure Frequency

EOD	Explosive Ordnance Demolition
EP	Extraction Procedure
EPA	United States Environmental Protection Agency
EPC	Exposure Point Concentration
FI	Fish Ingestion
FID	Flame Ionization Detector
FOIA	Freedom of Information Act
FORSCOM	United States Army Forces Command
FR	Federal Register
FS	Feasibility Study
FSO	Field Safety Officer
FSP	Field Sampling Plan
GC/MS	Gas Chromatography/Mass Spectrometry
GFAA	Gas Furnace Atomic Adsorption
GI	Gastrointestinal
GSD	Geometric Standard Deviation
HASP	Health and Safety Plan
HCH	Hexachlorocyclohexane
HEAST	Health Effect Assessment Summary Tables
HEPA	High Efficiency Particulate Absolute
HI	Hazard Index
HMX	cyclotetramethylene tetranitramine
HNU	HNU Inc., Manufacturer of Photoionization Detector
HPLC	High-Performance Liquid Chromatography
HRS	Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments
IAG	Inter-Agency Agreement
ICP	Inductively Coupled Argon Plasma Spectrometry
IDLH	Immediately Dangerous to Life and Health
IR	Installation Restoration
IR	Ingestion Rate (in Risk Assessment)
IRDMIS	Installation Restoration Data Management Information System
IRF	Intake Route for Fruits
IRP	Installation Restoration Program

IRV	Intake Route for Vegetables
IT	International Technologies Corporation
KO	Contracting Officer
Kp	Chemical-Specific Permeability
LADI	Lifetime Average Daily Intake
LCL	Lower Control Limit
LEL	Lower Explosive Limit
LOAEL	Lowest Observed Adverse Effect Level
LOF	Lack of Fit
LTL	Limit of Tolerance Level
LWL	Lower Warning Limit
MAAF	Moore Army Airfield
MC	methylene chloride
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDEP	Massachusetts Department of Environmental Protection
MDWPC	Massachusetts Division of Water Pollution Control
MEP	Master Environmental Plan
MGL	Massachusetts General Law
MRL	Minimal Risk Level
MS	Mass Spectrometry
MSA	Mine Safety Association
MSDS	Material Safety Data Sheet
MINIRAM	Miniature Real-Time Aerosol Monitor
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MSHA	Mine Safety and Health Administration
MSL	Mean Sea Level
NA	Not Analyzed
ND	Not Detected
NEPA	National Environmental Policy Act of 1969
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
No.	Number
NOAEL	No Observed Adverse Effect Level

NOEL	No Observed Effect Level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRWA	Nashua River Watershed Association
NWI	National Wetlands Inventory
OCLL	Office of the Chief of Legislative Liaison
OCPA	Office of the Chief of Public Affairs
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response (EPA)
OVA	Organic Vapor Detector
PA	Preliminary Assessment
PAH	Polynuclear Aromatic Hydrocarbon
PAO	Public Affairs Office
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PC	Permeability Constant
PCB	Polychlorinated Biphenyl
PID	Photoionization Detector
POL	Petroleum, Oil, and Lubricant
PP	Proposed Plan
PPE	Personal Protective Equipment
PPM	Parts Per Million
PRI	Potomac Research, Inc.
PSI	Pounds Per Square Inch
PVC	Polyvinyl Chloride
QAPjP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QL	Quantitation Limit
RAGS-HHEM	Risk Assessment Guidance for Superfund - Human Health Risk Evaluation Manual
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RDX	hexahydro-1,3,5,-trinitro-1,3,4-triazine

RfD	Reference dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RPD	Relative Percent Difference
RPM	Remedial Project Manager
SA	Study Area
SA	Skin Area
SARA	Superfund Amendments and Reauthorization Act of 1986
SAS	Special Analytical Services
SCBA	Self-Contained Breathing Apparatus
SDI	Subchronic daily intakes
SDVB	Styrene/Divinylbenzene
SDWA	Safe Drinking Water Act
SEAT	Superfund Exposure Assessment Team
SF	Slope Factor
SI	Site Investigation
SOP	Standard Operating Procedure
SOW	Statement of Work
SSHC	Site Safety and Health Coordinator
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit (Replaced by AOC or SA in these plans)
TAG	Technical Assistance Grant
TAL	Target Analyte List
TB	Toxicity Benchmark
TCE	trichloroethylene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TIC	Tentatively Identified Compound
TKN	Total Kjeldhal Nitrogen
TLD	Thermoluminescent Dosimeter
TNB	Trinitrobenzene

TNT	Trinitrotoluene
TOC	Total Organic Carbon
TOX	Total Organic Halogens
TPHC	Total Petroleum Hydrocarbons
TRC	Technical Review Committee
TSCA	Toxic Substances Control Act
TSDA	Temporary Storage and Disposal Area
TSS	Total Suspended Solids
UBK	Uptake Biokinetic
UCL	Upper Control Limit
UFF	Uptake Factor for Fruits
UFV	Uptake Factor for Vegetables
USACE	United States Army Corps of Engineers
USAEHA	United States Army Environmental Hygiene Agency
USATHAMA	United States Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	Underground Storage Tank
UTL	Upper Tolerance Limit
UV	Ultraviolet
UWL	Upper Warning Limit
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WWTP	Wastewater Treatment Plant
ZI	Zero Intercept

UNITS OF MEASURE

Btu	British thermal unit(s)
°C	degree(s) Celsius
cfs	cubic feet per second
cm	centimeter(s)
d	day
°F	degree(s) Fahrenheit
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
gal	gallon(s)
g	gram(s)
gpm	gallons per minute
h	hour(s)
in.	inch(es)
l	liter(s)
lb	pound(s)
m	meter(s)
mg	milligram(s)
mi	mile(s)
min	minute(s)
mo	month(s)
ppb	part(s) per billion
ppm	part(s) per million
s	second(s)
ton	short ton(s) (i.e., 2000 pounds)
wk	week(s)
yd^3	cubic yard(s)
yr	year(s)
µg	microgram(s)
µmho	micromho(s)

EXECUTIVE SUMMARY

Two Remedial Investigations (RIs) were undertaken at the Fort Devens Army Installation in Massachusetts by Ecology and Environment, Inc. (E & E), under contract to the United States Army Toxic and Hazardous Materials Agency (USATHAMA). In compliance with the terms of a Federal Facility Agreement between the United States Department of the Army and the United States Environmental Protection Agency (EPA), E & E conducted hydrogeologic and environmental investigations at two landfills, Shepley's Hill Landfill and Cold Spring Brook Landfill.

Shepley's Hill Landfill

The results for Shepley's Hill Landfill indicate that the landfill is contributing or has contributed arsenic, barium, cadmium, iron, and manganese to groundwater, and that these metals have accumulated in the sediments of an adjoining off-site body of water, Plow Shop Pond. Risks to human health under the present system of land use range up to 2.0E-03 for cancer, almost exclusively due to arsenic in sediment and to postulated bioconcentration in fish tissue and the attendant ingestion by fishermen and their families. If the site is developed for residential use and groundwater wells are installed, maximum cancer risk rises to 2.0E-02 if water is untreated. Under both scenarios, some non-cancer toxicity risks exceed a hazard index of 1, again primarily due to arsenic. Three wells affected by the landfill exceed a Safe Drinking Water Act (SDWA) action level for lead, as does one upgradient well. No impact on surface soils or air was noted.

Additional work is recommended to confirm groundwater quality, near-shore sediment contamination levels, bioaccumulation of metals in fish, and a Feasibility Study (FS) to select remedial measures. Results of calculations to estimate the environmental impact of the landfill imply that there are adverse impacts on indicator species, based on assumptions about bioaccumulation of metals, but these assumptions need to be confirmed by sampling.

Cold Spring Brook Landfill

The Cold Spring Brook Landfill was found to have similar but lesser impacts on its adjoining water body, a small two-acre pond formed between 1965 and 1972 by the damming of a culvert under Patton Road. Sediments in the pond show elevated polynuclear aromatic hydrocarbons (PAHs) and arsenic, manganese, nickel, and zinc. Surface soils also showed arsenic, manganese, nickel, and zinc. The groundwater at the west end of the landfill is contaminated with arsenic, and some of this water is captured by Patton Well, a water supply well for Fort Devens. The water from the well itself shows no detectable impact from the landfill, however. Nevertheless, if a future land use scenario is postulated and the arsenic levels found in one monitoring well are assumed to occur in domestic wells, then the cancer risk to a hypothetical resident rises from 5.0E-05 under present land use, to 6.0E-03. The primary contaminant of concern is again, arsenic in groundwater.

It is recommended that further work be performed to fill data gaps defined by the Risk Assessment and to perform a Feasibility Study if necessary. These include redevelopment and sampling of the well historically highest in arsenic, installation of a nearby well into the sand and gravel aquifer under the site to simulate a future water well, and sampling of this well, as well as sampling of fish from the pond to confirm bioaccumulation assumptions. Although no adverse ecological impacts were noted during fieldwork, results of calculations to estimate the effects of the landfill on indicator species implies that there could be adverse impacts.

Contents

1. INTRODUCTION

On 13 May 1991, the United States Department of the Army and United States Environmental Protection Agency (EPA) finalized and signed a Federal Facility Agreement for the conduct of environmental studies and remediation activities at the Fort Devens Army Installation in Massachusetts (Figure 1-1). This inter-agency agreement was prepared under Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and covers a broad spectrum of environmental restoration activities at Fort Devens. One part of the agreement deals with site inspections (SIs) (also referred to as site investigations) and remedial investigation (RI) activities at several defined locations at Fort Devens. The purpose of the SIs is to evaluate existing data about study areas (SAs) to determine the presence of toxic and hazardous materials, or the potential threat to human health and the environment. Wherever contamination is indicated by the historical use of the study area, appropriate samples of soil, sediment, water, and air are collected and analyzed to better determine the extent of the threat posed to human health and welfare, and the environment. If a threat or a significant potential threat is determined to exist, the study area is designated an area of contamination (AOC) and is recommended for the next phase of evaluation, the RI.

The purpose of the RI is to fully characterize a known, contaminated site to determine the extent of contamination and to identify the significance of the hazards posed by the site. The RI requires extensive sampling and monitoring to gain a precise understanding of the site and to allow investigators to collect sufficient information for follow-on recommendations on the best methods to remediate the site. The RI process is typically part of a RI/Feasibility Study (FS) in which the RI provides the data to support the FS. In order to select which data to collect, the RI typically includes a brief discussion of probable alternative remedial technologies. However, for the AOCs under investigation at Fort Devens, it is not yet possible to discuss remedial technologies, except in the most general terms, because the type and degree of impact of these AOCs is yet to be understood. Clearly, the most likely impact is on groundwater and on adjoining surface waters, although it is possible that no action will be necessary given the trends of the contaminant levels found in successive samplings. If contamination of groundwater is confirmed to be a problem, then capture and treatment of groundwater to prevent spread of this contamination is typically used. If surface water or sediment in the adjoining pond or wetland are contaminated, these would require separate remediation. For these reasons, the focus of the RI is on characterizing the hydrogeology, contaminant distribution, and paths of migration.

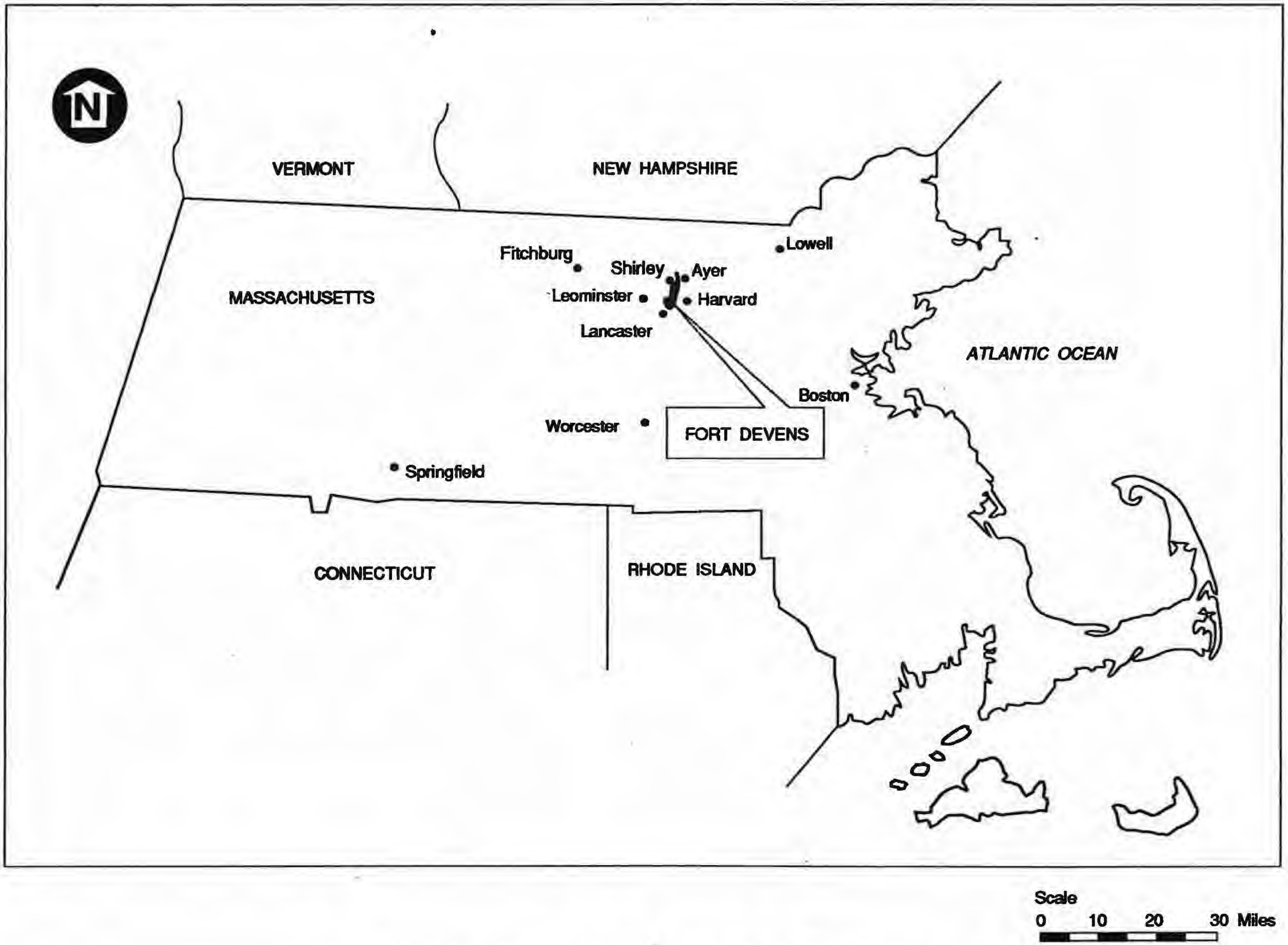


Figure 1-1 LOCATION OF FORT DEVENS IN MASSACHUSETTS

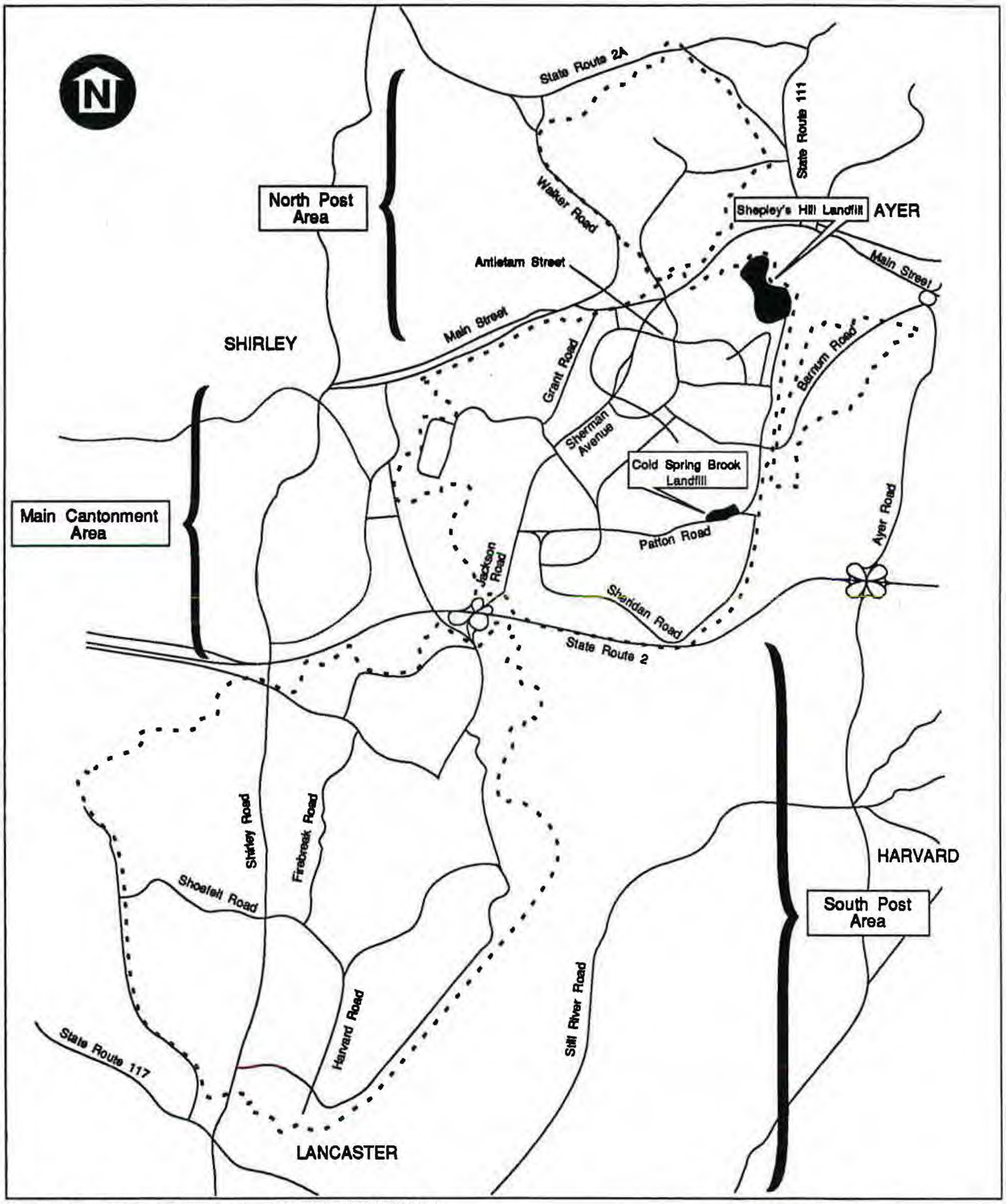
00409F.CDR

On 21 September 1990, the United States Army Toxic and Hazardous Materials Agency (USATHAMA), under Contract No. DAAA15-90-D-0012, assigned a delivery order to Ecology and Environment, Inc. (E & E) for the conduct of RIs at four areas (three of which are co-located) within Fort Devens. In order to properly conduct work at these sites, E & E developed five draft plans: the Remedial Investigation Work Plan, the Remedial Investigation Field Sampling Plan, the Health and Safety Plan, the Quality Assurance Project Plan, and the Community Relations Plan. The draft plans were reviewed extensively and comments were received from the Department of the Army (USATHAMA and Fort Devens), EPA Region I, the Massachusetts Department of Environmental Protection (MDEP), the United States Fish and Wildlife Service (USFWS), as well as the general public. E & E issued a formal response to these comments on 17 June 1991, and on 19 August 1991 E & E issued revised final draft plans, which were again submitted for review and comment. On 10 October 1991, E & E received comments on the final draft plans from the reviewing agencies. E & E modified the plans in accordance with the comments.

Concurrent with the revision process, field teams prepared for the field sampling program by drilling necessary monitoring wells, and collecting samples to characterize portions of the areas under investigation. Where feasible and appropriate, the work plans were modified to reflect the actual conditions and actions taken during the early stages of field work.

E & E conducted RIs at two landfills within the boundaries of Fort Devens: Shepley's Hill Landfill and Cold Spring Brook Landfill (Figures 1-2 and 1-3). The previous investigations performed at both landfills indicated the need for further characterization at the site. The RIs for the Shepley's Hill and Cold Spring Brook Landfills were designed to compile data needed to assess the type and location of hazardous materials at the sites and the impact of these materials on the surrounding environment. Following are the broad objectives of the RI:

- o describe physical and environmental conditions at the site;
- o determine the nature, extent, and source (when possible) of hazardous substances and/or wastes present at the site;
- o perform ecological characterization of the site;
- o define the geologic and hydrogeologic characteristics of the site that may affect contaminant migration and assess possible migration off site;
- o present contaminant concentrations, potential migration pathways, methods of contaminant release, sources of hazardous substances (when possible), and data summaries;
- o compare analytical data to Federal and State regulatory standards, including standards specific to Massachusetts;



Source: Interagency Agreement USEPA / USATHAMA

Legend

—— Road

- - - Installation Boundary

Scale in miles

1 3/4 1/2 1/4 0 1

Figure 1-2 LOCATION OF RI SITES IN RELATION TO THE NORTH POST, MAIN CANTONMENT, AND SOUTH POST AREAS

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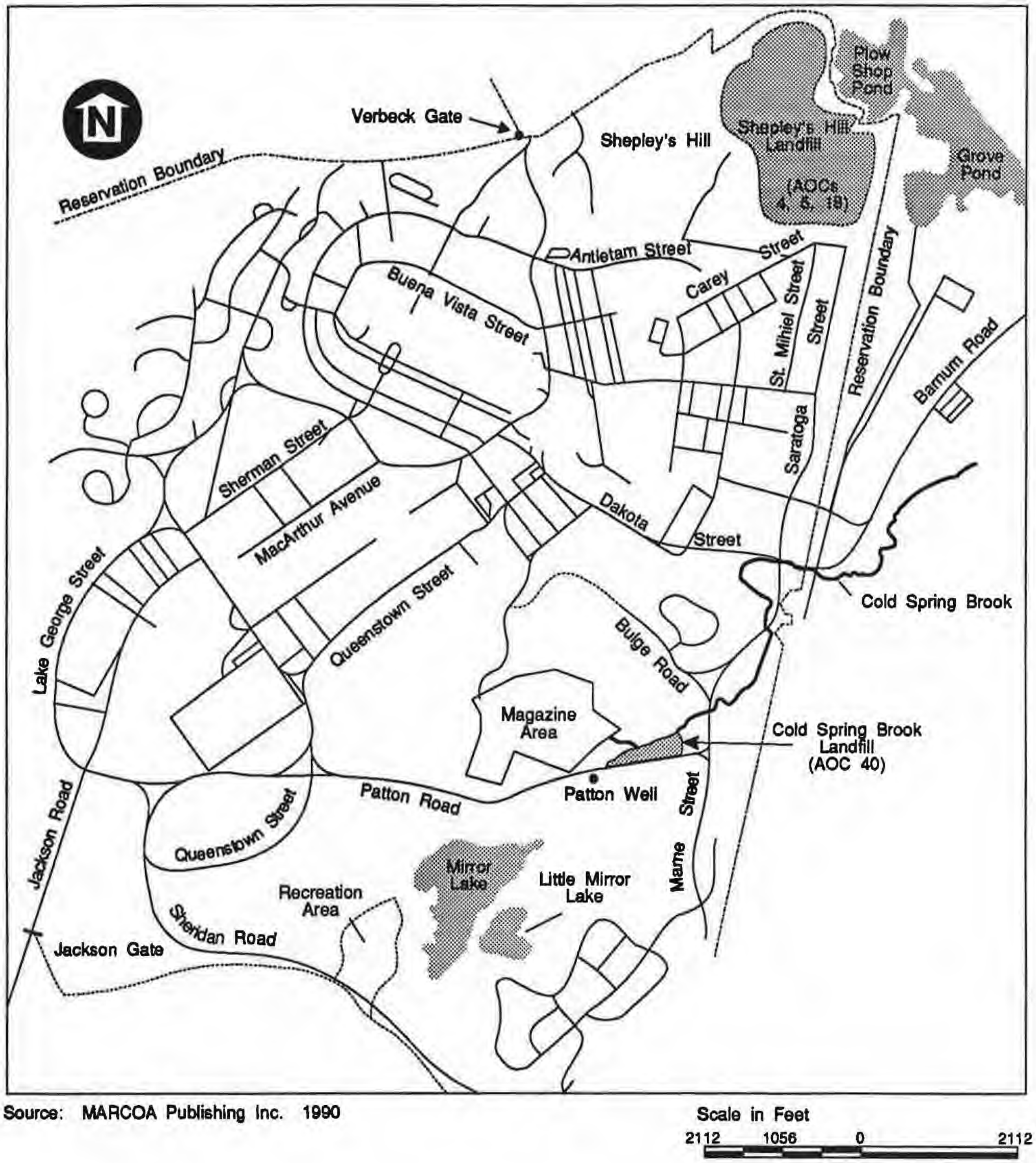


Figure 1-3 MAIN CANTONMENT AREA, FORT DEVENS

00409P4.CDR

- o assess potential risks posed by contaminants on human health and the ecology; and

- o develop recommendations on the basis of the risk assessments.

To achieve these goals, the RI involved review of existing data; evaluation of current site conditions; and performance of a field sampling and analysis program that includes soil, surface water, sediment, groundwater, and air.

The activities involved in these RIs qualify for a categorical exclusion (CX) in accordance with Department of the Army National Environmental Policy Act of 1969 (NEPA) regulations CX A18, Army Regulation 200-2, Appendix A, and did not require prior preparation of an environmental assessment under NEPA since no extraordinary circumstances existed to warrant this.

The RI process is derived from CERCLA, as amended. As discussed earlier, RI activities are normally paired with a FS, and this two-part investigation and evaluation is commonly referred to as the RI/FS. The RI/FS process is intended to provide a systematic approach to determining the nature and extent of risks posed by the site, which are then factored into an evaluation of potential remedies.

The RI serves as the mechanism for collecting data for site and waste characterization, and for conducting treatability testing as necessary to evaluate the performance and cost of the treatment technologies. The FS serves as the mechanism for developing, screening, and conducting a detailed evaluation of potential remedial alternatives. The RI and FS are conducted concurrently and the RI data influence the development of remedial alternatives. The identification of key data needed for the most probable remedial alternatives is part of the scoping of the RI. The RI consists of more than one phase of data collection, but when available, information from previous studies can be drawn upon to meet at least part of the data collection requirement.

The phased approach to the RI/FS process is displayed in Figure 1-4. Project planning is an important aspect of the RI and is used to determine the project's overall requirements and data quality objectives. In this phase, detailed plans are prepared for all aspects of field and analytical activities. The shaded portion of Figure 1-4 represents the portion of the RI/FS process addressed by this report.

The initial Risk Assessment is conducted in parallel with the field investigation. Concurrently, the FS process begins with the development of alternatives to control the hazardous waste by screening available technologies and identifying regulations and standards that need to be met.

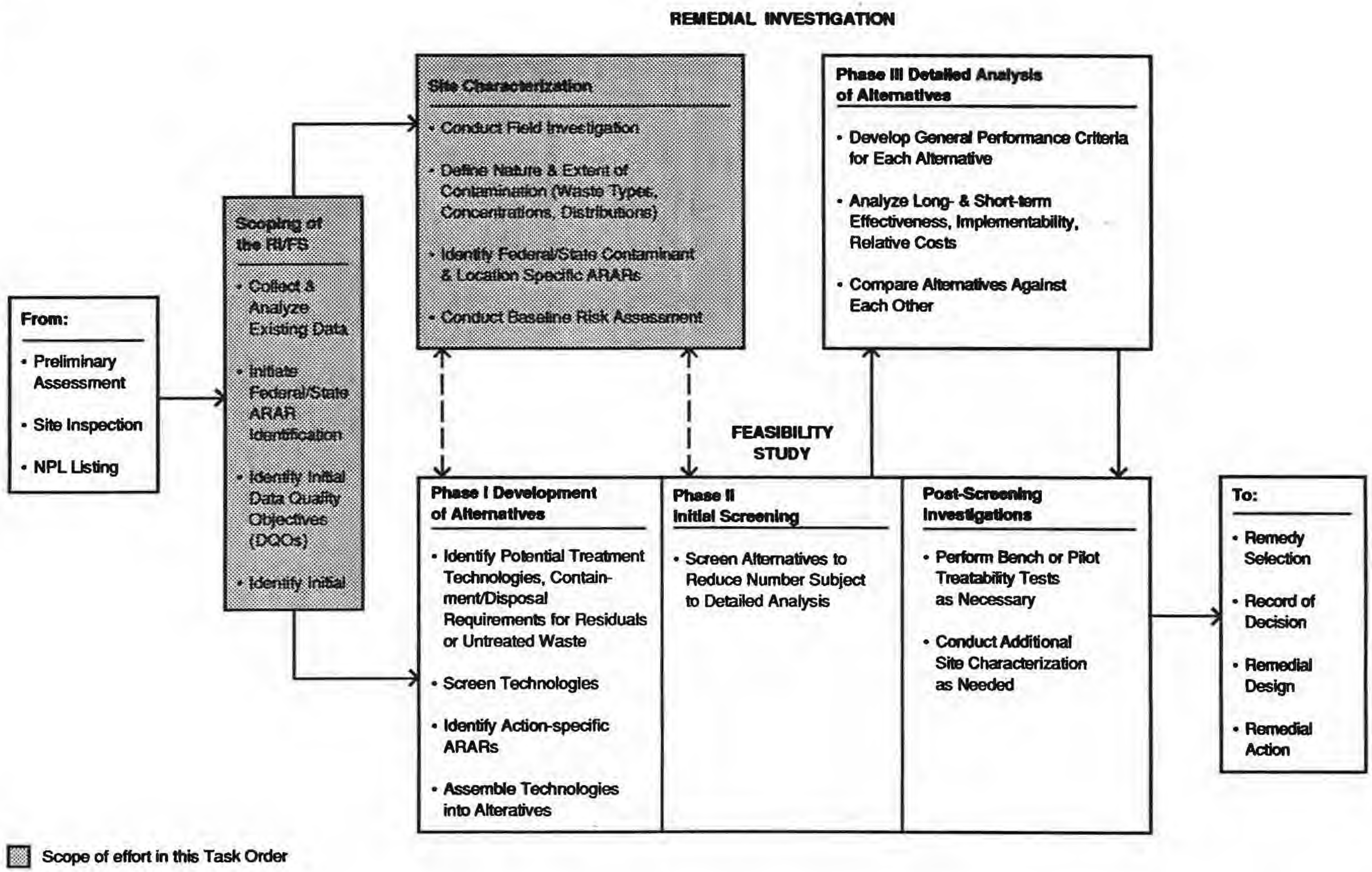


Figure 1-4 PHASED RI/FS PROCESS

The ultimate objective of the RI/FS is to provide decision-makers with sufficient information to select an appropriate remedy and develop a plan for action. Once a remedy is selected, the remedial process moves to the Remedial Design and Remedial Action phases.

In performing the RI field work, in accordance with NEPA guidelines, E & E considered the environmental effects of the field effort, incorporating monitoring requirements to identify hazards to health, and to segregate potentially contaminated investigation-derived waste, which were handled in accordance with the requirements of CERCLA, as amended by SARA, and the Resource Conservation and Recovery Act (RCRA).

Because this report actually represents four RI sites (three of which are co-located and collectively grouped as Shepley's Hill Landfill and the fourth site is located at Cold Spring Brook Landfill), the text for each section has generally been divided under headings for each landfill site. The only exception to this practice occurs when text discusses issues germane to both sites. The report is organized into 11 sections and has 18 appendices. The remainder of Section 1 describes the project organization developed to carry out the RI, and summarizes for each site the history, physical setting, and results of previous investigations. Section 2 describes E & E field activities and field procedures. The results of the field work are discussed in Section 3 in terms of better defining the physical characteristics of the landfill sites. The manner in which field and laboratory data were processed and checked for quality is discussed in Section 4, while in Section 5, the analytical results are evaluated to provide a description of the nature and extent of contamination at each landfill. In Section 6, the fate of identified contaminants and the means for transport of the contaminants are described for each of the media sampled (soil, groundwater, surface water, sediments, and air). Applicable or Relevant and Appropriate Requirements (ARARs) are described in Section 7. Section 8 is the human health risk assessment for each site, which, in combination with Section 9, the ecological risk assessment, provides an overall evaluation of the threat posed by each landfill site to human health and the ecology. On the basis of the risk assessments, E & E presents its conclusions, and recommendation for further action in Section 10. References cited or consulted in preparing the RI report are presented in Section 11.

Appendices A through V provide supporting data and reports of field work that were used in developing the RI report. These appendices cover various topics, including well and bore logs, a slug test report, chemical data, quality assurance/quality control reports, ecological reports, soil testing results, water quality parameters, and facility and regional water level measurements. For ease of reference, figures and tables are placed immediately after the page on which they are first referenced. The only exception is the oversized map, referred to as Plate 1, which is packaged in the pocket at the end of the report (following the Appendices).

1.1 PURPOSE AND ORGANIZATION OF THE FIELD WORK

The main purpose of the field investigation was to further characterize the nature and extent of site-related contamination, and to describe the potential for contaminant migration. This report details the sampling effort performed to examine the potentially contaminated media (i.e., surface water, groundwater, soil, air, and sediment). Chemical and physical analysis of samples from these media provided the information necessary to evaluate site conditions, perform risk assessments, and determine if any additional data are needed to evaluate and select remedial alternatives required to mitigate contamination at these landfills.

Because the two RI sites consist of landfills that had been emplaced above and possibly into highly permeable sandy glacial outwash aquifers, the RIs' objectives with respect to groundwater were as follows:

- o to investigate the impact of the landfill on the shallow part of the aquifer with monitoring wells screened across the water table;
- o to investigate the deeper part of the aquifer by installing monitoring wells screened at, or close to, the top of bedrock (Shepley's Hill Landfill);
- o to sample a water supply well screened in the deeper part of the aquifer and potentially impacted by the fill (Cold Spring Brook Landfill);
- o to determine directions of flow and discharge areas for the two aquifers affected by the two landfills and to assess surface water and sediment quality potentially impacted by the groundwater from the landfills; and
- o to assess ecological impacts of groundwater discharges.

It was not intended to investigate groundwater quality in bedrock during these RIs and no bedrock wells were installed. Significant bedrock contamination from these sites was not expected unless the outwash aquifers were heavily contaminated. Such an approach necessarily implies that additional investigations might be required to fill data gaps identified during this scope of work.

1.1.1 Project Approach

The delivery order required six site investigations (SIs) of Group 1B sites, three in the South Post and three in the Main Cantonment Area, as well as the RIs. The results of the SIs are not discussed further in this report with the necessary exception of Appendix D, where the QA/QC samples for the joint program are discussed and Appendix J where the site-wide water level measurements are listed. Upon assignment of this delivery order, E & E brought together a team of specialists and began planning for the RI project. These plans involved initial meetings, site visits, and scoping to assess the range of the RI project. After scoping the project, E & E hired subcontractor support: E & E Drilling and Testing for drilling monitoring wells and boreholes; Toledo Testing Laboratory, Inc., for soil analysis and classification; Arthur D. Little, Inc. (ADL), for laboratory services; and Gordon Solderholm and Associates, P.C., for surveying services. E & E then evaluated existing documentation on past investigations and practices at each of the RIs and also evaluated associated regulatory requirements and USATHAMA specifications. From this information, E & E developed data quality objectives, field and laboratory operation plans, and health and safety requirements, which were incorporated into written plans drafted for review by personnel from Fort Devens and USATHAMA, as well as from EPA, the USFWS, and the MDEP. Upon completion of iterative reviews, E & E incorporated final changes in the plans concurrent with ongoing field operations.

The SI and RI work at Fort Devens was mobilized at the same time to make efficient use of resources and eliminate duplication of effort. The mobilization consisted of:

- establishing a temporary field office at Fort Devens to facilitate communications and to serve as a base of operations;
- coordinating communications with Fort Devens DEH, Public Affairs Office (PAO), EPA Region I, and subcontractors;
- locating sources of supplies; and
- staging major equipment to support drilling, geophysical work, field work, and health and safety activities.

After initial mobilization, field work was continuous through the first major sampling period; when sampling was completed, E & E fully demobilized. Additional field work, such as water level measurements and the second round of groundwater sampling, did not require extensive field support.

E & E completed three rounds of groundwater elevation measurements, which included the new RI and SI monitoring wells, as well as the existing Fort Devens monitoring and production wells.

All samples collected were carefully packaged in accordance with USATHAMA requirements and then shipped to ADL for analysis. ADL followed rigorous USATHAMA protocols in analyzing the samples, and the results were checked for quality assurance.

1.1.2 Project Organization and Responsibility

The Fort Devens RI was accomplished using a functional task breakdown following the standard RI tasks. The Project Manager had the primary responsibility for implementing the RI, which included:

- coordinating the project through key task leaders;
- assuring that the necessary resources (personnel and equipment) were available;
- working with the review team leader to assure the quality of field operations, reports, and data; and
- providing continued communication with the USATHAMA Contracting Officer's Representative (COR).

Figure 1-5 presents the organization structure that E & E used to manage the RI. Figure 1-5 also indicates the key individuals selected for this project, from the Program Manager through the various team leaders such as the Office Geologist. Key support personnel were identified in the areas of field geology and field safety. Figure 1-5 also identifies, by function, other support personnel who were used for the RIs. In several instances, a single person performed multiple roles at the site and in the office or simultaneously with E & E's ongoing work for the SIs. Following are descriptions of the key positions associated with the Fort Devens RIs:

- **Program Manager.** The Program Manager for this contract is Mr. Lewis A. Welzel. He is the single point of contact for all work conducted under this contract and is E & E's sole authority for negotiating and committing the firm to the scope of work and level-of-effort. Through the Executive Vice President - Technical Services (G. Strobel, P.E.), the Program Manager is delegated the authority to acquire and marshal corporate resources to support this contract.
- **Project Manager.** The Project Manager for Fort Devens is Mr. Robert J. King, who is responsible for managing all personnel and day-to-day activities associated with this delivery order.
- **Office Geologist.** Mr. Hussein Aldis has technical responsibility for interpreting geotechnical data in conjunction with the field geologists and overseeing all related tasks. The office geologist also coordinates with other disciplines on the project to guarantee that information was developed to support site assessment and remedial action planning.
- **Field Geologist.** The functions/responsibilities of the field geologist include all tasks associated with geological investigation in the field, such as supervising and tracking all

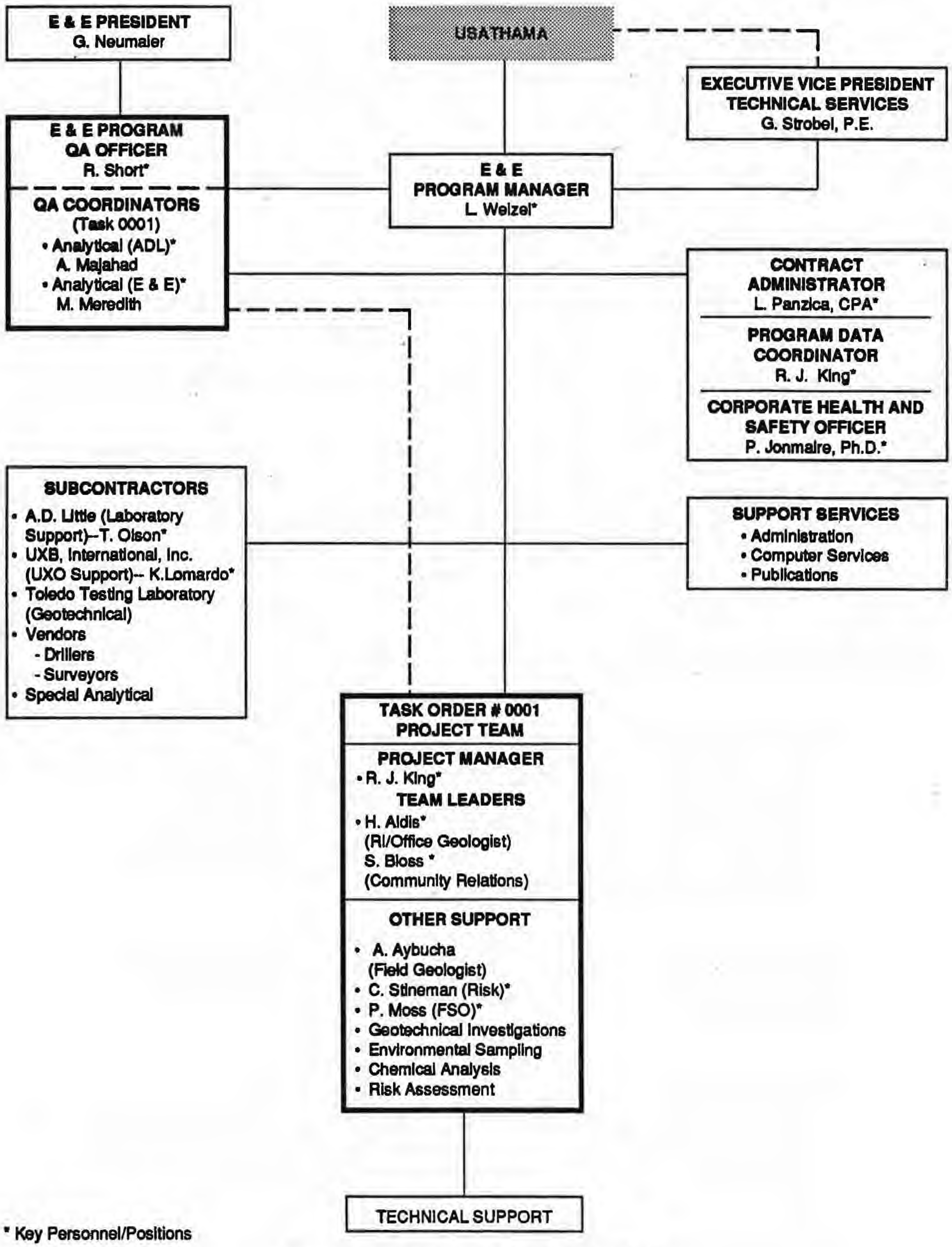


Figure 1-5 PROJECT ORGANIZATION

drilling, boring, and sampling activities. These duties were supervised by Mr. Amin Ayubcha and carried out by other staff geologists in order to maintain continuity.

- **Program Quality Assurance (QA) Officer.** The Program QA Officer, Mr. Russell Short, reports directly to E & E's President and is responsible for planning and executing administrative, laboratory, field, and engineering QA.

- **Laboratory QA Coordinator.** These are permanent positions operating in both Arthur D. Little's (ADL's) Chemical and Life Sciences Section and E & E's Analytical Services Center (ASC). The ADL QA Coordinator, Mr. Anthony Majhad, monitors and executes the analytical QA program and reports to Ms. Marcia Meredith of E & E, who reports to the Program QA Officer.

- **Corporate Health and Safety Officer.** Mr. Paul Jonmaire, Ph.D., is responsible for this permanent position, established for policy guidance and routine supervision of corporate safety. The Corporate Health and Safety Officer has the authority to stop an activity for safety reasons if undue risk is found or if corporate or contractual safety practices are abused.

- **Field Safety Officer.** The Field Safety Officers (FSOs) for Fort Devens were assigned on an as needed basis. This position provided direct safety support for field activities and reported directly to the Corporate Health and Safety Officer. The FSO is authorized to stop a field operation if pre-specified safety procedures were not followed or if hazards were encountered for which the teams were not prepared.

- **Project Data Coordinator.** The Project Data Coordinator reports administratively to the Program Manager and functionally to the Project Manager. He is responsible for the flow of data from creation through processing, storage, and retrieval within the parameters of the USATHAMA IRDMIS.

- **Subcontractors.** E & E used four subcontractors to support specialized work elements for the RIs. ADL, a USATHAMA Certified Laboratory, provided chemical analysis support services for analytes that the laboratory currently is certified to perform. ADL performed all of the chemical analyses required for Delivery Order No. 0001, except the air monitoring samples performed by IT Analytical Services, Cincinnatti, Ohio. Toledo Testing Laboratory performed all of the analyses of the collected geotechnical samples. Surveying services were provided by Gordon Solderholm and Associates, P.C. Drilling for boreholes and monitoring wells was provided by E & E Drilling and Testing.

The results of previous preliminary investigations conducted at both landfill sites indicated that actual or potential contamination of soil, sediment, groundwater, and surface water was occurring as the result of disposal activities at these sites. Based on the results of these investigations, USATHAMA determined that it was necessary to conduct more extensive investigations, including additional aquifer tests, risk assessment studies, and additional sampling to further define the extent and migration of contamination.

1.2 FACILITY HISTORY

Fort Devens was established in 1917 (circa World War I) as Camp Devens, a temporary training installation for soldiers from the New England area. Since that time it has been an installation of the U.S. Army Forces Command (FORSCOM). In 1922, the camp was designated a summer training camp for several military groups, Reserve Officer Training Corps (ROTC) Cadets, and Civilian Military Training Camp Candidates. Between 1929 and 1930, it served as the location for test firing of rockets. By 1931, the camp became a permanent installation and was renamed Fort Devens. Between 1931 and 1940, Fort Devens was a training installation. From November 1940 until May 1946, Fort Devens functioned as an induction center for an estimated 650,000 military personnel during World War II. At the close of the War, Fort Devens served as a demobilization center and was subsequently placed in caretaker status. It was again used as an induction and training center during and after the Korean and Vietnam conflicts.

During Operation Desert Shield and Operation Desert Storm, Fort Devens was used as an equipment preparation and mobilization area. Subsequently, it has been used for demobilization and out-processing of equipment assigned to units throughout the New England region.

Currently, the mission of Fort Devens is to command and train its assigned units and to support the United States Army Security Agency Training Center and School, United States Army Reserves, Massachusetts National Guard, Reserve Officer Training Programs, and Air Defense sites in New England. No major industrial operations occur at Fort Devens, although several small-scale industrial operations are performed under the Directorate of Plans, Training, and Security (DPTS); the Directorate of Industrial Operations (DIO); and the Directorate of Engineering and Housing (DEH). The major waste-producing operations performed by these groups are photographic processing and maintenance of vehicles, aircraft, and small engines.

A list of areas to be characterized for environmental investigation was initiated during 1985, when Fort Devens applied for a RCRA Part B Permit for its hazardous waste storage facility. The list included all Solid Waste Management Units (known herein as SAs or AOCs) that showed potential for release of hazardous waste to the environment. In cooperation with the MDEP, EPA Region I directed that action be taken at two landfills, Shepley's Hill and Cold Spring Brook Landfills, shown on Figure 1-3. In 1986, a final permit for the hazardous waste storage facility was issued, along with a list of 46 sites (or SAs). This was later expanded to 54 SAs in January 1990 and 58 SAs in the final draft Master Environmental Plan (MEP). Additional SAs are under consideration as a result of the draft Enhanced Preliminary Assessment (February 1992). Both Shepley's Hill Landfill and Cold Spring Brook Landfill scored high enough on the Hazard Ranking System (HRS), for the Region I EPA to place the sites on the National Priorities List (NPL).

Detailed history of the two landfills is provided in the following sections.

1.2.1 Shepley's Hill Landfill

The landfill area includes three AOCs: AOC 4, The Sanitary Landfill Incinerator; AOC 5, The Sanitary Landfill No. 1, or Shepley's Hill Landfill; and AOC 18, The Asbestos Cell.

Much of the information included in this section describing the history of the landfill has been drawn from the Fort Devens MEP (Biang, et. al 1991).

The sanitary landfill incinerator (AOC 4) was located near Cook Street within the area included in Phase I of the sanitary landfill closure (Figure 1-6). The site was located in former Building 38, which was built in 1941; the incinerator was operated until the late 1940s. Building 38 was a two-story, cinder-block building with a full basement and slate roof. Utilities included two overhead electric lines and an underground water line and sewer line (1.5 and 4 inches in diameter, respectively). No gas or steam lines served the building (Ford 1989).

The incinerator burned household debris generated on Fort Devens; glass and incinerator ash were placed in a landfill next to the building. In September 1967, the incinerator (which was not used after the 1940s) was demolished and placed in the sanitary landfill. In 1976, the building foundation was also removed and landfilled on site.

Because the incinerator was located and disposed of on a portion of the sanitary landfill (AOC 5), discussion of the geology and hydrology, the nature and extent of any contamination, and previous investigations are included in Sections 1.4, 1.5, and 1.6.

On AOC 5, the landfill itself, operations date as far back as 1917. A small portion of AOC 5 south of Plow Shop Pond (near wells SHL-3 and SHL-7) is the site of a former railroad roundhouse. The roundhouse was used between 1900 and 1935. Because of the age of the facility, any contaminants would probably be the result of coal and steam-era wastes. Currently, the landfill receives about 6,500 tons/year of household refuse, military refuse, and construction debris.

Review of the surficial geology map of Ayer Quadrangle (Jahns 1953), shows that in the early 1940s, the active landfill consisted of a small area off the end of Cook Road near what is now Well SHL-1 and covered approximately 5 acres. The fill was elongated north-south along a pre-existing small valley marked by at least two swamps (probably kettle holes) and lying between the bedrock outcrop of Shepley's Hill to

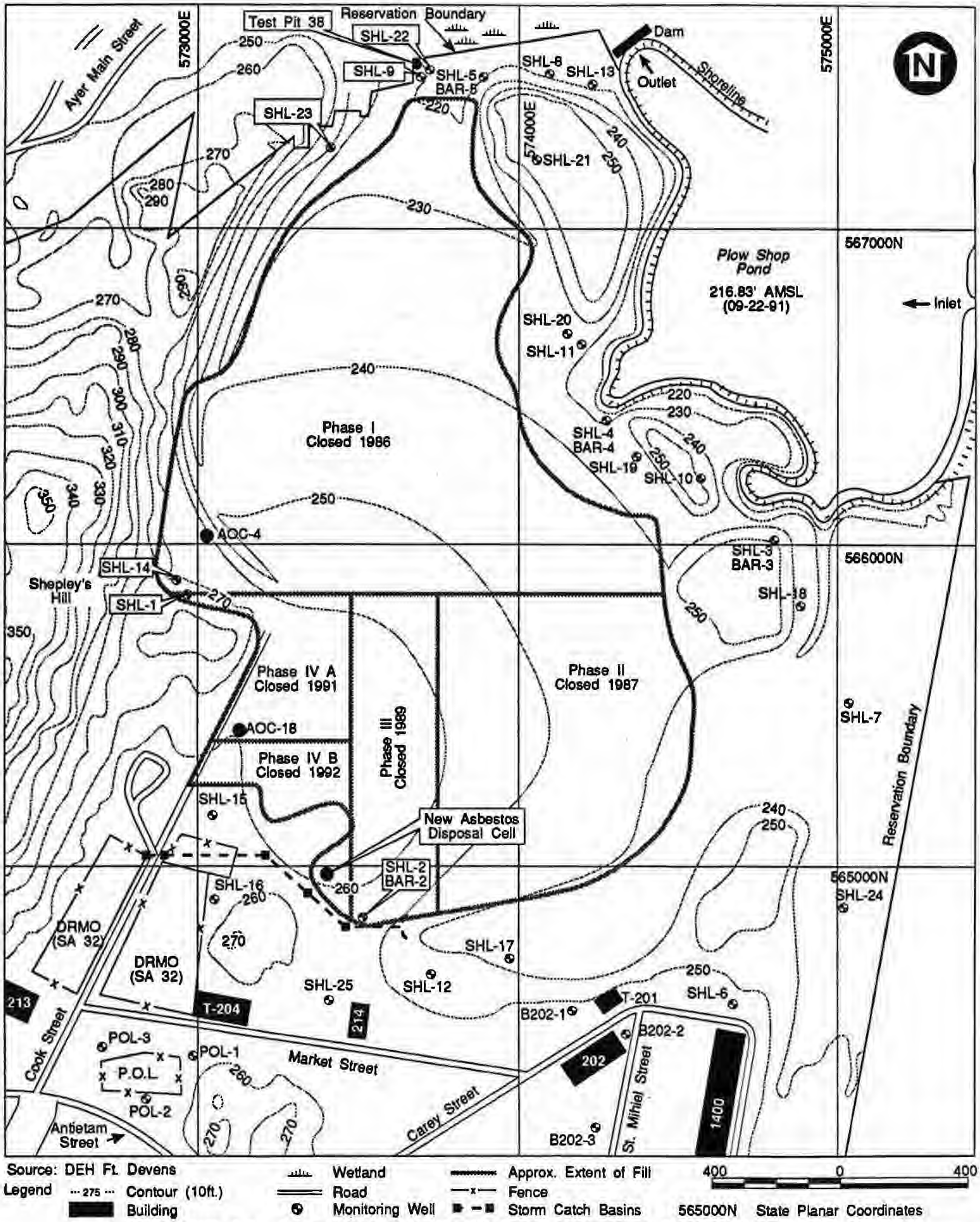


Figure 1-6 APPROXIMATE DIVISIONS OF SHEPLEY'S HILL LANDFILL AND EXTENT OF FILL (AS OF 1/1/84)

1ARI/Fig.1-6.CDR

the west and a flat-topped kame terrace with an elevation of 250 feet to the east, adjacent to Plow Shop Pond. Existing fill extending off the railroad embankment along the south shore of Plow Shop Pond is unrelated to Shepley's Hill Landfill although they later become contiguous. It is evident that during the landfill expansion, the pre-existing valley was largely obliterated, as was much of the kame terrace, much of which was presumably used for cover material.

Background information indicates that the landfill was formerly operated as an open burning site. Reportedly, flammable fluids were also disposed of in the southern portion of the landfill.

The landfill is operated using the modified trench method. There is evidence that trenches in the northwest portion have cut into previously used areas containing glass and spent shell casings. The glass dated from the mid-nineteenth century to as late as 1920. The total depth of the refuse is about 30 feet (DEH 1985b).

Fort Devens has an operating permit from the MDEP, and the landfill is operating within these requirements. In an effort to abate the potential for off-site contaminant migration, Fort Devens initiated the Fort Devens Sanitary Landfill Closure Plan in 1984, in accordance with 310 CMR 19.00. The four-stage plan, written by Gale Engineering, was submitted to MDEP for review and approval. In 1985, the MDEP reviewed and approved the closure plan. As shown in Figure 1-6, the landfill is being closed in phases. In Phase I, 50 acres were capped in October 1986; in Phase II, 15 acres were capped in November 1987; and in Phase III, 9.2 acres were capped in March 1989. In May 1989, Fort Devens presented a proposal to MDEP to extend the Phase IV closure date. A "conceptual approval" was given by the Worcester Office. In Phase IV, the last section of the landfill is scheduled for closure in 1992; most of the landfill has already been closed. Fort Devens is coordinating the closure with State authorities, which includes regrading, gas ventilation, membrane capping, and applying a final vegetative cover. Some of the areas adjacent to Plow Shop Pond lie within the 100-year floodplain. These areas were excavated according to the approved closure plan.

The initial stage of the closure study included determining the extent of the landfill. Toward this end, 40 test pits were placed throughout the landfill area. When the details of the pits were compiled, 15 acres on the eastern perimeter of the Phase I and Phase II sections of the landfill were classified as virgin soil. Drawings (No. 655-3339, 25 sheets) showing the details and locations of the borings are available through the DEH office at Fort Devens.

The second stage was the design for the final grade required to control surface erosion from rainwater run-on and run-off.

In the third stage, nine monitoring wells were placed outside the perimeter of the landfill, and a series of catch basins was constructed to control surface water on the uphill side of the landfill. The basin is located near Cook Street and is connected to five manholes along the southern side of the landfill. The run-off water collected by this system empties into an unlined ditch and either soaks into the ground in the Phase II area or flows north and discharges into Plow Shop Pond.

The fourth stage of the closure plan was the capping and gas-venting design. A 30-mil polyvinyl chloride (PVC) liner is sandwiched between two 12- to 18-inch layers of sand and overlain by an 8-inch layer of loam. Gas vents are located 400 feet apart and connect under the capped surface through perforated pipes (Black 1989). The MDEP requested the installation to reconsider the thickness of the liner that was originally approved in 1985, change the slope, and divide Phase IV into two sections. The Phase IV closure plan was modified to create Sections A and B. This closure is taking place independent of IRP activities.

The landfill contains a permitted asbestos cell (AOC 18) that was used for disposal of asbestos construction debris from on-site activities. An estimated 6.6 tons were placed in the cell between March 1982 and November 1985. It is located in Section A of the Phase IV area. The cell was originally scheduled for capping in late 1989 or early 1990. A new cell was opened in 1990 in the southeast corner of Phase IV (Phase IV B) and has been used for small volumes of asbestos disposal (Mullen 1992). The original Phase IV was divided into Phases IV A and IV B. The site was closed for receipt of solid waste in July 1992 and is currently being brought to final grade in accordance with the landfill closure plan (DEH undated).

As part of the Shepley's Hill Landfill Closure Plan, Fort Devens DEH excavated 40 test pits to define the actual limits of the landfill. Figure 1-6 shows these limits and provides a location of the various sections of the landfill and their closure status. Water was encountered in one excavation in the southeast corner of the Phase II area. In addition, water was encountered in seven of the northern-most pits of the section closed during Phase I. The north end of the landfill is within the 100-year floodplain and peat was noted in the northernmost pit, #38 (see Figure 1-6), which is clearly within the edge of the adjoining wetland.

1.2.2 Cold Spring Brook Landfill

Much of the information contained in this section on the history of Cold Spring Brook Landfill primarily was drawn from the MEP (Biang, et al. 1991).

The Cold Spring Brook Landfill (AOC 40) is in the southeastern part of the Main Cantonment Area near the Shoppette on Patton Road (Figure 1-7). It is considered an abandoned landfill and was discovered in November 1987, when fourteen 55-gallon drums were uncovered along Cold Spring Brook. The waste extended about 900 feet along the edge of the brook and involved an area of 3.5 acres. Wastes included concrete slabs, wire, tanks, rebar, timber, and debris found at depths of between

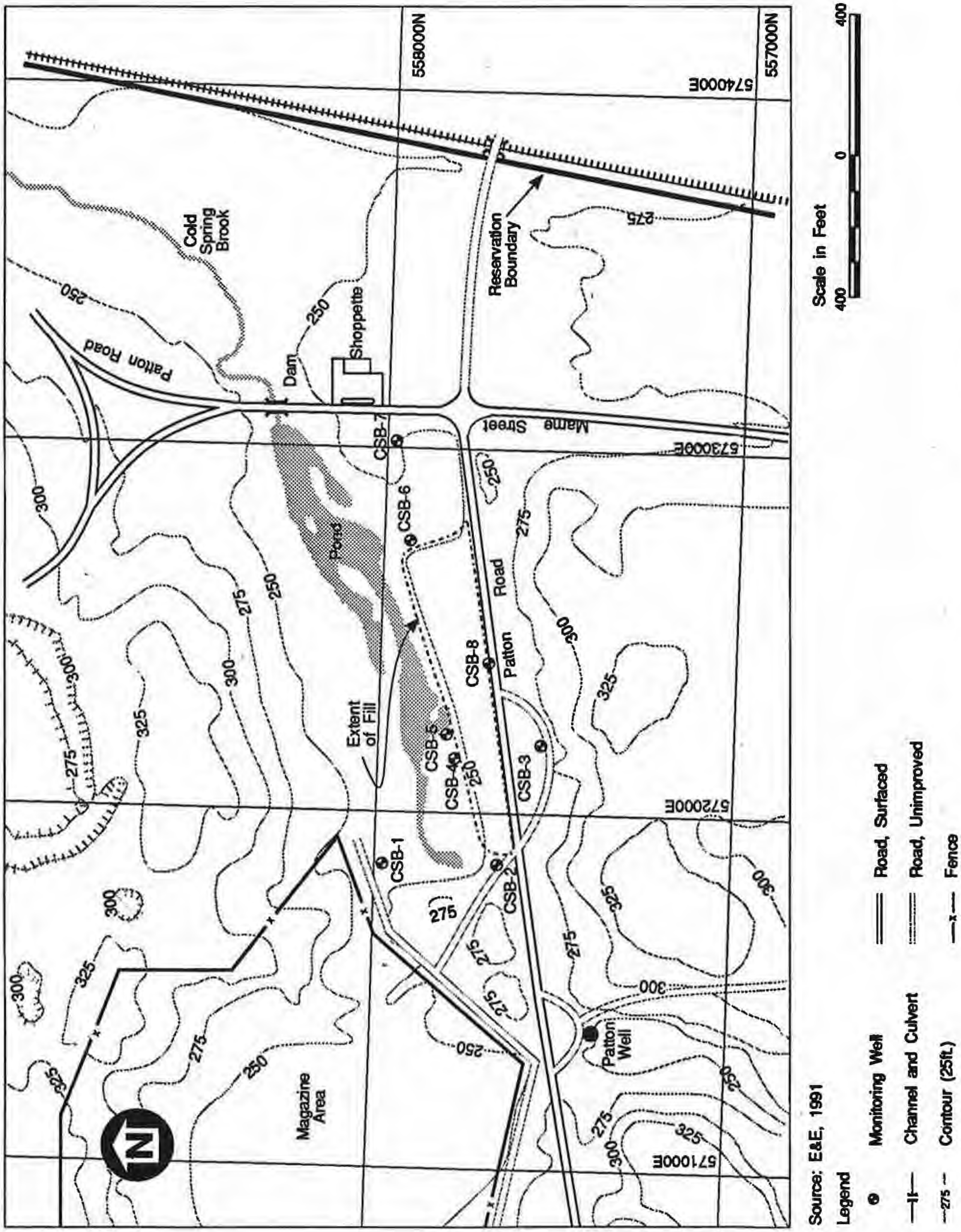


Figure 1-7 SITE MAP OF COLD SPRING BROOK LANDFILL

1ARVFig.1-7.CDR

10 and 20 feet (Hopkins 1988). It is possible that the area was filled to raise the surface elevation near Patton Road. It is not known if the drums were placed in the landfill when it was first created or at a later date.

An identification number on the drums indicated that the original contents had been antifreeze manufactured by Union Carbide and that they were 15 to 20 years old. Apparently, the drums had been painted yellow and reused (Hopkins 1988). In March 1988, the drums were examined by a response team from Union Carbide, New Hampshire.

The United States Army Environmental Hygiene Agency (USAEHA) completed a hydrological investigation of AOC 40 in 1988. Locations of the eight wells installed by USAEHA are shown in Figure 1-7. The investigation showed that the landfill is located over glacial sand and gravel deposits in, or adjacent to, a former wetland. United States Geological Survey (USGS) information indicates that the area is underlain by swampy deposits of muck and peat with adjacent units of sand and gravel from kame deposits. With the exception of two borings, coarse or medium- to fine-grained sand interspersed by fine to coarse gravel was the primary subsurface material. Two borings (CSB-4 and CSB-5) adjacent to a peat deposit contained organic matter with silt and sand or clay (Fox 1988b).

Quarterly monitoring of the water elevations and water quality in the wells have continued since their installation, although CSB-5 was destroyed in 1991.

A water supply well, the Patton Well, which provides drinking water for Fort Devens, is located about 600 feet west-southwest of the west end of the landfill. It is 67 feet deep and appears to tap the same aquifer as that monitored by the landfill wells.

An aerial photograph mosaic in the USATHAMA files at Aberdeen Proving Ground, dated December 1961, shows that the Cold Spring Brook Pond had been created by that date. It appears to have been excavated, which may explain its highly irregular shape and the peninsular running into the middle of the pond. At the time of the aerial photography there are no indications of any landfilling occurring along Patton Road or in the wetland adjoining the pond.

1.3 FACILITY PHYSICAL SETTING

Fort Devens is located on approximately 9,400 acres of land, approximately 35 miles west of Boston, Massachusetts, in Middlesex and Worcester counties. The City of Worcester is approximately 20 miles south of the installation. The installation includes portions of the towns of Ayer, Harvard, Lancaster, and Shirley. The installation is divided into three parts, or posts (Figure 1-2). The North Post (1,500 acres) is separated from the Central Post by Ayer's Main Street, which crosses Fort Devens east to west. The North Post contains Moore Army Airfield (MAAF), the wastewater treatment plant (WWTP), and training areas. The Central Post (2,300 acres), commonly referred to as the Main Cantonment Area, contains administrative and support facilities. The South Post (5,600 acres), which is separated from the Main Cantonment Area by State Route 2, contains ranges and training areas.

1.3.1 Climate

The climate of the Fort Devens area is characterized by long cold winters and short warm summers. Temperatures vary from a monthly average of 24°F in January to 71.9°F in July. Precipitation totals 43 inches on average. Precipitation is generally uniform throughout the year, averaging 3 to 5 inches per month. July, the driest month, averages 3.36 inches of precipitation, and November, the wettest month, averages 4.49 inches of precipitation (USDA 1985). Snow fall averages 69.4 inches per year.

Winds are moderate with a mean annual wind speed of approximately 4 miles per hour, and a predominance of westerly winds. The climate is generally variable, due to fluctuating influences from polar and tropical air masses, and marine and continental air flows. Extremes of cold and heat are brief episodes, and extremes of precipitation are typically due to remnants of tropical storms, or brief, violent localized thunderstorms in summer.

1.3.2 Aquatic, Wetland, and Terrestrial Ecology

The inland areas of the Commonwealth of Massachusetts can be characterized as supporting a variety of productive ecosystems due to a long growing season, abundant rainfall, fertile soils, and the presence of numerous marshes, ponds, and streams. The regional vegetation has been variously classified, but could be described generally as mixed coniferous-deciduous forest. Braun (1950) classified the area as part of the Hemlock-White Pine-Northern Hardwoods Region prevalent throughout New England. According to Eyer (1980), Fort Devens is located within the Eastern White Pine and Scarlet Oak (formerly Northern Pin Oak) forest cover types.

The highly varied topography, soils, and drainage of Fort Devens, in combination with human interference, have resulted in a patchwork of forest, marsh, grassland, and open water. Managed forest accounts for approximately 70 percent of land cover. The forest vegetation is dominated by oak and white pine in drier areas and maple and ash in wetter areas. Palustrine wetland is common in small areas along streams and around wetlands and open water, as are marshes and bogs. Open water occurs in kettle hole lakes such as Mirror Lake and Robbins Pond, and in artificially enhanced impoundments such as Plow Shop Pond and the pond alongside Cold Spring Brook Landfill. Abandoned oxbows along the Nashua River, as well as the river itself, also provide open bodies of water.

Grass is maintained in the ranges of the South Post and in much of the developed areas of the North Post, such as the airport and recreational areas.

The following briefly describes the ecosystems prevalent in the general vicinity of Fort Devens.

1.3.2.1 Aquatic Ecosystems

Fort Devens is located in the Nashua River watershed, which is situated in the Merrimack basin of Massachusetts (USGS 1985). The Nashua River watershed is characterized by numerous natural and man-made lakes and ponds and a number of streams. The numerous freshwater lakes and streams in this region generally support warm water fish species, although cold water species such as brown trout may be stocked in some areas. A biological survey of the Nashua River was conducted in 1985 by MDEQ. The results of this survey indicated that the benthic organisms present were frequently associated with moderate levels of organic contamination (USACE undated). Fish species likely to occur in the Nashua River include largemouth bass (Micropterus salmoides), small-mouth bass (Micropeterus dolomieui), and chain pickerel (Esox niger).

The Commonwealth of Massachusetts has designated water bodies in the Nashua River watershed as Class B. Class B designates waters to be maintained as suitable habitat for fish and other aquatic life, as primary and secondary contact recreation, and as a public water supply (where designated for this use) if the water undergoes the appropriate treatment.

1.3.2.2 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. Wetlands occur in a wide variety of forms, but all normally have three things in common: dominance of hydrophytes (water tolerant plants), presence of hydric soils, and a water table at or near the ground surface for at least one week during the growing season. The wetland types commonly found in the region around Fort Devens include wooded wetlands such as bottomland hardwood forests and shrub swamps, and emergent (i.e., herbaceous) wetlands, such as freshwater marshes. Each of these wetlands communities is discussed below.

Likely the most abundant type of wooded 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 during storm events. 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 predominance of a variety of woody species and presence of surface water attracts a diverse array of wildlife. Both aquatic and upland species as well as those specifically adapted to wetlands (e.g., wood duck, mink, and river otter) frequent these systems.

Shrub swamps also can be found scattered throughout this region. Shrub swamps represent an intermediate successional stage between emergent marsh and forested wetland; however, many shrub swamps are fairly stable and may persist for many years or decades. The vegetation consists of various shrub species such as buttonbush and dogwoods, intermingled with tree seedlings and saplings and emergent grasses, sedges, and rushes. The numerous berry-producing shrubs found here provide excellent food and cover for songbirds as well as large mammals such as the black bear and white-tailed deer. Shrub swamps often form in areas cleared for agriculture but abandoned because they were too wet to farm.

Freshwater emergent marshes include a diverse group of wetlands systems unified by the quality that all are dominated by grasses and sedges. Common species include reed grass, cattail, wild rice, bulrush and spike rush, pickerelweed, arrowhead, smartweed, jewelweed, horsetail, and various ferns. Freshwater marshes are especially important habitats for waterfowl. The combination of open water, abundant ground cover, and plentiful food sources makes marshes a favorite habitat of both migrating and breeding waterfowl. Other birds common to marshes include bitterns, herons, rails, plovers, and blackbirds. Various mammals also frequent marshes, most notably the muskrat.

1.3.2.3 Terrestrial Ecosystems

The terrestrial ecosystems encountered in the vicinity of Fort Devens include upland forest, reverting fields, maintained grasslands, and residential/commercial areas. Forests in this region have historically been subjected to heavy logging pressure 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 as they once existed. 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 lesser numbers throughout the region. The undergrowth consists of various shrubby species including sassafras, blueberries, and dogwoods. Upland forest supports a wide array of passerine birds, and common mammals like the white-tailed deer, black bear, raccoon, opossum, and skunk.

Reverting fields are areas that exist in a transitional successional stage between cleared land and upland forest, and include meadows, shrub thickets, and immature forests. These areas typically were once used for agriculture, but were abandoned for various reasons. The fruits of juneberry and dogwood shrubs provide abundant wildlife food, and the dense cover afforded by these fields attracts a wide array of early successional wildlife species such as various songbirds, deer, fox, woodchucks, and rabbits. Vegetation in the developed areas consists mainly of maintained lawns, hedgerows, and scattered ornamental trees. The wildlife habitat is poor, and normally only species with a tolerance for human activity are found here. Common species are sparrows, wrens, grackles, crows, pigeons, rabbits, squirrels, and small rodents. Transient visitors to this habitat include species such as deer, raccoons, opossum, and skunk.

1.3.3 Soils

The soils of the Fort Devens area are described by the United States Department of Agriculture, Soils Conservation Service in the 1985, Soil Survey of Worcester County, Massachusetts, Northeastern Part USDA 1985); and, as part of a cooperative effort with other agencies, for the Middlesex County Soil Survey (1989)

The mapped units covering Fort Devens Military Reservation consist of associations of soil series, in three sets: the Winooski-Limerick-Saco, the Hinkley-Merrimac-Windsor, and the Paxton-Woodbridge-Canton.

The Winooski-Limerick-Saco association is formed on the alluvium deposited by the Nashua River and the North Nashua River. The area covered by this association is covered approximately 34 percent by Winooski loams over sand (moderately well drained); 25 percent by Limerick silt loams over very fine sandy loam (poorly drained); and 16 percent by Saco silt loam over silt-loam or very fine sandy loam (very poorly drained), in pockets or depressions along the river. The remaining 25 percent of the area consists of minor soils, among which the only poorly drained soil is Swansea muck in bogs and depressions. These soils do not underlay any of the areas of investigation.

The Paxton-Woodbridge-Canton association is developed on glacial till and typically consists of 40 percent Paxton fine sandy loam, well drained, above a slow to very slow draining till substratum. Eighteen percent is typically Woodbridge fine sandy loam (moderately well drained) above a slow to very slowly draining till substratum. Eight percent is typically Canton sandy loam, a moderately rapid to rapid draining soil above a friable substratum of till formed from gneiss and granite. Thirty-four percent of the association consists of minor soils, including poorly drained soils in depressions and along drainageways such as Ridgebury and Whitman organic rich loam above fine sandy loam, and Swansea muck soils in swamps and wetlands. Based on the geologic maps, none of the areas of investigation are primarily on soils of this association.

The Hinkley-Merrimac-Windsor association is the most important association from the point of view of the RIs, since it appears that all or almost all the areas of investigation are on these soils.

These soils are formed on water-sorted deposits of glacial outwash and typically 27 percent are Hinkley loams or sandy loams, excessively drained, over sand and gravel; 20 percent are Merrimac loams or sandy loams, somewhat excessively drained, over sand and gravel; 9 percent are Windsor loamy fine sands, excessively drained, above sand; 44 percent of the soils in this association are other soils of minor extent. The only poorly drained soils are Scarboro mucky fine sandy loam over sand, in bogs and swamps, and the Freetown muck, which is over 51 inches thick, also found in swamps.

1.3.4 Geomorphology/Structure and Topography

Fort Devens is near the western boundary of the Seaboard Lowland Section of the New England-Maritime Physiographic province (Jahns 1953). It is adjacent to the Worcester County Plateau of the Central Uplands province and part of the installation lies within that province (Koteff 1966). The area constitutes a small part of a lowland belt in which Pleistocene glacial and post-glacial deposits form a discontinuous mantle over Paleozoic crystalline igneous and metamorphic bedrock. These surficial deposits thin to the west as the relief increases to approximately 500 feet in the plateau region.

The geomorphology of Fort Devens exhibits a typical continental glacial terrain with ice contact features. A pitted outwash plain, dotted with small conical and drumlinoid hills, is the most conspicuous geomorphologic feature on the installation; the plain was formed by glacial deltas prograding into various stages of glacial lake Nashua (Koteff 1966). Sand and gravel were deposited by the deltas around blocks of stagnant ice, and as the block ice melted, depressions known as kettles developed. Robbins Pond, Mirror Lake, Little Mirror Lake (formerly named Little Hell Pond), and Cranberry Pond are excellent examples of kettle lakes. Conversely, crevasses and depressions that were filled with the same detritus formed the small conical hills and terraces known as kames and kame terraces/plain. The terrace upon which the rapid infiltration sand beds are located, west of the Fort Devens airport, is an excellent example of a kame terrace. Drumlins or drumlin-like hills, with cores of bedrock such as Shepley's Hill and Whittemore Hill, are also in evidence on the installation. In these two cases, the hills are not strictly drumlins, which are defined as "a streamlined hill or ridge of glacial drift with long axis, paralleling the direction of flow of a former glacier." They are, however, partly mantled with glacial till, and evidently shaped by glacial ice into elongated ridges with axis parallel to the direction of flow of the former glaciers. Other evidence of glacial activity includes the following features: poorly drained swampy areas (primarily in the South Post) which suggest ground moraine; and eskers (formed as channel till under the ice), such as the ridge located between Mirror Lake and Little Mirror Lake.

The structural geology of Fort Devens and the surrounding area is very complex, as indicated by the outcrops of intensely folded and faulted bedrock. This is especially evident along the road near Jackson Gate on the southern corner of the Main Cantonment Area. The Bedrock Geologic Map of Massachusetts (Goldsmith, et al. 1985) shows low-angle thrust faults along the eastern boundary of the installation. Locally, folds parallel the fault trace. This is especially evident east of the installation where outcropping of Tower Ridge Quartzite occurs. No major folds are exhibited on the surface of the installation because they are masked by the mantle of unconsolidated glacial deposits.

Elevations on the post range from below 200 feet above mean sea level (AMSL) along the Nashua River where it leaves North Post to more than 450 feet AMSL at the top of Whittemore Hill in South Post. Most of the post lies between 250 feet and 400 feet AMSL, with broad kame terraces as well as isolated hills of till or bedrock and irregular moraine topography and kettle holes. Kettle holes are closed depressions in certain areas resulting from sedimentation around stagnant blocks of ice, and some are deep enough and poorly drained enough to contain wetlands or ponds. A belt of wetlands and floodplain along the Nashua River and North Nashua River bisects the post with elevations ranging from below 200 feet AMSL on the north to nearly 250 feet AMSL in the south and west.

1.3.5 Stratigraphy/Lithology

Five major bedrock stratigraphic units can be found on Fort Devens. Major bedrock outcrops are at the following locations: Shepley's Hill; two hills just north of Robbins Pond; a hill near Jackson Gate; and a rock quarry in South Post, west of the Nashua River. All of the units are Paleozoic in age and range from Upper Ordovician to Devonian. Goldsmith, et al. (1983) describes these formations in detail.

Ayer Granite crops out on Shepley's Hill. It is referred to as the Devens, Long Pond Facies of the Ayer Granite. The age of the unit ranges from Upper Ordovician to Lower Silurian. The lithology is characterized as equigranular to porphyritic gneissic biotite granite and granodiorite.

The Clinton Facies of the Ayer Granite is Lower Silurian in age. Lithologically it is characterized as a porphyritic biotite granite with a non-porphyritic border phase. It intrudes into the Berwick Formation and is therefore younger.

The Berwick Formation is lower Silurian in age and it is characterized as a metasediment composed of thin to thick bedded calcareous sandstones, siltstones with minor inclusions of muscovite schist, and augen gneiss. It crops out on Shepley's Hill in the Main Cantonment Area.

The Oakdale Formation is Silurian, and is described as a thin-bedded pelitic and calcareous metasiltstone and muscovite schist. It crops out in the South Post area.

The Worcester Formation is Upper Silurian to Lower Devonian in age. It crops out in a quarry near the South Post artillery impact area. It is lithologically described as a carbonaceous slate and phyllite with minor inclusions of metagraywackes.

The Silurian Tower Hill Quartzite crops out east of the installation where it forms several major northeast striking ridges. Lithologically it is composed of quartzite and phyllite. Several major faults parallel outcrops of this formation.

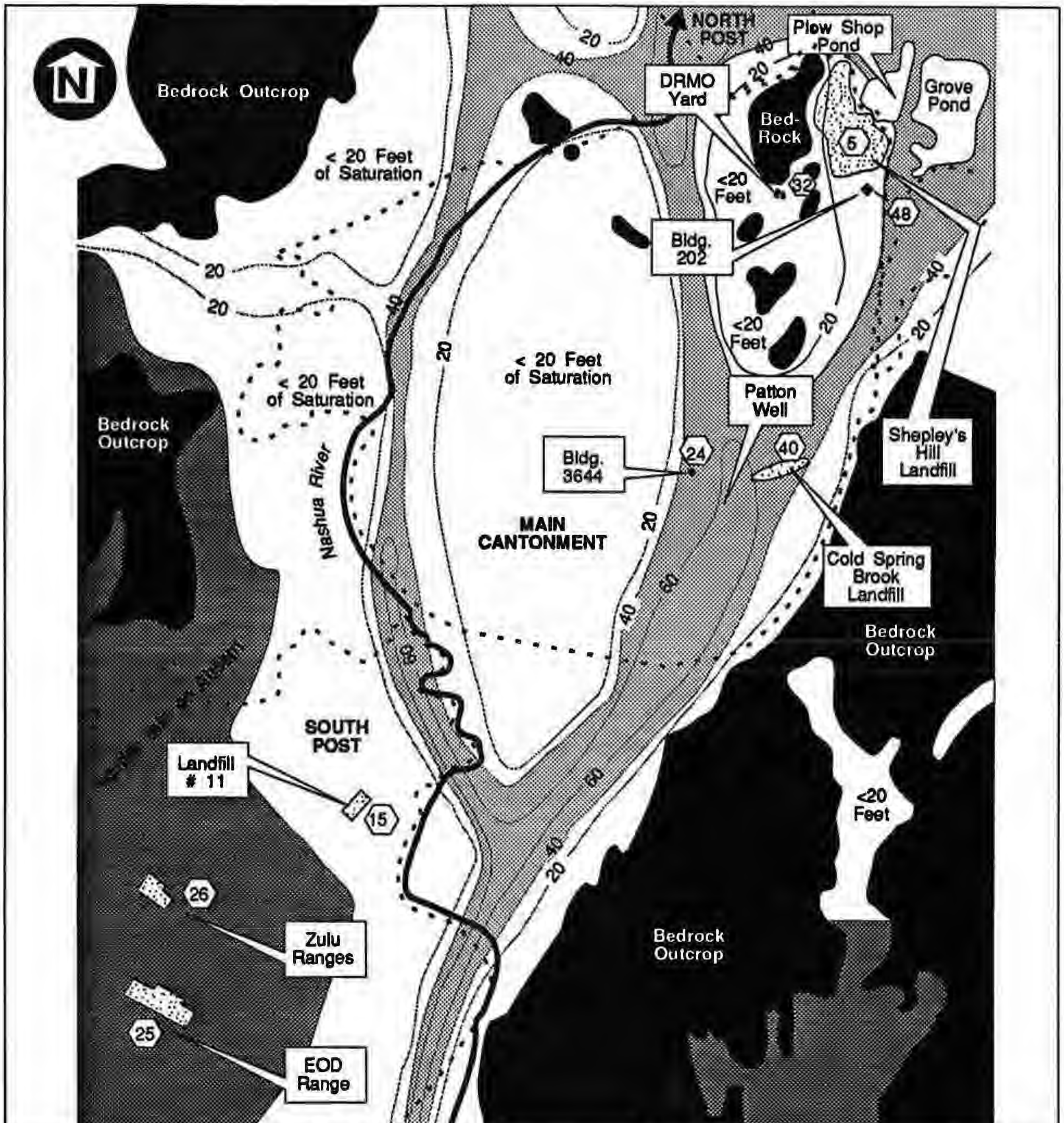
Surficial deposits, which mantle Fort Devens, are largely glacial in origin from the Pleistocene era (Jahns 1953; Koteff 1966; Schneider, et al. 1975). These deposits consist of two primary types: (1) glacial till consisting of poorly sorted clays, silts, sands and gravels; and (2) glacial-deltaic outwash deposits consisting of sand, gravel, and boulders. Outwash deposits of sand and gravel are from the Clinton, Pin Hill and Ayer stages of the retreat of the ice, respectively (Jahns 1953; Koteff 1966; Schnieder, et al., 1975) and approach 100 feet in thickness (Koteff 1966). Also present are glacial lacustrine deposits consisting of approximately 30 feet of sands and clays, which were deposited in glacial Lake Nashua. On Fort Devens, thin deposits of glacial till are exposed on Shepley's Hill and Whittemore Hill. However, in most cases, the till has been eroded and covered by the younger outwash deposits. According to Koteff (1966), the average thickness of the till is 10 feet in the Clinton area south of the installation. Conversely, Jahns (1953) reports that the till deposits have approached a thickness of 300 feet near Ayer.

1.3.6 Hydrology/Groundwater

Groundwater at Fort Devens occurs largely in the permeable glacial-deltaic outwash deposits of sand, gravel, and boulders.

A study by Goldberg-Zoino and Associates for the Montachusetts Regional Planning Board (1976) shows the estimated thicknesses of saturated glacial sediments within the study area and clearly indicates the major pre-glacial valleys, probably deepened by glaciation, which contain the more productive aquifers (see Figure 1-8). Because of the highly irregular nature of the bedrock surface, and the scattered distribution of wells, the accuracy and degree of detail on the distribution of aquifers at the sites investigated depends on the density of wells and boreholes installed. As a result of the Shepley's Hill Landfill investigation, it became clear that the Goldberg-Zoino map excluded a 100-foot-deep valley in bedrock underneath the fill at Shepley's Hill Landfill.

Small amounts of groundwater can be obtained from fractured bedrock with yields ranging from 2 to 10 gallons per minute (gpm). Well yields within the glacial sediments are dependent on the hydraulic characteristics of the aquifers and range from 0 to >300 gpm. Minor amounts of groundwater may be found in thin, permeable glacial lenses elsewhere on the installation. These zones may occur as multiple perched zones and in some cases exit the ground surface as springs and seeps. Springs are very common around the circumference of the



Source: Goldberg-Zoino and Associates 1976.

Scale in Miles
1 0 1

Legend

(25) Study Areas and Areas of Contamination with Numbers
Areas of Greater than 40 Feet of Saturation
Areas of Glacial Sediment Where the Zone of Saturation is Thin or Absent
Areas of Bedrock
----20---- Isopachs (feet) of Saturated Thickness
. . . . Ft. Devens Boundary

Figure 1-8 DISTRIBUTION OF AQUIFERS IN GLACIAL SEDIMENT

1ARI/Fig.1-8.CDR

artillery impact area in the South Post. Depth to the water table ranges from 0 to 90 feet. The specifics of groundwater flow directions are controlled by bedrock and till topography, and surface drainage, since groundwater in the glacial sediments is connected to surface water. Some changes in the direction of groundwater flow will also be the result of variations in hydraulic conductivity of the glacial sediments, but most show moderate to high hydraulic conductivities, being predominantly sand, gravel, and cobbles of outwash or lacustrine origins. Till and bedrock outcrops occur primarily as bedrock hills or drumlins and are typically groundwater divides.

1.3.7 Surface Water and Drainage

The Nashua River Basin encompasses approximately 543 square miles (1,405 Km^2) (Brackley and Hansen 1977). The river flows through the installation in a south to north direction and discharge rates average 55 cubic feet per second (cfs) (1.55 cubic meters per second (cms)). Depths range from 1 to 13 feet (0.3 to 4 meters). The drainage patterns are controlled by both surficial deposits and bedrock structure. In 1982, a 100-year flood occurred on the installation and the Quaternary alluvium deposited by the Nashua River and associated streams, which is mapped as such on the surficial geology maps, mirrors the areas flooded. In addition to the Nashua River, the terrain is dissected by numerous brooks that are associated with attendant wetlands. As indicated in Plate 1 (located in the back pocket of this report), there are several kettle ponds and one kettle lake located within the installation boundary.

South Post is drained on the west side by Spectacle Brook and Ponakin Brook into the North Nashua River, and on the east and north sides by an unnamed tributary of the Nashua river and by Slate Rock Brook. Both the latter brooks are artificially impounded before entering the river. The Main Cantonment is drained both directly by the Nashua River and by its tributaries such as Willow Brook and the Cold Spring Brook/Bowers Brook/Grove Pond/Plow Shop Pond/Nonacoicus Brook system. North Post is drained directly to the river and by short segments of Walker Brook, Mulpus Brook, and Nonacoicus Brook.

1.3.8 Demography and Land Use

The 9,400-acre Fort Devens installation is host to seven tenant and five assigned units for a total military personnel population of 6,225; 4,975 of whom reside on the installation. An additional 4,285 family members also reside on the installation. Approximately 2,652 civilians are employed by Fort Devens and 92,240 retired military personnel (including survivors and Veterans Administration recipients) make use of Fort Devens services.

A number of small towns and villages lie within five miles of Fort Devens. The largest is Clinton (13,222) to the south, and the two closest are Ayer (6,871) and Shirley (1,559) to the northeast and northwest respectively. Between Clinton and South Post lies Lancaster (6,661); north of Ayer is Groton (7,511); and east of South Post are the hamlets of Still River and Harvard. The center of Leominster (38,145) lies approximately five miles west of South Post, but parts of its eastern suburbs approach within two miles of South Post. All population figures are from the 1990 Census (Mondall 1992).

An important highway (State Route 2), bisects the facility, running between South Post and the Main Cantonment Area. The Boston and Maine Railroad runs along the eastern margin of the post and cuts off a small part of the Main Cantonment Area from the remainder. Ayer Main Street runs east/west from Ayer to Shirley and separates the Main Cantonment from North Post.

The area was initially forested, but after timbering operations it became a primarily agricultural area. Farm production in the area has been decreasing since about the 1800s because of the demands of urban and industrial growth. The main farm product is apples, but nurseries that produce ornamental stock are common. The major mineral resources are sand and gravel for construction purposes. Wachusett Reservoir was created by damming the Nashua River just south of Clinton. This reservoir supplies drinking water to the Boston Area. Since the early 1800s manufacturing industry in the area produced a variety of goods, many using the streams of the area for water power. In 1965, the major products were non-electrical machinery, fabricated metals, textile mill products, primary metals, rubber products, leather and leather products, and furniture and fixtures (USDA 1985). The town of Ayer has been a railroad center and manufacturing center since the mid-1800s. Notable industries potentially affecting the Fort Devens RIs include former plow manufacturing (Plow Shop Pond), a former tannery (Grove Pond), and an existing plastics factory (Plow Shop Pond).

The facility itself has a variable population of several thousand people, and operates several small-scale industrial activities, such as photographic processing and the maintenance of vehicles, aircraft, and small engines.

Range areas of the South Post are used for artillery and small arms fire and grenade detonations. Numerous vehicle fuel and heating fuel tanks exist or formerly existed on the facility. Managed forest accounts for approximately 70 percent of the facility area, and managed grassland for much of the remainder (See Section 1.3.2).

1.3.9 Water Use and Quality

The Fort Devens facility withdraws groundwater from three wells (the Sheboken, Patton, and McPherson, wells) and a wellfield known as the Grove Pond well. Locations of these wells, all of which are used for potable water, are shown on Plate 1. Fort Devens maintains a supply well (D-1, or the South Post well) along Trainfire Road in South Post, but it is not used for potable water.

The Sheboken well, constructed in 1941 and rebuilt in 1985, is 75 feet deep, has a nominal 20-inch casing, and has a rated capacity of

1,000 gallons per minute. This well is located at Building 3628 in the Main Cantonment Area along Sheridan Road north of Route 2 (Biang, et. al 1991).

The Patton well is located at Building 3630 in the Main Cantonment Area, north of Mirror Lake along Patton Road. This well, which was first installed in 1953 and reconstructed in July 1980, is 67 feet deep, has a nominal 20-inch casing, and has a rated capacity of 1,000 gallons per minute (Biang, et al. 1991).

The McPherson well, constructed in 1966, is 93 feet deep, has a nominal 18-inch casing, and has rated capacity of 1,000 gallons per minute. This well is located in the north post area, east of McPherson Road and the Nashua River and north of Verbeck Gate (Biang, et al. 1991).

The Grove Pond Wellfield formerly consisted of 74 well points connected to a single pumping system. The wellfield was subsequently reconfigured as 12 larger-diameter wells. The wells are sited along the south shore of Grove Pond, each within a few feet of the shoreline, so that they induce flow from the pond when they are pumping. The rated capacity of the wellfield is 600 gallons per minute. The wellfield is not a major supplier of water to the base but is activated for drinking water use at three-month intervals to keep the system operational.

Monthly pumpage records for the Fort Devens water supply wells indicate that for the period of January 1990 to June 1992 the average pumping rates were:

Sheboken Well	253 gpm or 11 million gallons per month
MacPherson Well	243 gpm or 10.5 million gallons per month
Patton Well	205 gpm or 9 million gallons per month

Each of these wells has a nominal capacity of around 1,000 gpm. The Grove Pond Wellfield has a nominal capacity of 600 gpm but is only pumped at three month intervals for brief periods to keep the system operational. The average pumping rate for the period of January 1990 to June 1992 was 13 gpm or 1,685,000 gallons every three months. Only 8 wells are pumped at any one time but all 12 wells are kept operational.

The groundwater supplies at Fort Devens are sampled and analyzed regularly in accordance with State requirements. The water quality is generally good, moderately hard, and requires minimal treatment. Except for sodium, the physical and chemical qualities of on-site potable water consistently have met Massachusetts water quality standards. The installation has been complying with the State regulation for reporting samples with sodium concentrations in excess of 20 mg/l. Recent analyses of the Grove Pond Wellfield (1988 to 1991) for volatile organics, have shown trace levels of trichloroethene, (non-detect to 0.8 µg/l), and what are presumably the results of chlorination, chloroform, (non-detect to 2.0 µg/l); bromoform (non-detect to 0.9 µg/l); bromodichloromethane (non-detect to 1.9 µg/l); and chlorodibromomethane (non-dectect to 1.9 µ/l). Simultaneous sampling of all four water supply sources (Grove Pond Wellfield, Patton Well, Sheboken Well and McPherson Well) on 5/30/90 showed no detectable volatiles in the Sheboken Well; 0.8 µg/l and 0.6 µg/l of trichloroethene in the Grove Pond Wellfield and in the McPherson Well respectively, and 1.6 µg/l bromochloromethane, 1.1 µg/l chlorodibromomethane and 1.0 µg/l of chloroform in the Patton Well. All the levels found are below their respective MCLs or insignificant (DEH 1991). Groundwater within Fort Devens was designated as Class I groundwater by Massachusetts and was considered to be a source of potable water (Biang, et al. 1991).

The Town of Ayer also has installed water supply wells adjacent to Grove Pond, but on the east side of the Fort Devens Grove Pond Wellfield. It is possible that the town's wells also induce flow from the pond into the groundwater. There are no known private water supply wells within the Town of Ayer that could be potentially impacted by the AOCs. Rural areas where private wells are common are well outside any probable impact areas for AOCs under consideration.

Local surface water bodies are used for recreational fishing (Plow Shop Pond) and boating (Grove Pond). The Town of Ayer has a public park with boat access on the North side of Grove Pond. The pond adjoining Cold Spring Brook has no known recreational use, and may have been created by beaver. It has been in existence at least since May 1972 as evidenced in an aerial photograph from that period but was not in evidence in an aerial photograph from April 1965.

The only water supply wells which could potentially be affected by the AOCs investigated are the Patton Well by Cold Spring Brook Landfill and the Grove Pond Wellfield by Shepley's Hill Landfill. This potential is being assessed by modeling of the aquifers at Fort Devens by Engineering Technologies Associates Inc. of Ellicott City, Maryland, for the Army under a separate contract (Engineering Technologies Associates 1992).

1.4 RI SITE LOCATIONS AND DESCRIPTION

1.4.1 Shepley's Hill Landfill

Shepley's Hill Landfill served the entire Fort Devens base but primarily the Main Cantonment Area and North Post, and it is located at the northeast portion of the Main Cantonment Area, just inside the base boundary (Figure 1-9). An aerial photograph of the landfill is included at the end of Section 1. The Main Cantonment Area consists of military housing, barracks, offices, and such support facilities as warehouses, magazines, and workshops. Residential facilities such as shops, churches, schools, parks, a golf course, and recreational areas make the Main Cantonment Area equivalent to a small town.

Plow Shop Pond is located outside the installation boundary to the northeast of the landfill with a water surface elevation of 216 to 217 feet AMSL. Plow Shop Pond is maintained by two small dams, one adjacent

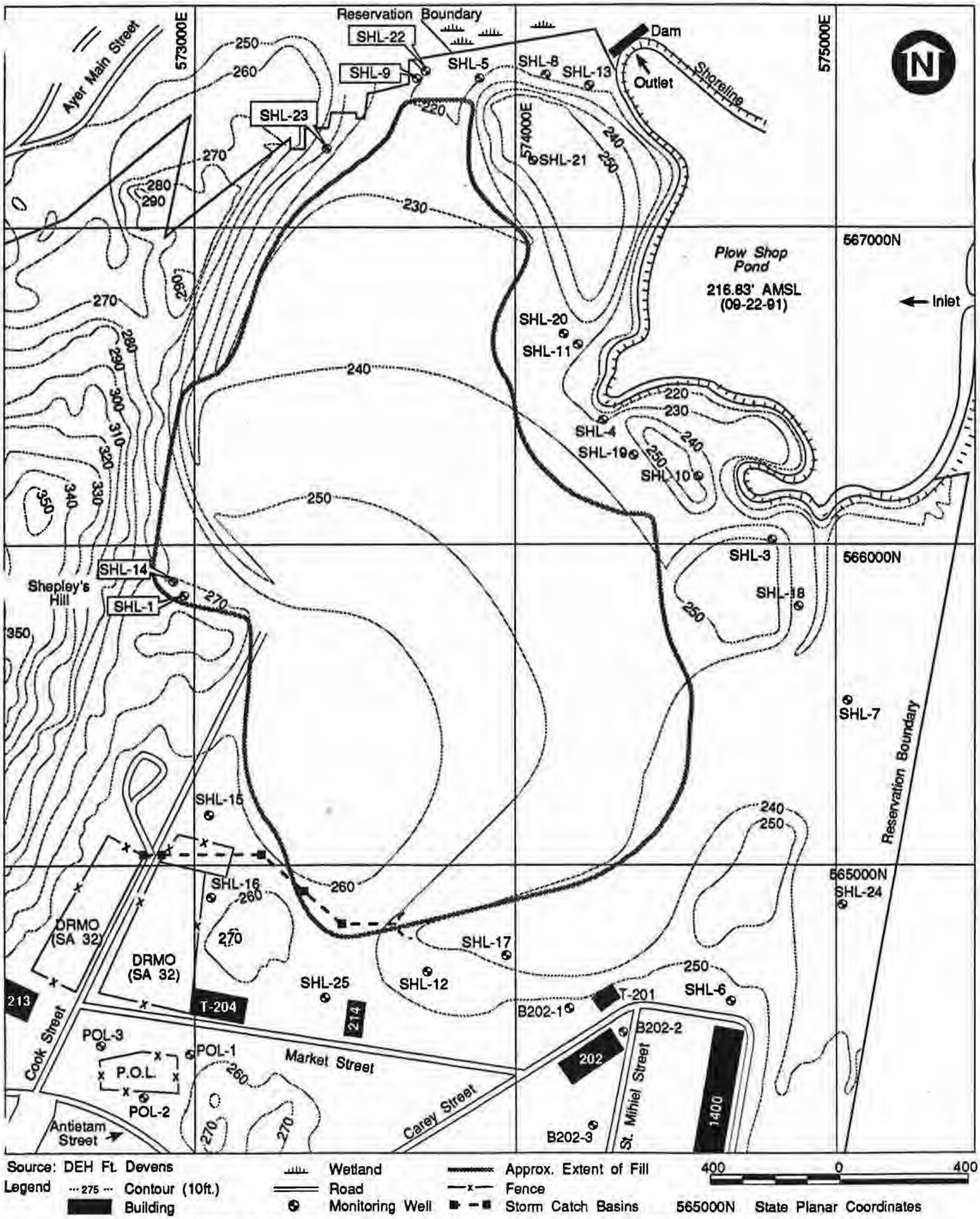


Figure 1-9 SHEPLEY'S HILL LANDFILL SITE MAP WITH MONITORING WELL LOCATIONS

to the landfill in the northwest corner of the pond and the other at Moore's Lumberyard at the north end of the pond. Beyond the pond is the small town of Ayer (population 6,871, 1990 Census). East of the landfill is the Boston and Maine Railroad. The railroad's embankment divides Plow Shop Pond from Grove Pond, although they are connected by a culvert under the railroad. The culvert is approximately 10 feet by 6 feet and 130 feet long. Headspace at normal flow is only approximately 1 foot, since Plow Shop Pond level was raised by a dam.

1.4.1.1 Topography and Surface Features

The topography of the landfill area has been extensively modified. The southern part of the landfill now consists of a gently sloping field extending approximately 1,600 feet across from the base of Shepley's Hill in the west (approximately 260 feet above mean sea level) to the railroad. There is remaining a fringe of trees and shrubs along the south shore of Plow Shop Pond which rises at least 15 feet abruptly from the water to several terrace remnants east of the fill area proper.

The north end of the landfill is narrower (approximately 1,000 feet from west to east) than the south end. A more extensive remnant of the original flat-topped hill adjoining the pond remains undisturbed and covered with trees along the northern 800 feet of the west side of the pond. Between this little hill and the northward extension of Shepley's Hill is the remnants of an original valley, partly filled and since capped, sloping gently north to the base boundary, which is marked by a narrow fringe of trees and shrubs. Just north of the landfill, off-site, is a small patch of wooded wetland (approximately 9 acres) identified on the National Wetlands Inventory Map, Ayer Quadrangle, as palustrine wooded wetland covered by deciduous trees.

The west side of the landfill is bounded by the tree-covered slopes of Shepley's Hill, a north-south elongated ridge of granodiorite and till. Shepley's Hill has a maximum elevation of 360 feet. The remaining active area of the landfill is located along the extension of Cook Street adjacent to the Defense Re-utilization and Marketing Office (DRMO), a site also proposed by USATHAMA for assessment. East of the DRMO, at the junction of Market and Carey Streets, is Building 202, site of a former underground storage tank (UST) also selected for investigation.

1.4.1.2 Ecology

Shepley's Hill Landfill is a disturbed open field, vegetated with a variety of grasses and forbs. The area is mowed on a regular basis thus restricting the growth of trees and shrubs (natural succession). The surrounding area can be characterized as forested on the west and east, while the southern boundary is developed. Located on the northeast side is the very shallow Plow Shop Pond, a Massachusetts Class B pond which is classifiable as an emergent wetland. Another state- and federally-regulated wetland occurs north of the landfill. A variety of wildlife species may utilize this area since a number of habitat types are represented: forest, wetland, meadow, and aquatic, as well as the edges between habitat types, which provide their own ecological niches. Species of concern, (i.e. a species listed as endangered, threatened, or of special concern by the State and/or Federal government), including the grasshopper sparrow, the upland sandpiper, and the bald eagle, have been observed by base personnel on or near the landfill site.

1.4.2 Cold Spring Brook Landfill

Cold Spring Brook Landfill is located on the north side of Patton Road. It extends for approximately 900 feet along Patton Road, covers approximately 3.5 acres, and extends out into the former wetland along Cold Spring Brook, now mostly submerged beneath the Cold Spring Brook Pond, which was created by the raised inlet of the Patton Road culvert (see Figure 1-7). An aerial photograph of Cold Spring Brook Landfill is included at the end of Section 1.

1.4.2.1 Topography and Surface Features

The upper surface of the landfill is gently sloping and from about 255 to 260 feet in elevation. It is densely covered with small trees and scrub, the trees being predominantly pines. The edge of the landfill falls off abruptly to the wetland or to the pond itself with an elevation drop of perhaps 15 to 20 feet on average.

Demolition debris and rusted drums are visible in places along the face of the landfill, with some of the drums resting in the water of the pond.

Across Patton Road to the south is a flat area with little vegetation that appears to have been excavated for gravel and sand, perhaps for cover for the landfill. There are no indications of fill material south of the road. Beyond the apparent excavation area, a low hill covered with trees rises abruptly to above 300 feet AMSL. A depression, that drains west and south to Little Mirror Lake, is located beyond a small hillock west of the pond. Just south of Patton Road adjacent to this depression is Patton Well, a water supply well for Fort Devens, which lies just over 400 feet from the south end of the landfill and 600 to 800 feet from the edge of the Cold Spring Brook Pond. A magazine area lies west of the pond, and Cold Spring Brook originates as drainage from a wetland in the center of this area. The brook drains north to Grove Pond, passing through several palustrine forested or scrub/shrub wetlands before reaching Grove Pond.

Apart from the upgradient magazine area and the Patton well, the only active facility near the landfill is a store on Patton Road, known as Shoppette.

1.4.2.2 Ecology

Unlike Shepley's Hill Landfill, this landfill has been allowed to revert to a forested area dominated by small trees and shrubs including scotch pine, red pine, staghorn sumac, and quaking aspen. A small impoundment of Cold Spring Brook is located on the northern border of the landfill; mature forest vegetation occurs on both the eastern and western edges of the landfill; while the southern boundary parallels Patton Road. A state- and federally-regulated wetland is located within 500 feet of the old landfill. No species of concern are known to occur in the general vicinity of the site, however, a number of aquatic and terrestrial wildlife species utilize the site area.

1.5 PREVIOUS INVESTIGATIONS

1.5.1 Shepley's Hill Landfill and Adjoining Areas (POL, DRMO Yard, Building 202)

Shepley's Hill Landfill has been extensively investigated since 1980 (see Table 1-1). Wells have been installed by SEA Consultants (1986) and Con-Test, Inc. (1988). The SEA Consultants' wells have been re-identified as SHL-1 through SHL-9. The Con-Test wells, formerly N-1 through N-4, are now SHL-10 through 13, and subsequent wells installed as part of the latest investigation have been numbered sequentially starting with SHL-14. Table 1-2 identifies the new well numbers and lists their old identification. The existing monitoring wells are shown on Figure 1-10.

A number of the SEA Consultants' well locations had BARCAD samplers installed adjacent to or in the same borehole as a conventional monitoring well. These were placed as single BARCADS (i.e., BAR-1 at WT-1), as two in one hole (BAR-2), as a BARCAD with a conventional well (BAR-2A and WT-2), as two BARCADS with a conventional well (BAR-4 and WT-4), and in one case, as a four-level BARCAD installation (BAR-5) (see Appendix A). Some of these wells (BAR-1, WT-1, WT-2) had been noted as dry when measured in 1989 and 1990. The most comprehensive water level measurements and water quality analyses took place in 1987, which was the last time these wells were reported as having water. Other wells were destroyed (WT-4 and BAR-8) and replaced.

Sampling, analyses, and water level measurements have been reported at irregular intervals since 1987: two sets of groundwater and two of surface water in 1987, one set of groundwater in 1988, five in 1989, four in 1990, and one in 1991 prior to the RI. Quarterly sampling of the previously existing wells are continuing, with analyses for volatiles and field filtered metals.

Several adjoining areas have been designated SAs or are currently being investigated. These include the DRMO yard, SA 32; the Building 202 UST site, SA 48; and the POL facility, just south of the DRMO yard. Three groundwater monitoring wells were installed at both the POL site and SA 48. These wells are used to characterize the hydrogeologic setting and groundwater chemistry of Shepley's Hill Landfill. Despite being down slope from the landfill, the DRMO yard does contribute surface run-off to a storm drain along the south side of the landfill. This drainage could impact parts of the landfill and affect groundwater

Table 1-1

SUMMARY OF PREVIOUS INVESTIGATIONS CONDUCTED AT SHEPLEY'S HILL LANDFILL

Date	Contractor or Consultant	Monitoring Work	Sampling Matrix	Results of Investigation
1980	Cpt. Robert Farrell	Geology Hydrogeology		- Site was formerly 4 kettle holes in a glacial sand gravel deposit over 100 feet deep. - Groundwater flow is toward NE & E. Leachate was suspected.
1985	Gale Engineering	Sampling	Surface Water & Groundwater	- Key leachate indicators such as chloride, iron, and specific conductance were above background.
1986	SEA Consultants	Well Installation (9 Wells) -Hydrogeology -Groundwater Sampling	Groundwater	- Groundwater flow direction is toward north. - Several unidentified VOCs were detected in groundwater. - Downgradient wells 3, 4, 5, 8, 9 contain most contamination. - Upgradient wells also showed contamination. - Defined local geohydrology of the site.
1987	Briggs Associates	Sampling (2 Rounds)	Groundwater	- Low level of Aromatic and halogenated hydrocarbons were detected in downgradient wells. - Elevated levels of toxic metals in both up and downgradient wells.
1989	ConTest	-Well Installation (N1..N4) -Hydrogeology	Groundwater	- Elevated levels of As, Cr, & Pb maximum Arsenic in ConTest well N2. Arsenic concentration above MCL in 9 of 11 wells. - Cr concentration above MCL in 2 wells, maximum in ConTest well N3. - Conductivity, hardness, iron, sodium above MCL in majority of wells. - Groundwater in wells N1 & 2 are perched not affecting the aquifer flow. - Hydraulic conductivity Shallow = 2.1×10^{-2} cm/sec Deep (fine grained) = 2.7×10^{-3} cm/sec

RC424

MCL: Maximum Contaminant Level

Source: E & E, 1991

Table 1-2

WELL IDENTIFICATION TABLE FOR SHEPLEY'S HILL LANDFILL

Location	SEA[1]	CONTEST[2]	BARCAD[3]	Status
SHL-1	BAR-1		Yes	Abandoned on 7/15/91
SHL-1A	WT-1		No	Repaired on 7/16/91
SHL-2	WT-2/BAR-2A		Hybrid	Abandoned on 7/17/91
SHL-2	BAR-2		Yes	Abandoned on 7/18/91
SHL-3	WT-3		No	Operational
SHL-3	BAR-3		Yes	Not to be sampled
SHL-4	WT-4/BAR-4		Hybrid	Operational
SHL-5	WT-5		No	Operational
SHL-5	BAR-5		Yes	Abandoned on 7/23/91
SHL-6	WT-6		No	Operational
SHL-7	WT-7		No	Operational
SHL-8	WT-8/BAR-8		Hybrid	Destroyed and replaced by SHL-8S/D
SHL-8S		SHL-8S	No	Operational (Shallow)
SHL-8D		SHL-8D	No	Operational (Deep)
SHL-9	WT-9/BAR-9		Hybrid	Operational
SHL-10		N-1	No	Operational
SHL-11		N-2	No	Operational
SHL-12		N-3	No	Operational
SHL-13		N-4	No	Destroyed and replaced
SHL-14			No	New well
SHL-15			No	New well
SHL-16			No	New well
SHL-17			No	New well
SHL-18			No	New well
SHL-19			No	New well
SHL-20			No	New well
SHL-21			No	New well
SHL-22			No	New well
SHL-23			No	New well
SHL-24			No	New well
SHL-25			No	New well
POL-1			No	Operational
POL-2			No	Operational
POL-3			No	Operational

RC424

(1) Wells constructed by SEA in 1986 (see Appendix B)

(2) Wells constructed by CONTEST in 1989 including replacements

(3) Hybrid: Wells that have a BARCAD unit in place below a regular well

Source: E & E, 1991

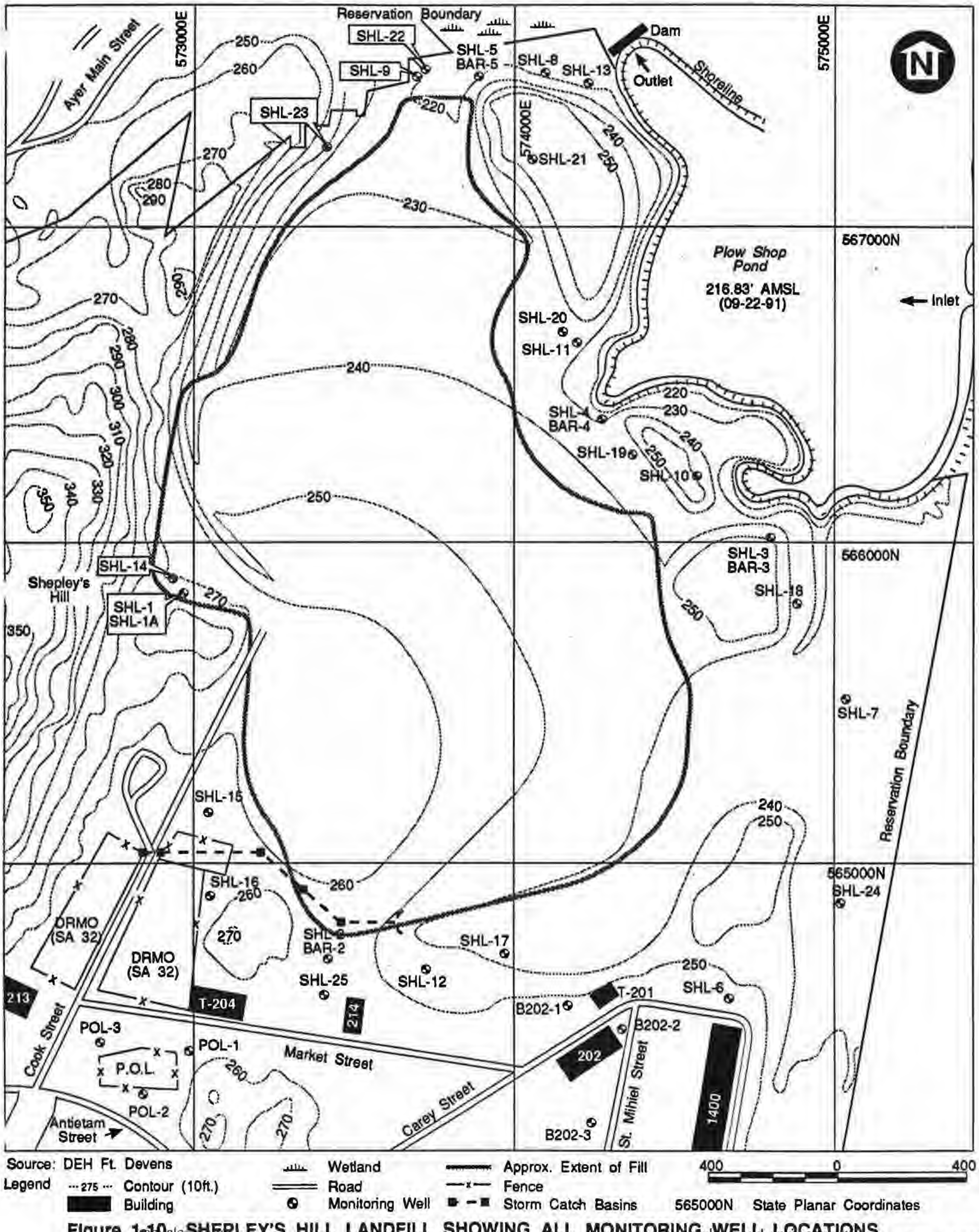


Figure 1-10 SHEPLEY'S HILL LANDFILL SHOWING ALL MONITORING WELL LOCATIONS

1ARI/Fig.1-10.CDR

under the landfill as well as Plow Shop Pond, which is adjacent to the landfill. Consequently, these sites will all be discussed as factors used to evaluate the landfill and its potential impact on human health and the environment.

1.5.2 Cold Spring Brook Landfill

In 1988, AEHA installed eight monitoring wells around the Cold Spring Brook Landfill and sampled them three times. Limited sampling and analysis was performed on the contents of exposed drums, on surface water and sediment, as well as on the water from the Patton Well. Sampling and analysis of wells was repeated in 1989 and 1990 (see Table 1-3).

1.6 RESULTS OF PREVIOUS INVESTIGATIONS AT SHEPLEY'S HILL LANDFILL

1.6.1 Soils and Geology

The type of soils originally covering the area now occupied by Shepley's Hill Landfill may be deduced from the map of the superficial geology (Jahns 1952), which showed sandy glacial outwash under most of the present landfill area with the exception of three small wetlands lying in a narrow valley along what are now the south and west sides of the landfill. The wetlands were most probably underlain by organic soils, and these were probably covered with fill without being disturbed. The test pits dug in 1983 to determine the extent of fill included one (TP-38) just north of wells SHL-5 and SHL-9 that encountered peat at a shallow depth showing organic soils under at least part of the wetland north of the landfill. It is obvious that much of the kame terrace which lay between the valley and Plow Shop Pond has been excavated and used as cover material for the landfill, as can be seen from the fact that only sand was visible at the surface during the site investigation. All the wells installed prior to the current investigation encountered sands at the surface.

The geology of the landfill consists of varying thicknesses of sand or till and sand lying above "granite", granodiorite, phyllite, schist, or gneiss. Including the latest set of boreholes, bedrock has been encountered at thirteen locations: SHL-1 through 5, 8, 10, 11, 14, 16, 22, 24, and 25 (see Table 1-4).

Based on the depth to bedrock encountered by wells and boreholes, and preliminary results of seismic surveys run by Army contractors at the DRMO Yard and around the north, east, and south sides of the landfill, the top of bedrock configuration is complex. A deep (< 125 feet AMSL) trough appears to underlie parts of Plow Shop Pond and Grove Pond, and probably a narrower trough (< 150 feet AMSL) runs under the landfill (see Figure 1-11). Because the trough under the landfill is encountered at both north and south ends of the fill, and similar bedrock valleys run north to south in this area, it is assumed that this trough also runs north to south underneath the landfill. Between the two troughs is a north to south elongated ridge culminating at SHL-3,

Table 1-3

SUMMARY OF PREVIOUS INVESTIGATIONS CONDUCTED AT COLD SPRING BROOK LANDFILL

Date	Contractor or Consultant	Monitoring Work	Sampling Matrix	Results of Investigation
1988	AEHA	Geohydrogeolgic Investigation	Groundwater	- Low groundwater gradient and seasonal water level variation prevent determination of an accurate groundwater flow direction. - Arsenic concentrations above MCL were detected in CSB4 & CSB5
1989 /1990	ConTest	Groundwater Sampling	Groundwater Quartly Sampling	- Heavy metals detected in some of the groundwater samples.

RC424

MCL: Maximum Contaminant Level

Source: E & E, 1991

Table 1-4

ELEVATION OF TOP OF BEDROCK
SHEPLEY'S HILL LANDFILL

Well #	Elevation of Ground Surface	Top of Bedrock (Feet AMSL)*
SHL		
1	271.00	247.30
2	254.90	222.90
3	247.31	210.07
4	226.73	201.80
5	217.81	138.41
8	220.04	147.45
10	247.44	210.11
11	234.86	196.33
22	219.58	104.58
24	237.68	123.03
25	257.10	222.90

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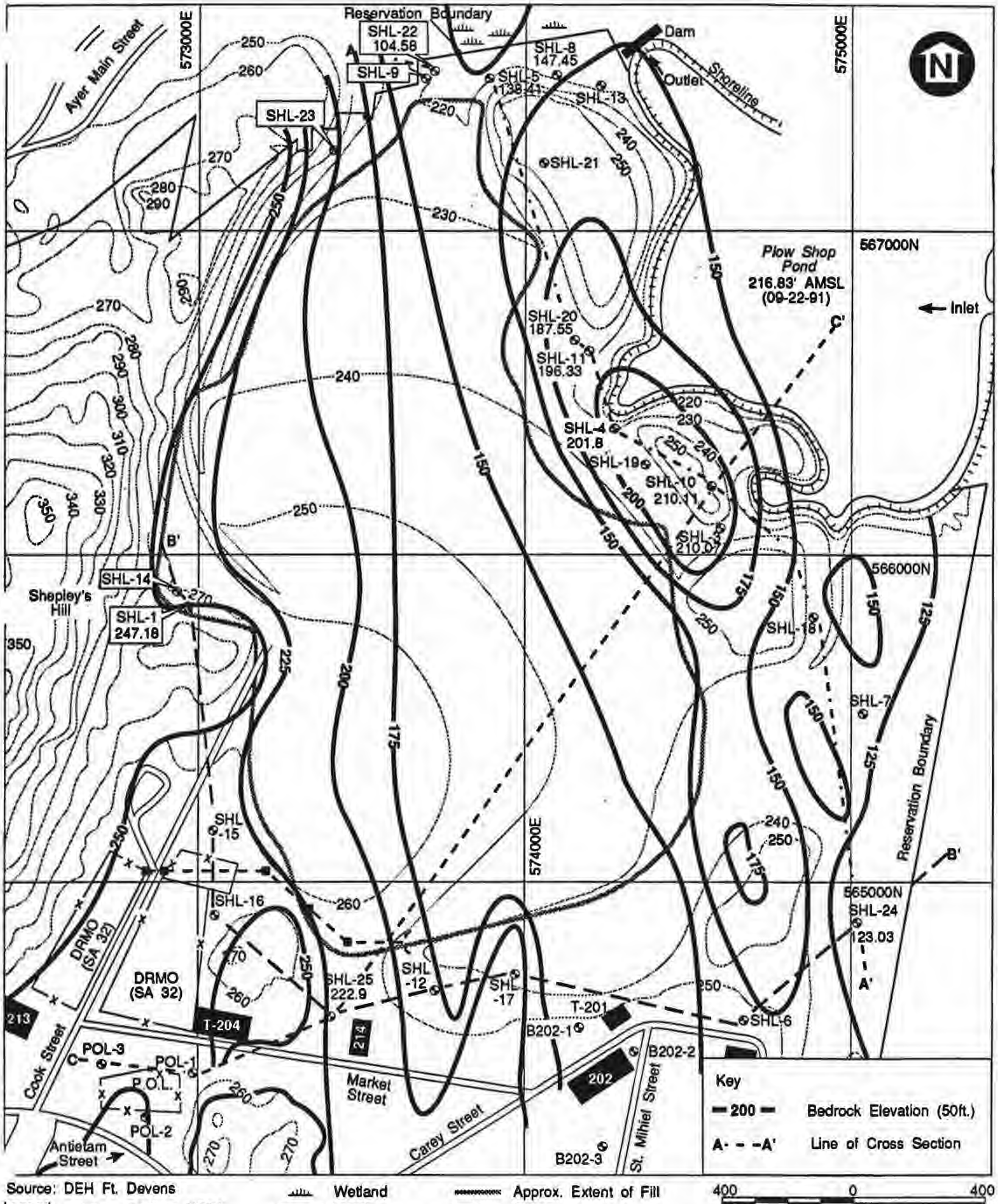
* Above Mean Sea Level

Source: E & E, 1992



Source: DEH Ft. Devens

Legend: ···275··· Contour (10ft.); Building; Wetland; Road; Monitoring Well; Approx. Extent of Fill; Fence; Storm Catch Basins; 565000N State Planar Coordinates

400 0 400

Figure 1-11 ELEVATION OF TOP OF BEDROCK AT SHEPLEY'S HILL LANDFILL AND LOCATION OF CROSS SECTIONS BASED ON WELL LOGS AND SEISMIC DATA

1ARI/Fig.1-11.CDR

SHL-4, SHL-10, and SHL-19 where it is above 200 feet AMSL. Bedrock outcrops occur along Shepley's Hill to the west of the landfill, and on two wooded knolls just east of the DRMO Yard and the POL area, respectively.

Figure 1-12, Section A-A', runs from the outcrop of the Ayer Granite (granodiorite), across the bedrock trough through wells SHL-22 and SHL-5, down the east side of the landfill along the bedrock "high" adjoining Plow Shop Pond, and back into the trough, which is postulated to run under the landfill, at the south end near well SHL-7 and well SHL-24. This illustrates how the bedrock "high" forms a partial barrier to groundwater flow from under the landfill into Plow Shop Pond. The unconfined flow in the aquifer is forced into a thin layer less than 10 feet thick between wells SHL-3 and SHL-10, and no more than 22 feet thick between SHL-10 and SHL-11.

Figure 1-13, Section B-B', runs from the granodiorite outcrop of Shepley's Hill and around the south side of the landfill through wells SHL-15, SHL-25, SHL-12, SHL-17, SHL-6, and SHL-24. It clearly shows the bedrock outcrop between dry borehole SHL-16 and well SHL-25, and how the top of bedrock drops off with an apparently gentler slope into the trough at the south end of the landfill than it does at the north end of the landfill.

Figure 1-14, Section C-C', runs from the Petroleum, Oil, and Lubricants (POL) storage area outside the southwest corner of the landfill area, through SHL-25 northeast to SHL-10 and Plow Shop Pond. Because of the absence of wells within the fill area, the cross-section shows the trough under the fill, as extrapolated from other well data, and the seismic survey.

Thickness of the fill is unknown, and while there are no data suggesting that the fill extends into the groundwater, it could be that this occurs in places.

Plow Shop Pond is known to be shallow but the thickness of peat or organic-rich sediment beneath the bottom of the pond is speculative.

1.6.2 Groundwater Hydrology

Initial (1986) elevation measurements of water levels made shortly after well installation (see Table 1-5) indicate a sharp hydraulic gradient from southwest to northeast across the site (see Figure 1-15). This implies that much of the flow within the landfill is discharging to Plow Shop Pond. On the north end of the landfill however, three wells show elevations of the water table below the surface elevation of Plow Shop Pond. This implies a northerly flow of groundwater discharging to Nonacoicus Brook below the dam at the outlet of Plow Shop Pond. It also implies leakage from the pond into the bank and around the dam.

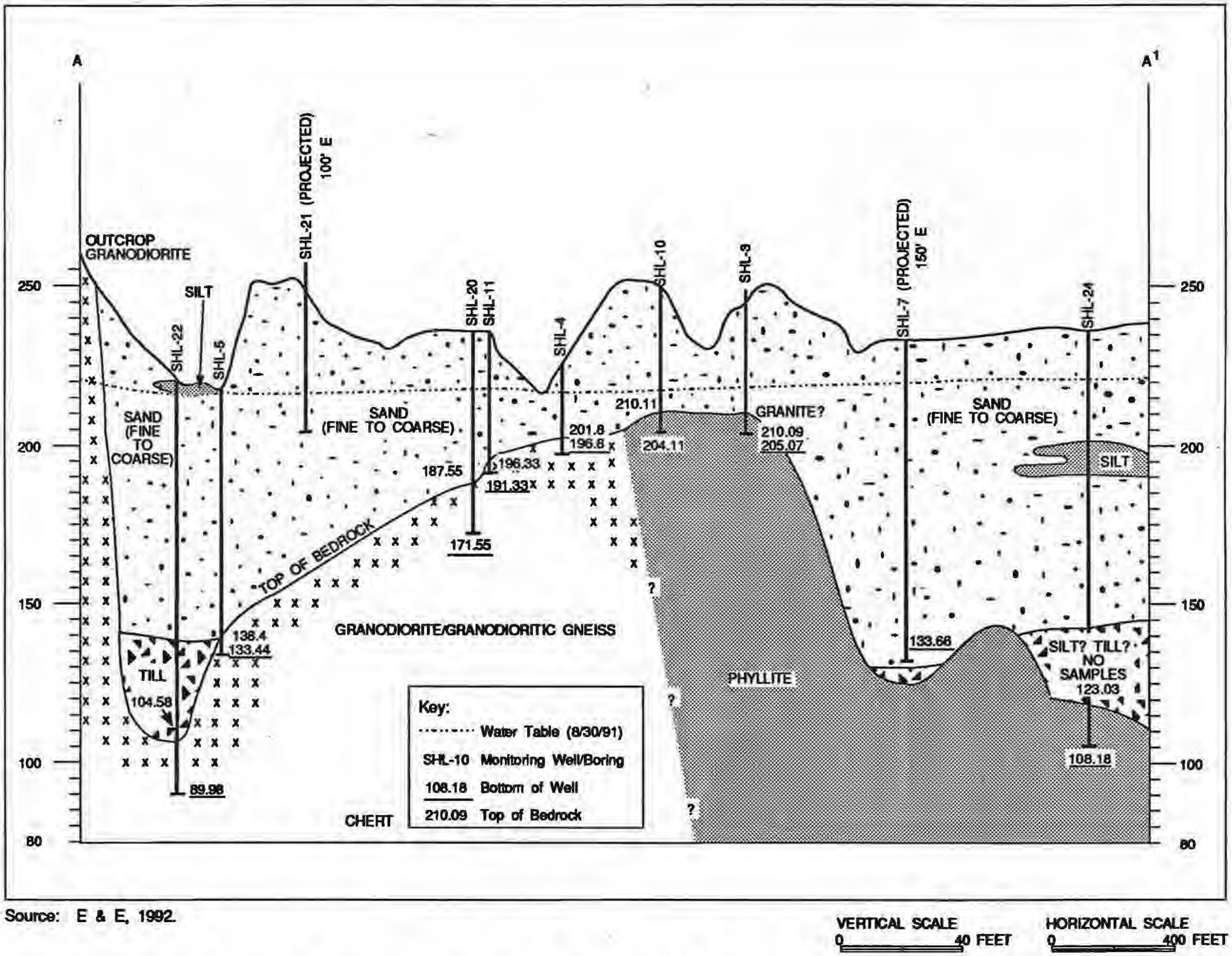
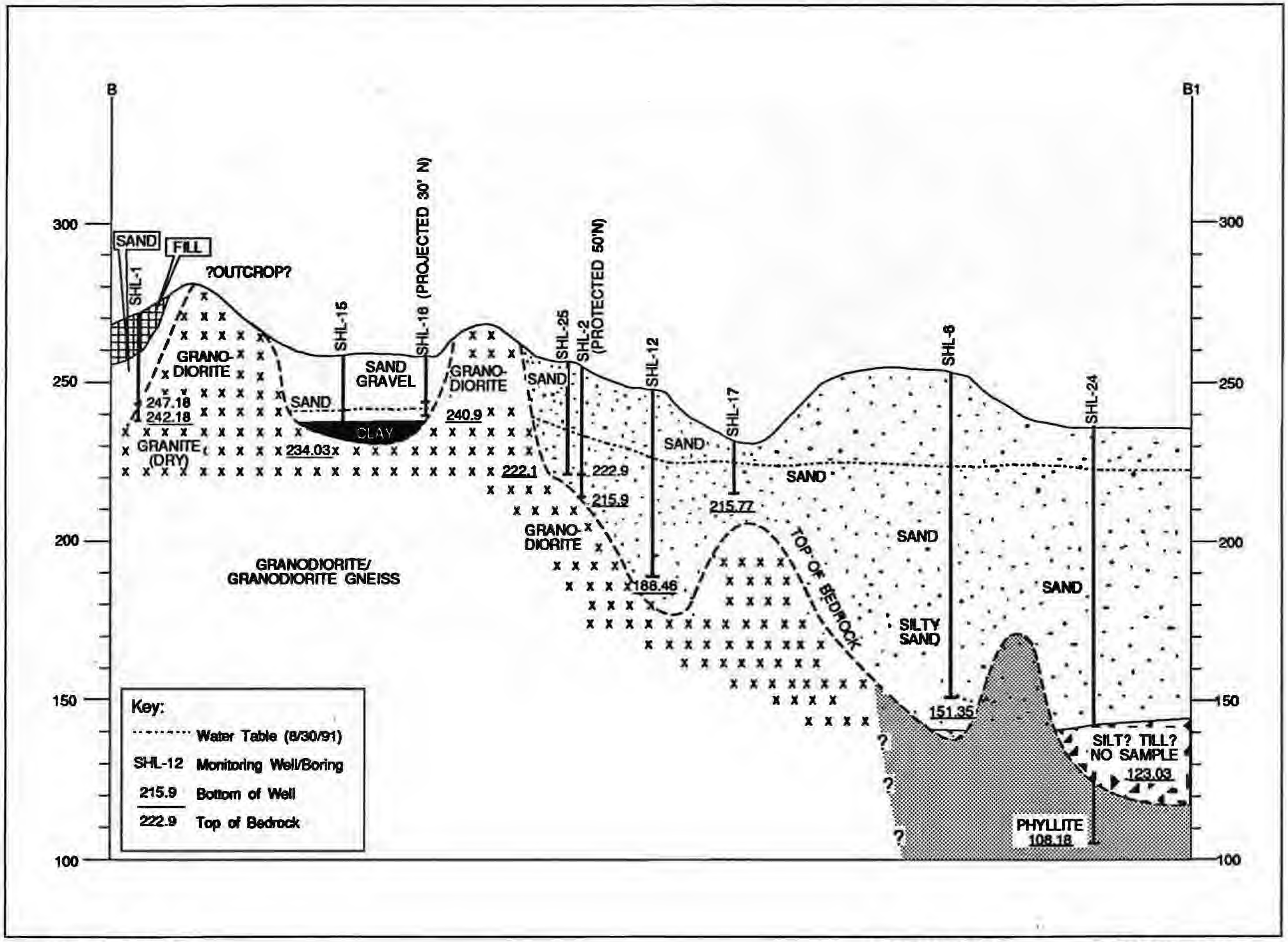


Figure 1-12 SHEPLEY'S HILL LANDFILL CROSS SECTION A - A' BASED ON WELL LOGS AND SEISMIC DATA

SHLA-A'.CDR



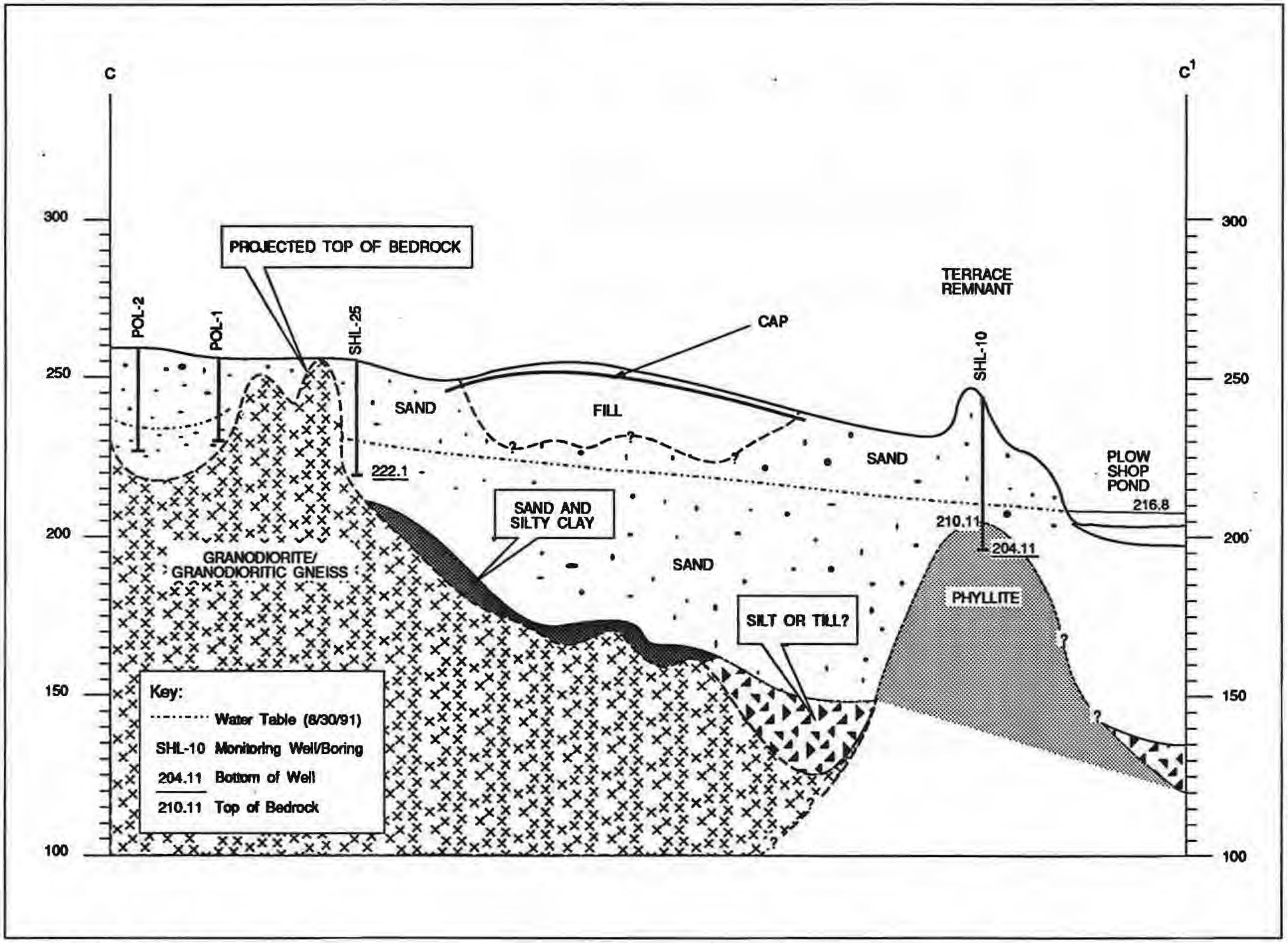
Source: E & E, 1992.

VERTICAL SCALE 0 40 FEET

HORIZONTAL SCALE 0 400 FEET

Figure 1-13 SHEPLEY'S HILL LANDFILL CROSS SECTION B - B' BASED ON WELL LOGS AND SEISMIC DATA

SHLB-B'.CDR



Source: E & E, 1992.

VERTICAL SCALE 0 40 FEET

HORIZONTAL SCALE 0 400 FEET

Figure 1-14 SHEPLEY'S HILL LANDFILL CROSS SECTION C - C' BASED ON PROJECTED SEISMIC DATA AND WELL LOGS

SHLC-C'.CDR

Table 1-5

WATER TABLE ELEVATIONS AT SHEPLEY'S HILL LANDFILL (1986)

SEA Report Well #	SHL Well #	Depth of Well (ft)	Ground Surface	Top of Casing	Depth to Water (Feet)	Date	Water Table Elevation	Top of Bedrock
BAR-1	-	28	270.88	272.55	12.55	3/7	260.00	247.18
WT-1	SHL-1	7	268.98	272.28	6.4	3/7	265.88	247.3
BAR-2(2)*	-	28	254.90	256.73	24.15	3/7	232.58	-
WT-2	SHL-2	25	256.47	257.55	22.03	3/7	235.52	222.9
BAR-3	-	42.5	247.57	249.15	29.5	2/16	218.07	210.1
WT-3	SHL-3	34'	247.34	248.46	30.43	3/7	218.03	210.1
WT-4	SHL-4	13'	226.00	228.75	10.9	3/17	217.85	201.80
BAR-4(2)	-	18.5	226.00	228.75	10.5	3/17	218.25	-
BAR-4(1)	-	28'	226.00	228.75	10.5	3/17	218.25	-
WT-5	SHL-5	13'	216.35	218.59	4.3	3/7	214.29	138.35
BAR-5(1)	-	79'	216.41	217.55	2.15	3/7	215.40	-
BAR-5(2)	-	60'	216.41	217.55	3.50	3/7	214.05	-
BAR-5(3)	-	45'	216.41	217.55	5.41	3/7	212.14	-
BAR-5(4)	-	25'	216.41	217.55	4.2	3/7	213.35	-
WT-6	SHL-6	59.5	252.85	254.15	28.65	10/8	225.5	NR
WT-7	SHL-7	21.0	235.16	237.04	18.65	10/8	218.39	NR
WT-8	SHL-8	14.0	219.45	220.41	7.00	10/8	213.41	147.45
BAR-8(1)	-	71.0	-	-	7.13	10/8	213.28	-
BAR-8(2)	-	56.0	-	-	6.37	10/8	214.04	-
WT-9	SHL-9	25.0	222.94	224.22	10.40	10/8	213.82	NR
BAR-9(1)	-	100.0	-	-	10.85	10/8	213.37	-
BAR-9(2)	-	40.0	-	-	10.41	10/8	213.81	-

RC424

*BAR-2(1) damaged during auger withdrawal
NR = Not Reached. (All below 101.5 feet from surface)

Source: SEA Consultants Inc. 1986

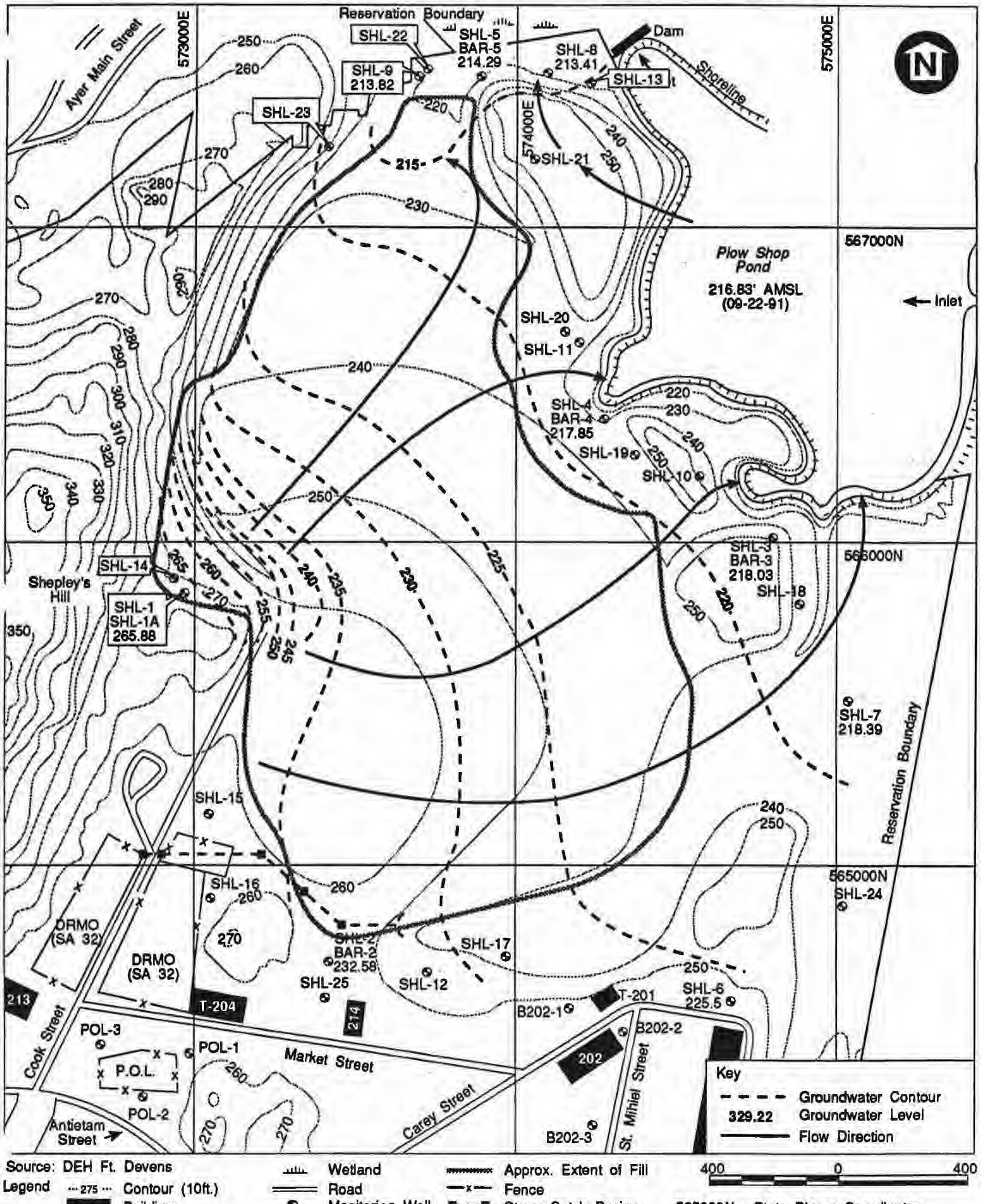


Figure 1-15 SHEPLEY'S HILL LANDFILL WATER TABLE CONTOURS (1986)* WITH FLOW DIRECTIONS

*Using data from February, March, and October (see Table 1-5).

1ARI/Fig.1-15.CDR

While later (1989 to 1990) water elevation measurements determined that upgradient wells SHL-1 and SHL-2 were dry, the same general flow pattern exists (see Table 1-6 and Figure 1-16).

Fluctuations in water levels have been relatively slight in those wells that continue to show water, the range being typically less than 2 feet (see Table 1-6), although Well WT-2 (SHL-2) declined 4 feet before going dry. This lack of fluctuation implies a relatively steady balance between recharge and discharge over the year, as well as relative closeness of the water table elevation to the base levels of the receiving water bodies (Plow Shop Pond and Nonacoicus Brook).

At all of the locations where there were both wells and BARCAD samplers, it was possible to measure water levels (hydraulic heads) at different depths below the water table at the same location. This allowed for the calculation of vertical gradients. For example, the four BARCAD samplers in BAR-5 were completed at 79 feet, 60 feet, 45 feet, and 25 feet. Between the shallowest BARCAD (No. 4) and the next deepest (No. 3), there is a vertical distance of 20 feet. The difference in hydraulic head is 1.21 feet and giving a downward vertical gradient of 0.06 feet per foot. It is downward because the level in BARCAD No. 3 is lower than that in the BARCAD above it (No. 4). Below this the vertical hydraulic gradient reverses and becomes upward as the water levels in the deeper BARCADs (Nos. 1 and 2) are above the level in BARCAD No. 3. This results in vertical hydraulic gradients that are upward between BARCAD No. 2 and BARCAD No. 3 at 0.13 feet per foot, and upward between BARCAD No. 1 and BARCAD No. 2 at 0.07 feet per foot.

In contrast, at the location of SHL-9 (BARCAD-9 and WT-9 in Appendix A, measured 8 October 1986), the hydraulic gradient is downward throughout from 25 feet to 100 feet (although with an average vertical gradient of only 0.006 feet per foot). The implication here is that flow is essentially horizontal. At the location of SHL-4, the two BARCAD samplers below the well have identical hydraulic head, again implying horizontal flow since there is zero vertical hydraulic gradient.

At the location of SHL-8 (WT-8), the highest hydraulic head is in the intermediate BARCAD (No. 2), which implies vertical gradients upward in the upper part of the borehole at 0.015 feet per foot and downward in the lower part of the borehole at 0.05 feet per foot. This could imply discharge from overburden to bedrock, but as the lowest BARCAD is still above bedrock, it may only imply overall horizontal flow with minor fluctuations of hydraulic head within the overburden.

Shepley's Hill Landfill is clearly a recharge area for the glacial overburden aquifer, with precipitation entering the groundwater through the soil. The vertical gradients within the unconfined aquifer are slight and nearly horizontal flow appears to predominate. After leaving the area of the fill, the groundwater flows to the south and west sides of Plow Shop Pond, discharging to the pond along the shoreline and bottom up to a point north of SHL-20 and SHL-11. Somewhere along the

Table 1-6

WATER TABLE ELEVATIONS AT SHEPLEY'S HILL LANDFILL (1989-1990)

Well #	SHL #	Date (Month/Year) 9/89	12/89	3/90	6/90	Depth/Remarks/Range
WT-1	1A	-	-	-	-	7 ft. Dry
WT-2	2	-	-	-	-	25 ft. Dry
WT-3	3	217.71	218.04	218.18	218.12	34 ft./0.47
WT-4	4	217.97	217.77	217.97	218.07	13 ft./0.30
WT-5	5	213.80	214.29	215.89	214.87	13 ft./2.09 ft.
WT-6	6	225.34	226.03	225.92	226.60	59.5 ft./1.26 ft.
WT-7	7	218.36	218.73	218.85	218.97	21 ft./0.61 ft.
WT-8	8	213.99	N/A	N/A	N/A	14 ft./N/A
WT-9	9	214.10	214.84	215.39	215.05	25 ft./1.29 ft.

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N/A = Not Available (Well destroyed)

Source: DEH, 1990

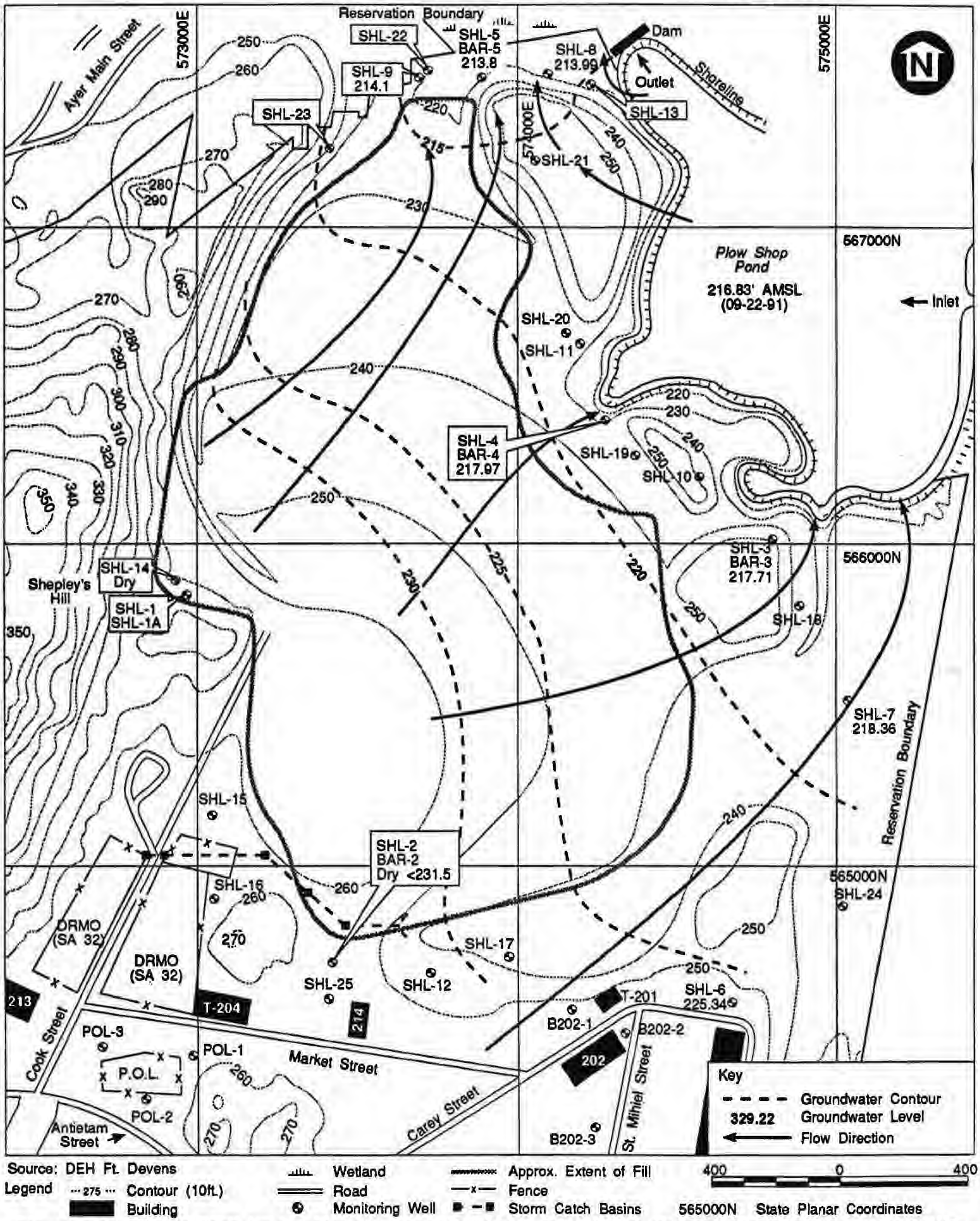

Figure 1-16 SHEPLEY'S HILL LANDFILL WATER TABLE CONTOURS (9/19/89) WITH FLOW DIRECTIONS

1ARI/Fig.1-16.CDR

western shoreline, close to the dam at the northwest corner of the pond, the surface water begins to flow out of the pond and into the groundwater through the bottom and bank of the pond. This occurs because the dam has raised the hydraulic head (elevation) of the surface water above the hydraulic head of the groundwater, as shown by SHL-13, SHL-8S, SHL-8D, SHL-5, and SHL-21. The groundwater at the northern end of the landfill drains toward an area of lower hydraulic head in the wetland north of the landfill. The hydraulic head in the wetland in turn is controlled by the level of Nonacoicus Creek below the dam, which receives discharge from the wetland. These relationships mean that the entire area of Shepley's Hill Landfill underlain by fill is a recharge area for the glacial overburden unconfined aquifer.

Whether the area of the landfill is a recharge area or discharge area for bedrock groundwater or is partly a recharge area and partly a discharge area for bedrock groundwater is unknown and cannot be determined on the basis of existing data. It is known that all leachate derived from contact with the landfill first enters the unconfined aquifer in the overburden and discharges in great part, or possibly in its entirety, to Plow Shop Pond or to the wetland area north of the landfill and then to Nonacoicus Creek.

1.6.3 Surface Water Hydrology

Most of the groundwater from underneath Shepley's Hill Landfill discharges to Plow Shop Pond. Some groundwater from the north end of the landfill discharges to a wetland north of the landfill, which in turn discharges to Nonacoicus Creek.

Because the water level in Plow Shop Pond is artificially raised by dams at the northwest and northeast corners, the surface water level is above the local groundwater at least at the north end of Shepley's Hill Landfill. The elevated surface water level results in water entering the pond bank and discharging into the wetland north of the landfill by going around the dam in the vicinity of wells SHL-13 and SHL-8 (see Figure 1-17). Because Plow Shop Pond receives the discharge of Grove Pond, it receives the accumulated flow of a series of ponds east of Grove Pond, as well as the flow of Bowers Brook and of Cold Spring Brook. This implies that Plow Shop Pond may receive contaminants from many sources other than Shepley's Hill Landfill, both on- and off-base.

1.6.4 Contaminant Distribution

1.6.4.1 Groundwater Contamination

The direction of flow of groundwater under Shepley's Hill Landfill implies that upgradient wells include SHL-1, SHL-2, SHL-6, and SHL-12. However, the 1986 investigation and well investigation shows that only SHL-2 and SHL-6 are completely outside the filled areas. All other wells are downgradient of part of the landfill. SHL-1 and SHL-2 have periodically gone dry. Possibly this is partly due to the covering of

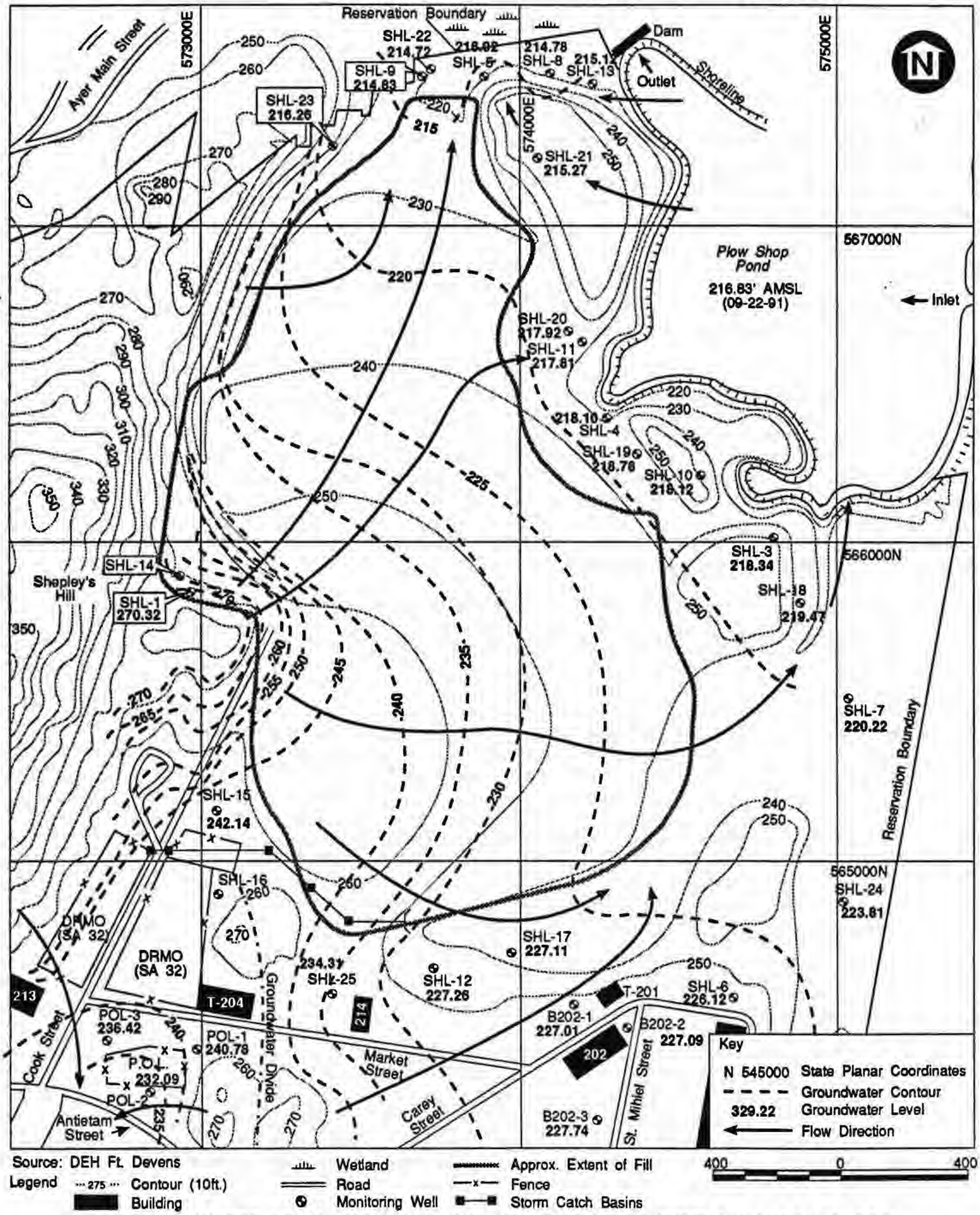

Figure 1-17 WATER LEVEL CONTOURS AT SHEPLEY'S HILL LANDFILL (12/12/91-12/13/91) 1ARI/Fig.1-17.CDR

the landfill with an impermeable cap, which reduces infiltration and hence results in a lowering of the water table.

The only complete set of samples, from both monitoring wells and BARCAD samplers installed in the first nine locations, was taken in March and April 1987. As shown on Table 1-7, the results for inorganics indicated that drinking water standards were exceeded for iron (13 wells or BARCADS), cadmium (4 wells or BARCADS), lead (6 wells or BARCADS), selenium (one BARCAD), arsenic, (one well and one BARCAD), and sodium (8 wells or BARCADS). The upgradient wells exceeded groundwater standards for iron (SHL-1), lead (SHL-1 and 1B), and sodium (SHL-1).

Detectable levels of organics (Table 1-8) were found in BARCAD samples at SHL-4, SHL-5, and SHL-8, all in the northern half of the landfill. Of the eight BARCAD samplers affected, five contained a trace of acetone, seven contained significant levels of benzene (8 to 23 micrograms per liter (µg/l), seven contained chloroform (1 to 3.9 µg/l), four contained toluene (1.6 to 3.3 µg/l), and all contained methylene chloride (3.2 to 9.3 µg/l), which may possibly be affected by laboratory contamination. A few hits of other compounds occurred. The only compound exceeding drinking water standards is benzene, which has a Maximum Contaminant Level (MCL) of 5 µg/l.

Wells SHL-5, SHL-8, and SHL-9 indicate that flow is leaving the landfill in a northerly direction and discharging to a wetland and to Nonacoicus Brook. In 1987, these wells exceeded drinking water standards for benzene, iron, cadmium, lead, and sodium, and the ambient water quality criterion for mercury. Data from six wells or BARCADS with several years of sampling results were tabulated. These included SHL-3 SHL-4, SHL-5, SHL-8, BARCAD No. 1 (SHL-8), and BARCAD No. 2 (SHL-8) (see Tables 1-9 through 1-14, respectively). The last two tables have results for 1987 and from 1990 and 1991, and are not from the original BARCADS. The first two BARCADS at Well No. 8 were not sampled after 1987, and a new well pair was installed in 1990 after Well No. 8 was destroyed by a fencing contractor. Since they were in the same location and at the same or similar depths, they are treated as equivalent, and listed on the same tables.

In general, the long-term trend in all these wells/BARCADS is that groundwater quality is improving. In March 1987, there were nine violations of drinking water standards at six sampling points, (for sodium, iron, cadmium, arsenic, and benzene). But by March 1991, or the last time any of the six points was sampled, there were only four violations of drinking water standards, three for iron and one for sodium. Mercury was non-detect in all cases.

1.6.4.2 Surface Water Contamination

Samples of surface water were taken at and around Shepley's Hill Landfill in March and April 1987 (Table 1-15). These showed elevated iron (0.42 milligrams per liter (mg/l) and 1.43 mg/l) near SHL-3 and near SHL-4, but levels of iron were also elevated "near the train

Table 1-7

**MONITORING WELL INORGANICS AND GENERAL PARAMETERS MARCH/APRIL 1987
SHEPLEY'S HILL LANDFILL (MG/L EXCEPT AS NOTED)**

SHL #	1A	–	2	3	4	–	–	5	–	–	–	–
SEA #	1	1B[1]	2	3	4	4B1	4B2	5	5B1	5B2	5B3	5B4
Depth to Water	6'7"	N/A[2]	22'8"	28'4"	10'4"	25'	N/A	2'6"	N/A	N/A	N/A	N/A
PARAMETERS												
pH (S.U.)[3]	6.08	6.24	10.4	7.61	6.24	7.52	N/A	5.63	6.22	6.87	7.33	6.72
Conductivity µmhos	79	56	340	300	310	530	N/A	61	210	910	1450	40
Hardness	28.1	40.9	235.4	62.5	92.5	190.7	N/A	58.7	160.7	186.6	178.7	422.6
Chlorides	6.1	9.2	48	5.62	15.8	71.1	N/A	16.4	22.0	53.7	33.7	24
TOC	74.0	6.4	229	175	30	28.0	160.0	534	69	69	31	3.3
TOX	1.0	1.0	<1.0	1.5	<1.0	1.0	20.5	4.1	<1.0	6.1	4.1	9.2
Iron	1.67*	0.24	<0.01	0.01	4.33*	0.14	1.42*	0.91*	8.75*	2.21*	30.61*	0.12
Cadmium	0.01	0.01	<0.01	0.01	0.02*	0.01	0.02*	0.03*	0.01	0.01	0.01	0.01
Chromium	0.01	<0.01	0.04	0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Lead	0.06*	0.33*	<0.01	0.01	<0.01	0.08*	0.07*	<0.01	0.04	0.03	0.24*	0.06*
Mercury (µg/l)	0.38	0.10	0.10	0.17	0.2	0.13	0.26	0.38	0.13	<0.10	0.16	0.10
Selenium	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.02*	<0.01
Arsenic	0.05	0.01	0.01	0.02	0.03	0.03	0.01	0.08*	0.05	<0.01	0.08*	0.01
Sodium	54.2*	0.08	11.5	46.2*	6.17	9.97	82.6*	5.31	8.9	27.9*	434*	9.13
°C	6	9	15	11	10	8	N/A	5	9	10	10	11

RC424

*Exceeds State or Federal drinking water standards

1 – BARCAD Sampler
2 – Not Available/Not Analyzed
3 – Standard Units
ND – Not Detected

Source: DEH Report Files, 1987

Table 1-7 (Cont.)

**MONITORING WELL INORGANICS AND GENERAL PARAMETERS MARCH/APRIL 1987
SHEPLEY'S HILL LANDFILL (MG/L EXCEPT AS NOTED)**

SHL #	6	7	8	–	1	9	–	–
SEA #	6	7	8	8B1[1]	8B2	9	9B1	9B2
Depth to Water	27'10"	18'2"	5'5"	N/A[2]	N/A	8'3"	N/A	N/A
PARAMETERS (cont)								
pH (S.U.)[3]	5.65	6.50	6.96	6.96	7.5	6.1	7.53	6.63
Conductivity (μmhos)	280	270	90	260	510	540	610	560
Hardness	64.2	132.4	68.8	106.3	76.5	185	271	214.9
Chlorides	47.2	32.7	8.7	14.8	52.1	12.8	59.3	29.14
TOC	7.3	20	61	24	3.2	106	6.0	9.1
TOX	<1.0	2.04	1.0	7.2	<1	<1	3.0	4.1
Iron	0.86*	1.2*	0.34*	6.3*	0.08	7.19*	0.13	8.74*
Cadmium	0.01	0.01	<0.01	0.01	<0.01	0.02*	0.01	0.01
Chromium	0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01
Lead	0.04	<0.01	<0.01	0.02	0.03	0.02	0.03	0.03
Mercury (μg/l)	0.10	0.12	0.10	<0.10	<0.10	0.27	0.13	0.10
Selenium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	0.02	0.04	0.02	0.01	0.01	0.03	0.01	0.02
Sodium	21.2*	13.0	259*	8.97	73.5*	7.07	38.4*	18.9
°C	13	12	6	11	11	10	8	12

RC424

*Exceeds State or Federal drinking water standards

1 – BARCAD Sampler
2 – Not Available/Not Analyzed
3 – Standard Units
ND – Not Detected

Source: DEH Report Files, 1987

Table 1-8

MONITORING WELL ORGANICS RESULTS MARCH/APRIL 1987
SHEPLEY'S HILL LANDFILL (μG/L)

SEA Sampler #	BARCAD #1	BARCAD #2	BARCAD #1	BARCAD #2	BARCAD #3	BARCAD #4	BARCAD #1	BARCAD #2
SEA Well #	WELL #4	WELL #4	WELL #5	WELL #5	WELL #5	WELL #5	WELL #8	WELL #8
SHL Location	SHL-4	SHL-4	SHL-5	SHL-5	SHL-5	SHL-5	SHL-8D	SHL-8D
PARAMETERS								
Acetone	Trace	ND	Trace	ND	Trace	ND	Trace	Trace
Benzene	9.0*	9.0*	11.0*	8.0*	23*	9.9*	12.0*	ND
Chlorobenzene	ND	ND	1.5	ND	ND	ND	ND	ND
Chloroform	2.0	ND	3.9	1.5	1.0	1.0	3.7	2.6
1,1-dichchloroethane	3.4	ND	ND	ND	ND	ND	ND	ND
1,1-trans-dichloroethene	ND	4.1	ND	ND	ND	ND	ND	ND
Methylene Chloride	6.1	6.3	7.8	5.3	9.3	7.7	3.3	3.2
Toluene	2.6	ND	3.3	ND	1.6	1.8	ND	ND
1,1,1-Trichloroethane	1.9	ND	ND	ND	ND	ND	ND	ND

RC424

ND - Not Detected
*Exceeds State or Federal drinking water standard

Source: DEH Report Files, 1987

Table 1-9

SELECTED ANALYTICAL RESULTS FOR WELL SHL-3
SHEPLEY'S HILL LANDFILL (μG/L ORGANICS, MG/L INORGANICS EXCEPT AS NOTED)

Month/Year	3/87	7/87	8/88	1/89	3/89	6/89	9/89	12/89	3/90	6/90	9/90	12/90	3/91
PARAMETERS													
Conductivity μmhos	300	80	90.5	N/A	160	63	200	47	86	58	4.1	36	N/A
Inorganics/General													
Chlorides	5.62	8.0	2.0	N/A	2.0	6.0	5.1	<0.25	2.5	ND	0.25	ND	N/A
TOC	175	<10	ND	N/A	3.7	2.9	3.5	<1	<1	<1	<1	<1	N/A
TOX	1.5	<0.5	NA	N/A	0.02	18	ND	0.024	0.035	0.02	<0.01	<0.01	N/A
Iron	0.01	1.12*	10.2*	7.0*	9.67*	5.47*	1.05*	2.5*	1.4*	0.89*	0.09	0.04	N/A
Cadmium	0.01	<0.01	ND	<0.03	ND	ND	ND	<0.001	<0.001	ND	0.001	<0.001	N/A
Lead	0.01	0.01	0.11*	<0.05	ND	0.98*	ND	NA	0.002	0.002	ND	ND	N/A
Mercury (μg/l)	0.17	<0.1	ND	<0.5	ND	ND	ND	<0.3	ND	ND	ND	ND	N/A
Arsenic	0.02	<0.01	ND	<0.01	ND	ND	ND	0.005	ND	ND	ND	ND	N/A
Sodium	46.2*	5.92	2.97	3.71	3.71	2.29	1.68	4.53	3.4	1.3	1.6	1.8	N/A
Organic													
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
1,1-dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
1,1-trans-dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
1,1,1-trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A

RC424

*Exceeds State or Federal drinking water standards
ND - Not Detected
N/A - Not Available/Not Analyzed

Source: DEH Report Files, 1991

Table 1-10

SELECTED ANALYTICAL RESULTS FOR WELL SHL-4
SHEPLEY'S HILL LANDFILL (µG/L ORGANICS, MG/L INORGANICS EXCEPT AS NOTED)

Month/Year	3/87	7/87	8/88	1/89	3/89	6/89	9/89	12/89	3/90	6/90	9/90	12/90	3/91
PARAMETERS													
Conductivity µmhos	310	1200	430	N/A	240	150	150	148	145	105	255	120	77
Inorganics/General													
Chlorides	15.8	66.6	15	N/A	4.0	5	15.4	3.75	ND	5.0	20	ND	1.8
TOC	3.0	<10	10.9	2.2	2.4	2.4	8.0	3.0	3.0	<1	8	3	2.0
TOX	<1	<0.5	ND	ND	0.07	0.06	0.049	0.004	<10	0.024	0.089	0.015	0.014
Iron	4.33*	1.32*	65.8*	363*	12.3*	32.8*	28.1*	22*	16*	15*	17	4.0*	7.3*
Cadmium	0.02*	0.01	ND	<0.03	ND	ND	ND	<0.001	ND	<0.001	ND	<0.001	ND
Lead	<0.01	0.06*	0.14*	<0.05	ND	ND	ND	N/A	0.004	0.006*	ND	ND	0.001
Mercury (µg/l)	0.2	0.28	ND	<0.5	ND	ND	ND	<3	ND	ND	ND	ND	0.3
Arsenic	0.03	0.03	0.56*	0.14*	0.12*	0.125*	ND	0.27*	0.09*	0.16*	0.04	0.006	0.014
Sodium	6.17	47.6*	12.4	14.91	10.4	4.3	5.94	17.3	5.1	6.3	4.0	3.2	2.4
Organic													
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-dichloroethane	ND	ND	2.0	ND	ND	ND	ND	ND	ND	ND	6	ND	ND
1,1-trans-dichloroethene	ND	ND	8.4	ND	ND	ND	ND	ND	ND	ND	37	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17*	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

RC424

*Exceeds State or Federal drinking water standard
ND - Not Detected
N/A - Not Available/Not Analyzed

Source: DEH Report Files, 1991

Table 1-11

SELECTED ANALYTICAL RESULTS FOR WELL SHL-5
SHEPLEY'S HILL LANDFILL (µG/L ORGANICS, MG/L INORGANICS EXCEPT AS NOTED)

Month/Year	3/87	7/87	8/88	1/89	3/89	6/89	9/89	12/89	3/90	6/90	9/90	12/90	3/91
PARAMETERS													
Conductivity µmhos	61	240	140	N/A	140	160	425	180	100	150	170	225	67
Inorganics/General													
Chlorides	16.4	5.0	4.0	N/A	4.0	6.0	10.3	<0.25	ND	ND	0.5	ND	0.75
TOC	534	15	ND	12	1.7	2.1	19	17	10	14	21	12	18
TOX	4.1	3.98	N/A	ND	0.025	0.024	0.044	0.005	<0.01	0.027	0.052	0.018	0.026
Iron	0.91*	3.12*	7.75*	17.9*	1.87*	5.87*	5.75*	4.5*	3.0*	0.73*	7.0*	4.6*	2.7*
Cadmium	0.03*	0.03*	ND	<0.03	ND	ND	ND	<0.001	ND	ND	ND	0.002	ND
Lead	<0.01	0.03	0.16*	<0.05	ND	ND	ND	N/A	ND	0.001	ND	ND	ND
Mercury (µg/l)	0.38	<0.1	ND	<0.5	ND	ND	ND	<0.3	ND	0.6	ND	ND	ND
Arsenic	0.08*	0.03	N/A	0.02	ND	ND	ND	0.007	ND	ND	0.02	ND	ND
Sodium	5.31	7.2	49.1*	3.59	1.48	1.87	1.28	3.8	1.2	1.5	1.8	1.5	1.2
Organic													
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-trans-dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

RC424

*Exceeds State or Federal drinking water standards
ND - Not Detected
N/A - Not Available/Not Analyzed

Source: DEH Report Files, 1991

Table 1-12

SELECTED ANALYTICAL RESULTS FOR WELL SHL-8
SHEPLEY'S HILL LANDFILL (µG/L ORGANICS, MG/L INORGANICS EXCEPT AS NOTED)

Month/Year	3/87	7/87	8/88	1/89	3/89	6/89	9/89	12/89	3/90	6/90	9/90	12/90	3/91
PARAMETERS													
Conductivity µmhos	30	82	90	ND	64	90	175	N/A	N/A	N/A	N/A	N/A	N/A
Inorganics/General													
Chlorides	8.7	<0.1	4.0	N/A[1]	ND[2]	4.0	5.1	N/A	N/A	N/A	N/A	N/A	N/A
TOC	61	<10	ND	2.7	ND	ND	3.0	N/A	N/A	N/A	N/A	N/A	N/A
TOX	1.0	<0.5	N/A	ND	0.003	0.003	0.017	N/A	N/A	N/A	N/A	N/A	N/A
Iron	0.34*	0.78*	14.4*	22.1*	1.41*	0.73*	2.97*	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	<0.01	<0.01	ND	<0.03	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Lead	<0.01	<0.01	0.09*	<0.05	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Mercury (µg/l)	0.1	<0.1	ND	<0.5	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	0.02	<0.01	N/A	0.015	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	2.59	4.73	14.8	4.2	2.47	3.67	2.65	N/A	N/A	N/A	N/A	N/A	N/A
Organic													
Acetone	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
1,1-dichloroethane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
1,1-trans-dichloroethene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Toluene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
1,1,1-trichloroethane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	N/A	N/A	N/A	N/A	N/A	N/A
								well destroyed					

RC424

* Exceeds State or Federal drinking water standards
ND - Not Detected
N/A - Not Available/Not Analyzed

Source: DEH Report Files, 1991

Table 1-13

SELECTED ANALYTICAL RESULTS FOR WELL SHL-8 BARCAD #1 AND SHL-8 DEEP (FROM 03/90)
SHEPLEY'S HILL LANDFILL (µG/L ORGANICS, MG/L INORGANICS EXCEPT AS NOTED)

Month/Year	3/87	7/87	8/88	1/89	3/89	6/89	9/89	12/89	3/90	6/90	9/90	12/90	3/91
PARAMETERS													
Conductivity µmhos	260	198	N/A	N/A	N/A	N/A	N/A	N/A	127	100	84	135	81
Inorganics/General													
Chlorides	14.8	8.9	N/A	N/A	N/A	N/A	N/A	N/A	7.0	6.8	6.0	1.5	6.0
TOC	24	<10	N/A	N/A	N/A	N/A	N/A	N/A	7.0	<1	<1	<1	2.0
TOX	7.2	1.8	N/A	N/A	N/A	N/A	N/A	N/A	<0.01	0.022	0.025	0.021	<0.01
Iron	6.3*	0.1	N/A	N/A	N/A	N/A	N/A	N/A	1.4*	0.25	0.06	0.06	0.03
Cadmium	0.01	<0.01	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	ND	ND	<0.001	ND
Lead	0.02	<0.01	N/A	N/A	N/A	N/A	N/A	N/A	ND	0.001	ND	ND	ND
Mercury (µg/l)	<0.1	<0.1	N/A	N/A	N/A	N/A	N/A	N/A	ND	0.5	ND	ND	ND
Arsenic	0.01	<0.01	N/A	N/A	N/A	N/A	N/A	N/A	ND	0.007	ND	ND	ND
Sodium	8.97	7.87	N/A	N/A	N/A	N/A	N/A	N/A	8.0	2.8	6.3	6.2	5.0
Organic													
Acetone	Trace	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Benzene	12*	7.7*	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Chloroform	3.7	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
1,1-dichloroethane	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
1,1-trans-dichloroethene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Toluene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
1,1,1-trichloroethane	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Methylene chloride	3.3	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND

RC424

*Exceeds State or Federal drinking water standards
ND - Not Detected
N/A - Not Available/Not Analyzed

Source: DEH Report Files, 1991

Table 1-14

**SELECTED ANALYTICAL RESULTS FOR SHL-8 BARCAD #2 AND SHL-8 SHALLOW (FROM 03/90)
SHEPLEY'S HILL LANDFILL (µG/L ORGANICS, MG/L INORGANICS EXCEPT AS NOTED)**

Month/Year	3/87	7/87	8/88	1/89	3/89	6/89	9/89	12/89	3/90	6/90	9/90	12/90	3/91
PARAMETERS													
Conductivity µmhos	610	160	N/A	N/A	N/A	N/A	N/A	N/A	148	115	145	85	N/A
Inorganics/General													
Chlorides	59.3	8.9	N/A	N/A	N/A	N/A	N/A	N/A	2.75	3.0	4.3	2.5	N/A
TOC	6.0	<10	N/A	N/A	N/A	N/A	N/A	N/A	2.0	<1	1	<1	<1
TOX	3.0	<0.5	N/A	N/A	N/A	N/A	N/A	N/A	<0.01	0.031	0.013	0.015	0.012
Iron	0.13	0.13	N/A	N/A	N/A	N/A	N/A	N/A	0.71*	0.34*	0.11	0.04	0.05
Cadmium	0.01	<0.01	N/A	N/A	N/A	N/A	N/A	N/A	0.95*	<0.001	ND	0.003	ND
Lead	0.03	<0.01	N/A	N/A	N/A	N/A	N/A	N/A	0.001	0.004	ND	0.001	ND
Mercury (µg/l)	0.13	<0.1	N/A	N/A	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Arsenic	0.01	<0.01	N/A	N/A	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Sodium	38.4*	18.6	N/A	N/A	N/A	N/A	N/A	N/A	8.8	5.8	5.8	6.4	5.1
Organic													
Acetone	Trace	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Benzene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Chloroform	2.6	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
1,1-dichloroethane	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
1,1-trans-dichloroethene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Toluene	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
1,1,1-trichloroethane	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND
Methylene chloride	3.2	ND	N/A	ND	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND

RC424

*Exceeds State or Federal drinking water standards
ND - Not Detected
NA - Not Available/Not Analyzed

Source: DEH Report Files, 1991

Table 1-15

SURFACE WATER SAMPLING RESULTS MARCH 1987
SHEPLEY'S HILL LANDFILL (MG/L EXCEPT AS NOTED)

	Culvert at SHL-2	Plow Shop Pond nr SHL-3	Ditch nr SHL-7	Plow Shop Pond nr Train Trestle	Plow Shop Pond nr SHL-4	Plow Shop Pond at Spillway	Runoff nr SHL-5	Runoff nr SHL-9	Runoff Off Post	Swamp Off Post
PARAMETERS										
pH (S.U.)	6.95	6.27	7.10	6.47	6.23	6.29	6.85	6.67	6.65	6.52
Conductivity (μmhos)	23	175	9	175	185	155	28.5	21	220	200
Hardness	10.1	40.5	7.49	31.4	34.6	46.6	15.9	15.2	29.4	32.4
Chlorides	18.4	24.0	4.6	34.2	30.67	35.8	4.6	15.8	34.8	35.3
TOC	12.3	2.0	2.6	3.5	3.5	1.4	14.0	18.0	4.1	5.3
TOX	1.0	2.05	<0.1	1.0	13.3	<1.0	<1.0	<1.0	<1.0	<1.0
Iron	0.19	0.42*	0.16	0.25	1.43*	0.36*	0.37*	0.29	0.34*	0.30
Cadmium	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01
Chromium	0.01	0.01	0.01	0.02	0.02	0.01	<0.01	0.01	0.01	0.01
Lead	<0.1	<0.01	0.08*	<0.01	<0.01	0.08*	0.02	<0.01	<0.01	<0.01
Mercury (μg/l)	0.16	0.10	0.16	0.16	0.10	0.10	<0.10	0.10	0.20	0.13
Selenium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01
Sodium	4.79	13.1	3.65	14.3	11.7	14.4	2.06	1.35	14.9	13.7
°C	9	12	8	7	7	4	3	1	2	6

RC424

Note: Wells identified to current Shepley's Hill Landfill well numbers.
*Exceeds State or Federal drinking water standards

Source: DEH Files, Briggs, 1987

trestle" (0.25 mg/l), and at the spillway (0.36 mg/l). Lead exceeded drinking water standards at the spillway. These results imply that other sources of contamination may contribute to Plow Shop Pond, since these levels exceed those observed in the pond adjacent to the landfill. Samples taken in July, presumably from some of the same locations although they are not identified in a consistent manner, show sharply elevated pH, increased hardness, and increased sodium. TOC was notably higher at the sluiceway (spillway) of Plow Shop Pond, but not elsewhere (see Appendix V).

1.6.4.3 Sediment and Soils Contamination

No soil sampling has been performed for chemical analysis at Shepley's Hill Landfill, therefore, there are no data on the potential sources and types of contaminants either from soils to the environment or to soils from the fill materials deposited in the landfill.

Again, no sediments from areas potentially affected by the landfill have been sampled and analyzed, so no data exist on the source and type of contaminants from the sediments to surface water, or of contaminants potentially accumulating in the sediments from run-off or groundwater discharge.

1.6.4.4 Air Quality

There are no data on air quality upwind and downwind of the landfill to indicate that the landfill is or is not contributing significant levels of contaminants to the air. Since parts of the landfill are capped and vented, they are emitting methane and probably carbon dioxide as well.

1.7 RESULTS OF PREVIOUS INVESTIGATIONS AT COLD SPRING BROOK LANDFILL

1.7.1 Soils and Geology

Soils adjoining the Cold Spring Brook Landfill include areas of Ninigret fine sandy loam (to the east), Quonset loamy sand (to the south and west), and Hinkley sandy loam (to the southwest). The former wetland into which the landfill was extended was probably an area of Freetown muck soil, similar to the wetland in the Magazine Area a few hundred feet west of the landfill, but this area was largely covered with water and not mapped at the time of the soil survey (USDA 1985). The surface soils on the landfill itself are sandy and most probably come from the excavated area of Quonset soil across Patton Road to the south.

The geology, as indicated on the Ayer Quadrangle (Jahns 1952), consists of sandy glacial outwash. This is confirmed by most of the borings for monitoring wells (Fox 1988b), which showed coarse to fine grained sand interbedded with fine to coarse gravel. Exceptions were CSB-4 and CSB-5, which were within the peat wetland immediately north of the fill, and were installed in organic soil, silt, sand, and clay. This probably represents the sediment filling a former kettle hole pond.

1.7.2 Groundwater Hydrology

The existing data suggest that two monitoring wells (CSB-4 and CSB-5) were not only screened in different types of sediment than the other wells, but show different water quality (See 1.7.4.1 below). Because CSB-4 shows a markedly higher hydraulic head (greater than 244 feet AMSL), when compared to the other wells on most rounds of groundwater level measurements (Table 1-16), it appears that it is showing the effect of a mounded water table within the landfill at its western end. This mound implies increased infiltration and/or an underlying layer of low hydraulic conductivity in this area. Discharge from this mounded water table into the pond could account for the similar water quality in CSB-4 and CSB-5, both of which show elevated levels of arsenic.

This implies that the water quality in wells CSB-4 and CSB-5 is representative of a low hydraulic conductivity zone which is not part of the aquifer from which the Patton Well is pumping. Any future water supply well will also withdraw from the sand and gravel aquifer, rather than from the shallow silty layer monitored by CSB-4 and CSB-5. The water from this layer is discharging either into the underlying aquifer or the adjoining pond.

The survey of the wells and the pond elevation during the latest investigation has shown that the pond surface elevation is between 241 and 242 feet AMSL. This differs sharply from the elevation implied by the Fort Devens base map, which showed the former wetland now occupied by the pond as having a surface elevation of between 245 and 250 feet AMSL. Apparently a contour was omitted from the map during surveying or during the preparation of the map, leading to the erroneous conclusion that the pond surface had to lie above the 245 foot contour and below the 250 foot contour. This implies that the groundwater around the pond can, and does, drain toward it from most directions. Only CSB-2 appears to show groundwater elevations lower than the surface of the pond. However, because the pond fluctuates in surface elevation with changes in the balance of inflow and leakage through the partially blocked culvert that drains the pond, and also because the surface elevations were not measured at the same time as the groundwater elevations, this cannot be unequivically asserted for the data shown in Table 1-16 (see Table 3-12 for comparison). Since this well is closest to the Patton Well, it is assumed that flow from the area around CSB-2 goes toward the Patton Well when it is pumping.

Groundwater flow contours for the highest and lowest levels of groundwater head as measured between August 1989 and June 1990 are shown on Figures 1-18 and 1-19, respectively. The implications of these contours are that flow from the west end of the landfill goes both toward the Patton Well and to the pond. Flow from the east end of the landfill goes to the pond only. Upgradient wells (not affected by the

Table 1-16

WATER TABLE ELEVATIONS AT COLD SPRING BROOK LANDFILL
(AUGUST 1989 - JULY 1990)

Date	Well CSB-1	Well CSB-2	Well CSB-3	Well CSB-4	Well CSB-5	Well CSB-6	Well CSB-7	Well CSB-8
8/22/89*	241.86	240.80	241.10	244.46	241.80	241.51	241.15	241.66
10/27/89	242.72	241.24	241.39	244.40	241.81	242.69	243.76	242.60
12/1/89	242.56	241.79	241.74	244.32	242.32	242.75	243.47	242.61
12/19/89	242.22	241.56	241.78	244.31	242.00	242.19	242.36	242.50
1/23/90	241.83	241.39	241.36	243.82	241.64	241.62	241.61	241.83
2/26/90	242.79	242.33	242.41	244.26	242.29	242.82	244.43	243.03
4/17/90	242.94	242.91	243.20	244.19	242.55	243.06	244.65	243.99
5/31/90**	243.47	243.33	243.66	244.30	242.88	243.29	244.54	244.31
6/29/90	243.08	242.88	243.13	244.05	242.63	242.73	242.62	243.47
7/24/90	242.41	242.10	242.51	244.04	242.45	242.45	241.43	242.73
Range (Feet)	1.61	2.53	2.56	0.64	1.24	1.78	3.50	2.65

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Note: Water table elevations are listed at feet above mean sea level
*Low Level of Groundwater 8/22/89
**High Level of Groundwater 5/31/90

Source: DEH Report Files, 1991

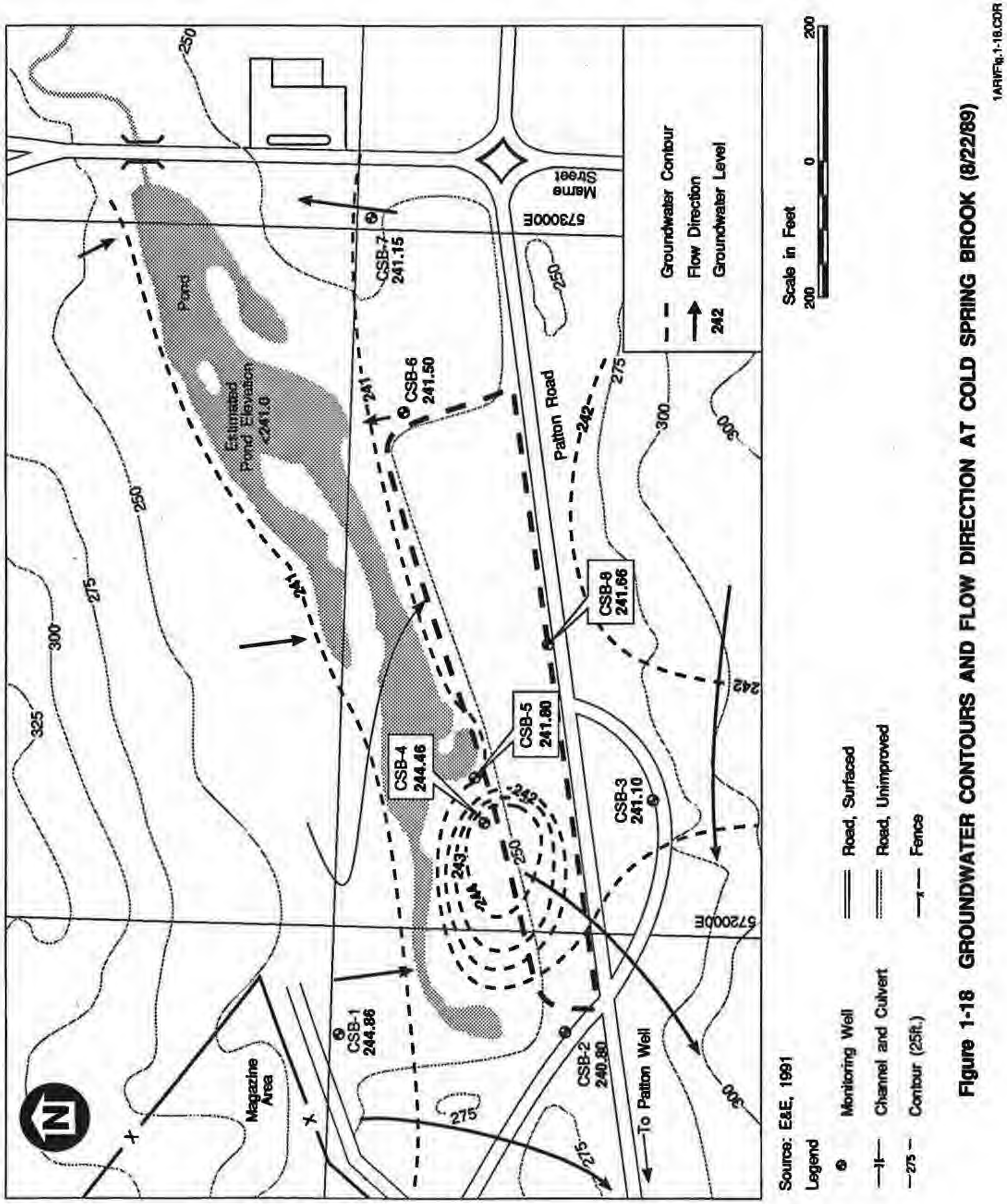

Figure 1-18 GROUNDWATER CONTOURS AND FLOW DIRECTION AT COLD SPRING BROOK (8/22/89)

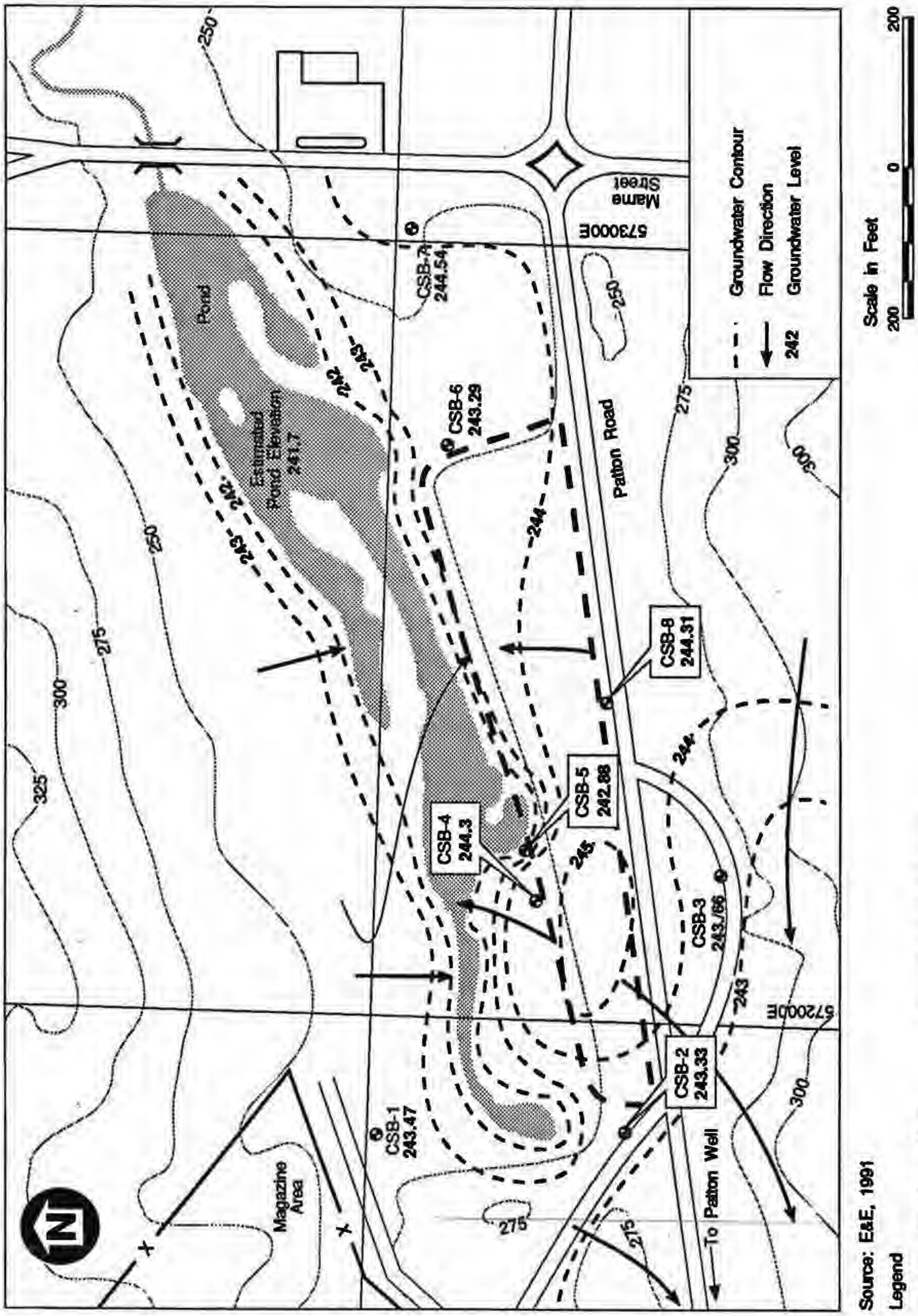

Figure 1-19 GROUNDWATER CONTOURS AND FLOW DIRECTION AT COLD SPRING BROOK (5/31/90)

landfill), are therefore CSB-1 and CSB-7. All other wells may be affected by flow originating partly in the landfill.

1.7.3 Surface Water Hydrology

The only surface water affected by the landfill is the immediately adjacent pond and Cold Spring Brook, which is a tributary to Bowers Brook, Grove Pond, Plow Shop Pond, Nonacoicus Brook, and the Nashua River.

1.7.4 Contaminant Distribution

1.7.4.1 Groundwater Contamination

The analytical results for metals in groundwater from 23 August 1989 through 25 July 1990 show fluctuating and erratic results (Table 1-17). During five quarters of sampling, arsenic exceeded the drinking water standard twice in each of two wells, CSB-3 and CSB-5, and was elevated in CSB-4 compared to background. Cadmium exceeded the drinking water standard by a wide margin during one sampling event only in three wells, one of which is unaffected by the landfill (CSB-1). Chromium exceeded the drinking water standard once in one well, CSB-3.

During the first two quarters of 1991, arsenic exceeded the drinking water standard twice in the same well, CSB-5 (see Table 1-18). All other wells meet the drinking water standards for the eight metals tested: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. All samples were filtered in the field when sampled. The Patton Well has not shown metals levels in excess of MCLs.

1.7.4.2 Surface Water Contamination

In March 1988, AEHA conducted limited surface water sampling among corroded drums resting in the edge of the pond at the foot of the landfill near Well CSB-5.

Maximum concentrations of three priority pollutant organics recorded were: 1,1,1 trichloroethene (18.4 μg/l), bromoform (32,200 μg/l), and 1,2 dichloroethane (7.2 μg/l). Their respective MCLs for drinking water are 0.2 mg/l, 0.1 mg/l, and 0.005 mg/l.

On 12 April 1988, four surface water samples were taken in the same area of corroded drums. The samples showed elevated levels of arsenic, selenium, and silver. The levels of selenium and silver exceeded their respective chronic ambient water quality criteria (AWQC) of 10 μg/l and 0.12 μg/l.

On 19 April 1988, four surface water samples from below the landfill were collected and analyzed for volatile organics. None was detected.

Table 1-17

SUMMARY OF PREVIOUS GROUNDWATER SAMPLING RESULTS
AT COLD SPRING BROOK LANDFILL (METALS ANALYSIS mg/L)

Element	Sample Date	CSB-1	CSB-2	CSB-3	CSB-4	CSB-5	CSB-6	CSB-7	CSB-8
	08-23-89	ND	ND	ND	ND	ND	ND	ND	ND
	10-27-89	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SILVER	01-24-89	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
	04-18-90	ND	ND	ND	ND	ND	ND	ND	ND
	07-25-90	ND	ND	ND	ND	ND	ND	ND	ND
	08-23-89	ND	ND	0.088	0.038	0.171	ND	ND	ND
	10-27-89	<.0027	0.003	0.007	0.028	0.034	0.0028	0.0032	0.0093
ARSENIC	01-24-89	<.0053	<.0053	0.8200	0.0175	0.0906	<.0053	<.0053	<.0053
	04-18-90	ND	ND	.0075	0.017	0.032	ND	0.0059	ND
	07-25-90	.0063	ND	ND	0.023	0.27	ND	ND	ND
	08-23-89	.010	.009	.077	.012	.009	.003	.007	.057
	10-27-89	0.1	0.1	0.2	0.1	0.1	<0.1	<0.1	0.3
BARIUM	01-24-89	<.05	<.05	0.31	<.05	<.05	<.05	<.05	0.11
	04-18-90	ND	ND	0.07	ND	ND	ND	ND	0.09
	07-25-90	ND	0.02	ND	ND	ND	ND	0.05	0.12
	08-23-89	ND	ND	ND	ND	ND	ND	ND	ND
	10-27-89	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
CADMIUM	01-24-89	<.00042	<.00042	<.00042	<.00042	<.00042	<.00042	<.00042	<.00042
	04-18-90	ND	.00055	ND	ND	ND	ND	ND	ND
	07-25-90	0.67	ND	ND	1.4	0.84	ND	ND	ND
	08-23-89	ND	ND	.033	ND	ND	ND	ND	ND
	10-27-89	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
CHROMIUM	01-24-89	<.0032	.0054	0.26	.0076	.0046	<.0032	<.0032	<.0032
	04-18-90	ND	ND	0.026	.0035	ND	0.0087	.0054	0.015
	07-25-90	ND	ND	ND	ND	ND	ND	ND	ND
	08-23-89	ND	ND	ND	ND	ND	ND	ND	ND
	10-27-89	<.0003	<.0003	<.0003	<.0003	<.0003	<.0003	<.0003	<.0003
MERCURY	01-24-89	<.0003	<.0003	<.0003	<.0003	<.0003	<.0003	<.0003	<.0003
	04-18-90	ND	ND	ND	ND	ND	ND	ND	ND
	07-25-90	ND	ND	ND	ND	ND	ND	ND	ND

RC424

Note: Underlining (___) indicates that result exceeds drinking water standard.

NA: Not Analyzed
ND: Not Detected (Detection limit not provided in report)

Source: DEH Files

Table 1-17 (Cont.)

SUMMARY OF PREVIOUS GROUNDWATER SAMPLING RESULTS AT COLD SPRING BROOK LANDFILL (METALS ANALYSIS mg/L)

Element	Sample Date	CSB-1	CSB-2	CSB-3	CSB-4	CSB-5	CSB-6	CSB-7	CSB-8
	08-23-89	ND	.007	.049	ND	.010	ND	ND	.008
	10-27-89	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
LEAD	01-24-89	<.0013	<.0013	.0180	<.0013	<.0013	<.0013	<.0013	<.0013
	04-18-90	ND	ND	.011	ND	ND	.0052	.0040	.0098
	07-25-90	ND	ND	ND	ND	ND	ND	ND	ND
	08-23-89	ND	ND	ND	ND	ND	ND	ND	ND
	10-27-89	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
SELENIUM	01-24-89	<.0015	<.0015	<.0015	<.0015	<.0015	0.0015	.0028	.0035
	04-18-90	ND	ND	ND	ND	ND	ND	ND	ND
	07-25-90	ND	ND	ND	ND	ND	ND	ND	ND

RC424

Note: Underlining (___) indicates that result exceeds drinking water standard.

NA: Not Analyzed
ND: Not Detected (Detection limit not provided in report)

Source: DEH Files

Table 1-18

GROUNDWATER WATER-WELLS ANALYSES FOR METALS (μG/L)
COLD SPRING BROOK LANDFILL (JANUARY/APRIL 1991)

		Cold Spring Brook Well # and date of sampling (Month/Year)																	
	Limit of	1		2		3		4		5		6		7		8		Field Blank	
Parameter	Detection	1/91	4/91	1/91	4/91	1/91	4/91	1/91	4/91	1/91	4/91	1/91	4/91	1/91	4/91	1/91	4/91	1/91	4/91
Arsenic	5	-	-	-	-	-	-	-	21	110	140	-	-	-	-	-	-	-	-
Barium*	20/50	-	-	-	-	20	-	-	-	20	-	-	-	-	-	130	60	-	-
Cadmium	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury	0.3	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Selenium	3	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver*	20/50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

RC424

*Note: Limits of detection changed from 20 to 50 for 4/91 sampling.
- Below limit of detection.

Source: DEH Report Files, 1991

The precise locations of the samples collected by AEHA were not noted in their report nor was their rationale for choice of analytes. No alternative sources of information have been located.

1.7.4.3 Sediment and Soils Contamination

The AEHA took five sediment samples from the pond just at the foot of the landfill on 12 April 1988 and analyzed them for metals. No unusually elevated levels were noted. Of three sediment and seven soil samples taken on 19 April 1988 and analyzed for volatile organics, only two sediment samples showed detectable levels (3.3 and 1.7 mg/l of 1,1-dichloroethene).

The precise locations of the samples collected by AEHA were not noted in their report nor was their rationale for choice of analytes. No alternative sources of information have been located.

SHEPLEY'S HILL LANDFILL

COLD SPRING BROOK LANDFILL

2. FIELD ACTIVITIES

In this section, E & E describes the field procedures used to perform the RI at Shepley's Hill Landfill and at Cold Spring Brook Landfill. Included for each site are procedures for installing and abandoning wells; developing wells; boring into soil; collecting samples of soil, surface water, sediment, groundwater, and air; and conducting the ecological assessment. The quality control (QC) procedures followed for both sites are described in Section 2.3.

2.1 SHEPLEY'S HILL LANDFILL

2.1.1 Well Abandonment

Under the RI at Shepley's Hill Landfill, five groundwater monitoring wells were abandoned or permanently closed. Figure 2-1 shows the locations of these five former wells, which are listed below:

- SHL-1, (formerly identified as BAR-1) a BARCAD well, overdrilled and grouted to ground surface;
- SHL-2, (formerly identified as BAR-2) a BARCAD well, overdrilled and grouted to ground surface;
- SHL-2, (formerly identified as WT2) grouted to ground surface;
- SHL-3, (formerly identified as BAR-3) a BARCAD well, permanently closed with a locked cap; and
- SHL-5 (formerly identified as BAR-5) a BARCAD well, overdrilled and grouted to ground surface.

In addition, well SHL-1A was to be abandoned if it could not be repaired. This well has been repaired and the integrity of the well re-established. Table 2-1 presents a complete listing of Shepley's Hill Landfill well names and aliases.

Normally, wells to be abandoned are grouted with the well-screen and casing in place after the protective casing and riser have been cut off at ground level and removed. Because three of the BARCAD type wells (BAR-1, BAR-2, and BAR-5) did not have well casings below the well pad, they were over-drilled using hollow-stem augers. The resulting boreholes were then grouted to ground surface following USATHAMA guidelines for borehole abandonment. All original records on well abandonment were sent to USATHAMA.

As required, the water and bentonite used for abandonment was approved by USATHAMA prior to operations. Representative samples were provided to the Fort Devens Directorate of Engineering and Housing (DEH). Construction materials were approved by the National Sanitation Foundation/American Society for Testing and Materials (NSF/ASTM). The

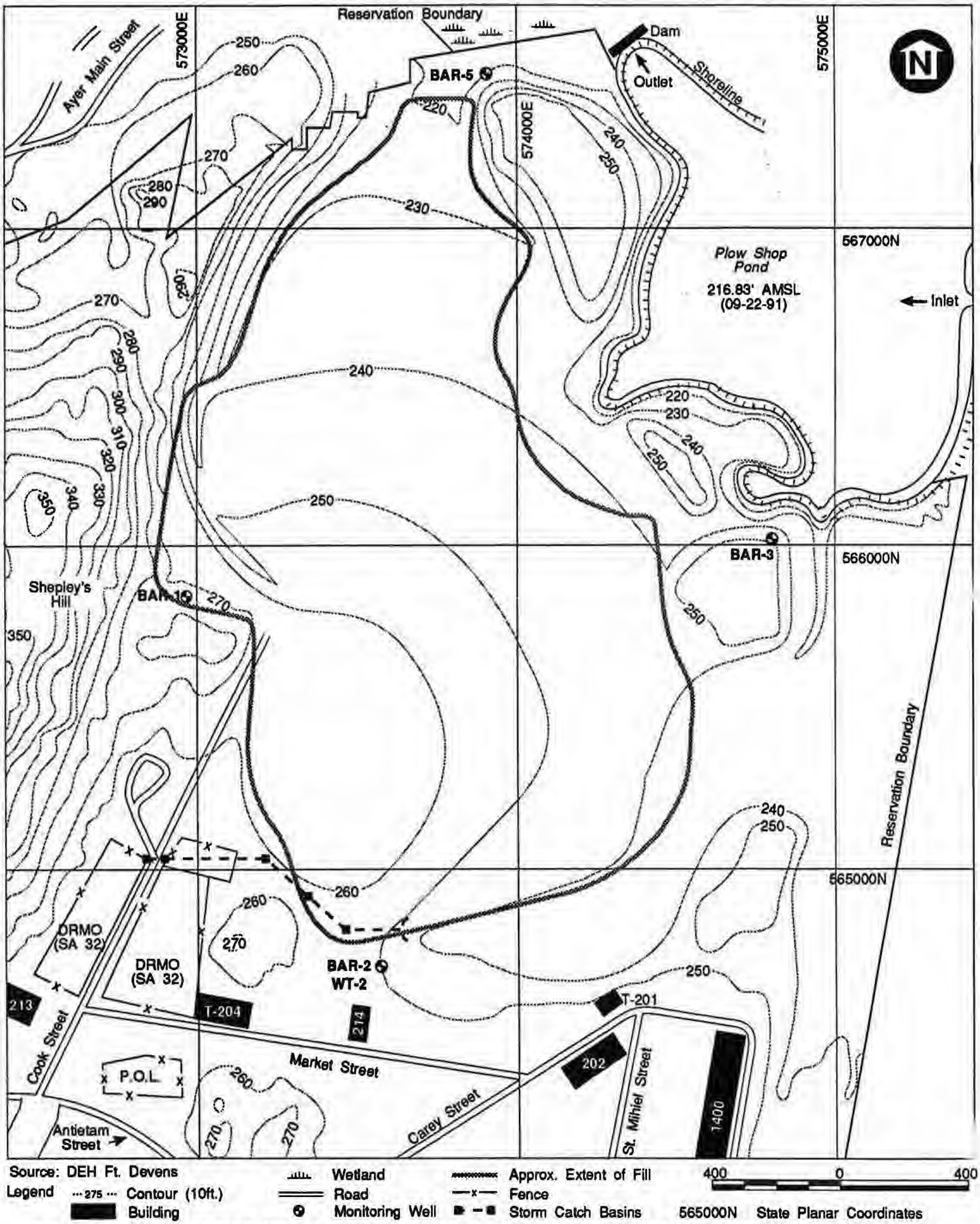

Figure 2-1 SHEPLEY'S HILL LANDFILL WELLS TO BE ABANDONED OR PERMANENTLY CLOSED

SHL2.CDR

Table 2-1

WELL IDENTIFICATION TABLE FOR SHEPLEY'S HILL LANDFILL

Location	SEA[1]	CONTEST[2]	E & E[3]	Status
SHL-1	BAR-1			Abandoned on 7/15/91[4]
SHL-1	WT-1/SHL-1A			Operational
SHL-2	WT-2/BAR-2A			Abandoned on 7/17/91[5]
SHL-2	BAR-2			Abandoned on 7/18/91[4]
SHL-3	WT-3			Operational
SHL-3	BAR-3			Closed with locked cap[4]
SHL-4	WT-4/BAR-4			Operational[5]
SHL-5	WT-5			Operational
SHL-5	BAR-5			Abandoned on 7/23/91[4]
SHL-6	WT-6			Operational
SHL-7	WT-7			Operational
SHL-8	WT-8/BAR-8			Destroyed and replaced by SHL-8S/D[5]
SHL-8S		SHL-8S		Operational (Shallow)
SHL-8D		SHL-8D		Operational (Deep)
SHL-9	WT-9/BAR-9			Operational[5]
SHL-10		N-1		Operational
SHL-11		N-2		Operational
SHL-12		N-3		Operational
SHL-13		N-4		Destroyed and replaced
SHL-15			SHL-15	Operational
SHL-17			SHL-17	Operational
SHL-18			SHL-18	Operational
SHL-19			SHL-19	Operational
SHL-20			SHL-20	Operational
SHL-21			SHL-21	Operational
SHL-22			SHL-22	Operational
SHL-23			SHL-23	Operational
SHL-24			SHL-24	Operational
SHL-25			SHL-25	Operational
POL-1				Operational
POL-2				Operational
POL-3				Operational

RC424

(1) Wells constructed by SEA Inc., in 1986
(2) Wells, including replacements, constructed by CONTEST in 1989
(3) Wells constructed by Ecology and Environment, Inc. in 1991
(4) BARCAD wells
(5) Hybrid: Wells that have a BARCAD unit in place below a regular well

Source: E & E, 1991

USATHAMA-approved water source for the project was Fort Devens production well D-1, located on the South Post.

Over-drilling was accomplished using hollow-stem augers. The only lubricant used on the drilling augers was Teflon tape.

Grouting was accomplished through a tremie pipe lowered to the bottom of the zone to be grouted. The grout was composed by weight of 20 parts Portland cement, Type II or Type V, and 1 part bentonite. A maximum of 8 gallons of water was used per 94-pound bag of cement. Tremie pipes were constructed of rigid polyvinyl chloride (PVC).

Investigation-derived materials showing evidence of contamination, either visually or by readings greater than 10 ppm on the organic vapor analyzer (OVA) or HNu Photoionization detector (HNu), were placed in 55-gallon drums and stored in a secured area pending recommendation for proper disposal.

2.1.2 **Monitoring Well Installation**

Twelve new monitoring wells were proposed for Shepley's Hill Landfill under the RI program (see Table 2-2). These included nine shallow wells screened just across the water table and three relatively deep wells screened just above the bedrock. Deep well locations were at SHL-20, SHL-22, and SHL-24 (see Figure 2-2). At two of the proposed well locations, SHL-14 and SHL-16, boreholes encountered bedrock before intercepting an aquifer. As a result, only ten wells were installed at the landfill during the RI. All wells were constructed according to USATHAMA geotechnical requirements.

As required, the water, sand, and bentonite used for well installation was approved by USATHAMA prior to the drilling operation. Representative samples were provided to the Fort Devens Directorate of Engineering and Housing (DEH). The USATHAMA-approved water source for the project was Fort Devens production well D-1, located on the South Post.

Drilling was accomplished through hollow-stem augers. Geotechnical soil samples were collected using split spoons at 5-foot intervals. The collected soil samples were used for lithologic descriptions only and representative samples were saved and provided to the Fort Devens DEH. The only lubricant used on the drilling augers was Teflon tape.

When a borehole for a shallow well encountered water above bedrock, the well was then constructed and developed to USATHAMA specifications. When rock was encountered before water was found, the driller then cored the rock for 15 feet to ensure that it was bedrock before grouting the hole to ground surface and abandoning it. Two further boreholes were then drilled to bedrock in the same general vicinity to explore for possible deeper pockets of overburden. In cases where all three boreholes were dry at refusal, the holes were grouted to ground surface and abandoned.

Table 2-2

SHEPLEY'S HILL LANDFILL
RATIONALE FOR PROPOSED LOCATION OF WELLS

Well Number	Rationale
SHL-14	To replace SHL-1 (dry well) if possible; in an upgradient location. (Aquifer not encountered during attempted installation.)
SHL-15	An additional upgradient well between DRMO and the landfill; drilled to bedrock.
SHL-16	An additional upgradient well between DRMO and the landfill; drilled to bedrock. (Aquifer not encountered during attempted installation.)
SHL-17	To fill the gap between SHL-2 or its replacement and SHL-6; water table well; upgradient.
SHL-18	To fill the gap between SHL-7 and SHL-3; water table well; downgradient.
SHL-19	To fill the gap between SHL-10 and SHL-4; water table well; downgradient.
SHL-20	To determine vertical hydraulic gradient and vertical distribution of contamination in conjunction with SHL-11.
SHL-21	To fill the gap between SHL-11 and SHL-13; water table well; downgradient.
SHL-22	To determine vertical hydraulic gradient and vertical distribution of contamination in conjunction with SHL-9.
SHL-23	To determine aquifer thickness and water quality at north end of landfill in an upgradient direction.
SHL-24	To determine depth of bedrock and ground water quality in base of aquifer at south end of landfill.
SHL-25	Replaced SHL-2 upgradient well at south end of landfill.

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Source: E & E, 1991

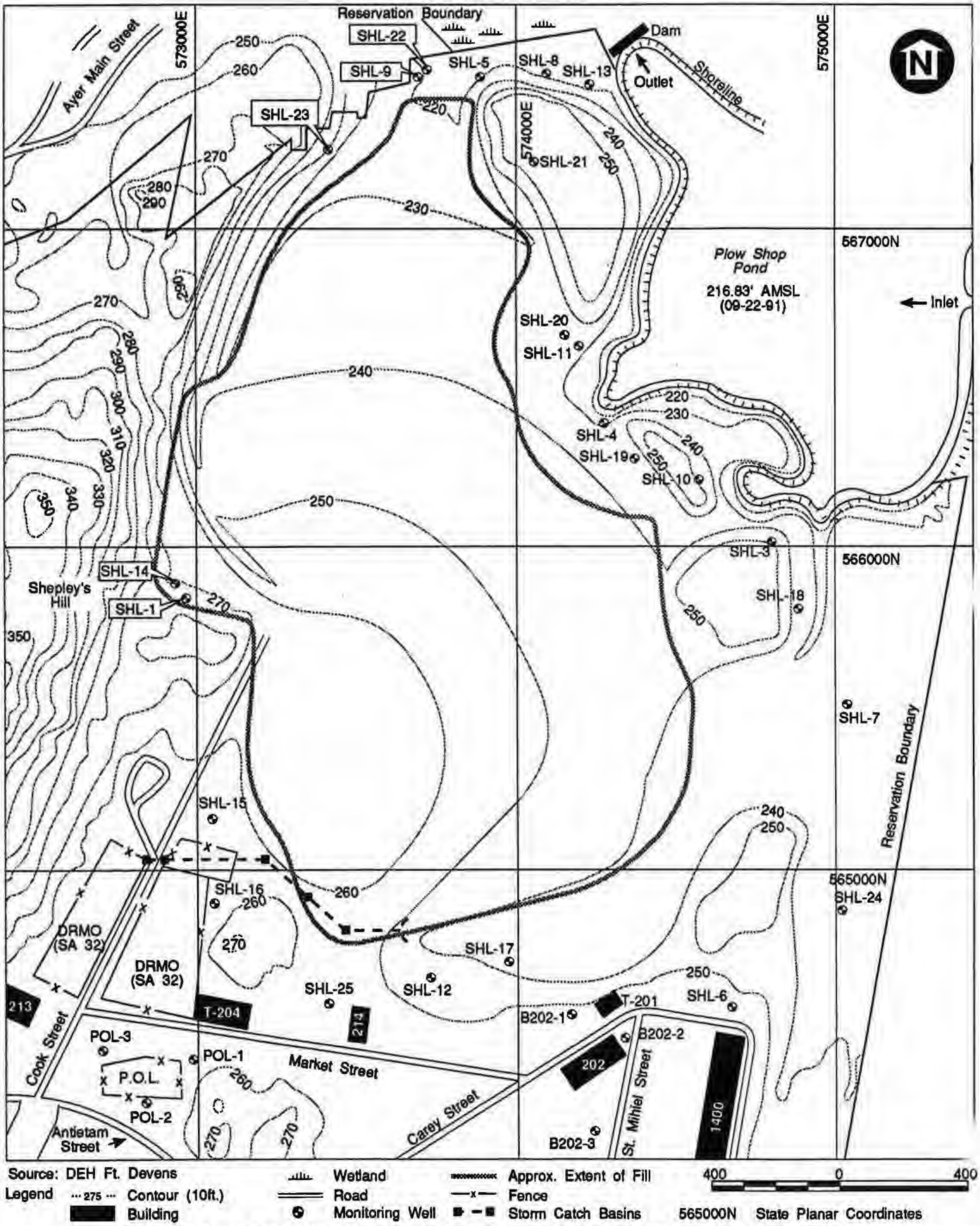


Figure 2-2 LOCATIONS OF MONITORING WELLS ON SHEPLY'S HILL LANDFILL

The three deeper wells were drilled in areas already known to have significant saturated zones above bedrock. Again, all boreholes were advanced to refusal while sampling every 5 feet. The rock was then cored for 15 feet to demonstrate that it was bedrock, and the hole grouted and abandoned. The rig was then moved 10 feet, a bore was advanced to the top of bedrock, and the well installed with 10 feet of screen set just above the top of bedrock.

All monitoring wells were constructed within the unconsolidated glacial deposits above bedrock. Monitoring wells were constructed of 4-inch inside diameter (ID), threaded, flush joint, PVC riser casing, and a 10-foot section of a 4-inch ID, flush joint, PVC casing with a 0.010 inch, machine-slotted screen. Figure 2-3 shows details of general monitoring well construction used at Shepley's Hill Landfill, and Appendix A provides the well construction records and bore logs.

All construction material was approved by the NSF/ASTM. All well installations included a sand filter pack around the screen, extending 5 feet above it. A 5-foot bentonite seal was placed above the sand and a mix of bentonite/Portland cement grout extends to the surface. Grouting was accomplished through a tremie pipe lowered to the bottom of the zone to be grouted. The grout was composed by weight of 20 parts Portland cement, Type II or Type V, and 1 part bentonite. A maximum of 8 gallons of water was used per 94-pound bag of cement. The tremie pipe was rigid PVC.

A steel protective casing with locking cap was installed around the PVC casing. Four steel pickets were erected radially around the well. The protective casing was brush-painted orange and the well designation number was painted in white.

Investigation-derived material showing evidence of contamination, either visually or by readings greater than 10 ppm on the OVA or HNu, was placed in 55-gallon drums and stored in a secured area pending recommendation for proper disposal.

2.1.3 Well Development

The newly installed monitoring wells were developed no sooner than 48 hours and no later than 1 week after installation. All wells were developed for a minimum of 1 hour to improve efficiency, remove any foreign material introduced during drilling, and to reduce turbidity in the groundwater sample. Well development was accomplished by use of variable flow submersible pumps at these sites. Fully developed wells met the following USATHAMA specifications:

- o The well water was clear to the unaided eye.
- o The sediment thickness remaining in the well was less than one percent of the screen length.

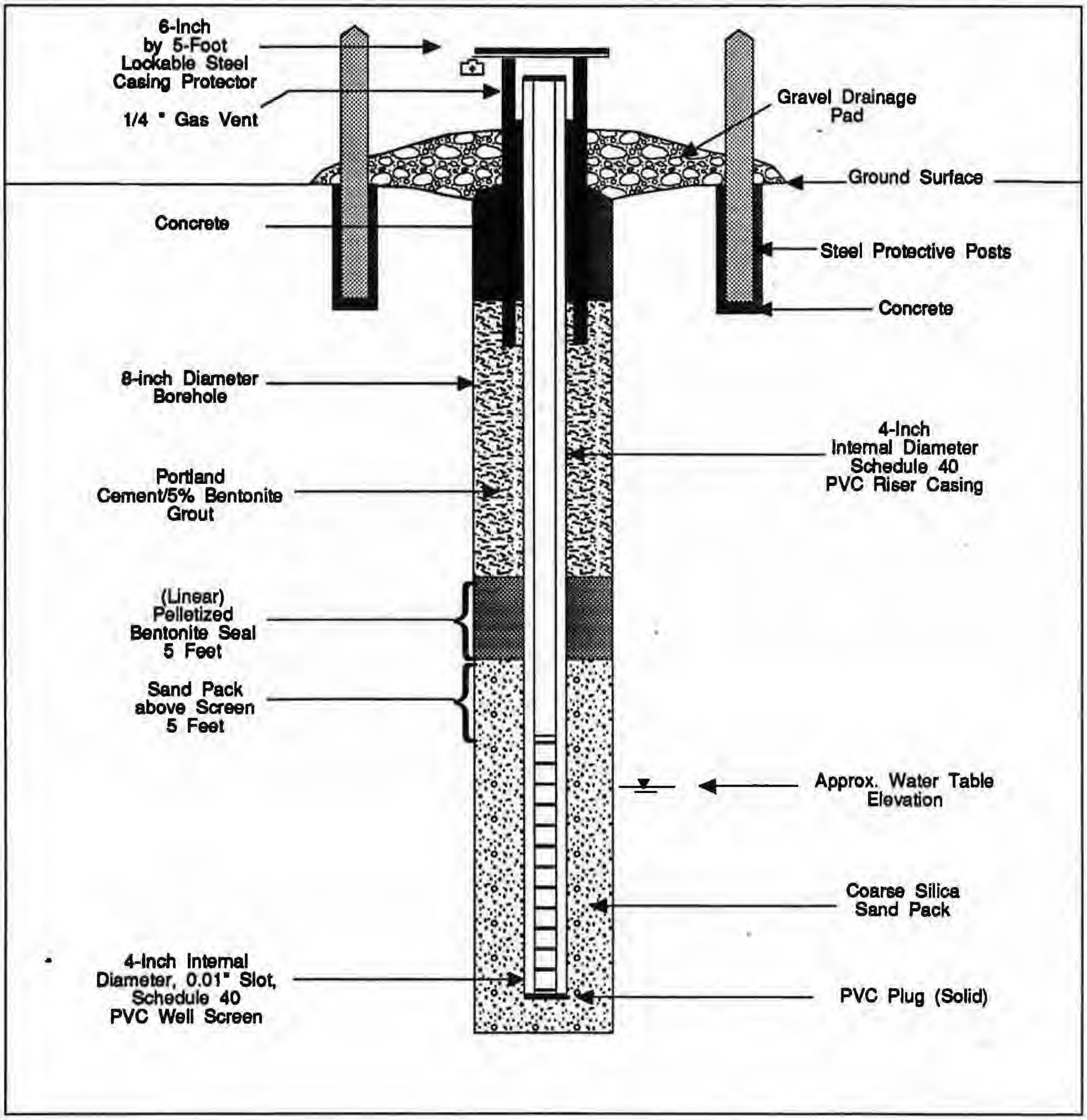


Figure 2-3 MONITORING WELL CONSTRUCTION

- o The total volume of water removed from the well equaled five times the standing water volume in the well (including the well screen and casing plus saturated annulus, assuming 30 percent porosity within the sand pack) plus five times the volume of drilling fluid lost.

2.1.4 Soil Borings

All soil borings under the RI at Shepley's Hill Landfill were drilled in conjunction with efforts to install groundwater monitoring wells.

At the landfill, the RI required three deep wells with the well screen placed at the bedrock interface. To establish the bedrock interface, borings were driven to bedrock and then cored to 15 feet in the bedrock. Once this was accomplished, the bore was abandoned following prescribed USATHAMA geotechnical specifications (see Section 2.1.1). In addition, for borings that encountered rock prior to intercepting an aquifer, three borings per location are drilled. The first boring at each location was cored 15 feet into rock to confirm that bedrock had been reached, and then two more borings were drilled in the same location. Each borehole was abandoned following USATHAMA specifications.

Well locations SHL-14, SHL-16, SHL-20, SHL-22, and SHL-24 (see Figure 2-2) all required soil borings, which were abandoned upon completion.

As required, the water, sand, and bentonite used for soil boring and abandoning boreholes were approved by USATHAMA prior to operations. Representative samples were provided to the Fort Devens DEH. The USATHAMA-approved water source for the project was Fort Devens production well D-1, located on the South Post. All construction material was approved by the NSF/ASTM.

Drilling the boreholes was accomplished through hollow-stem augers. The only lubricant used on the drilling augers was Teflon tape.

Once the soil boring was complete, and the need for abandonment was determined, the hole was grouted to ground surface using a rigid PVC tremie pipe lowered to the bottom of the hole. The grout was composed by weight of 20 parts Portland cement, Type II or Type V, and up to 1 part bentonite. A maximum of 8 gallons of water was used per 94-pound bag of cement.

Investigation-derived material showing evidence of contamination, either visually or by readings greater than 10 ppm on the OVA or HNu, was placed in 55-gallon drums and stored in a secured area pending recommendation for proper disposal.

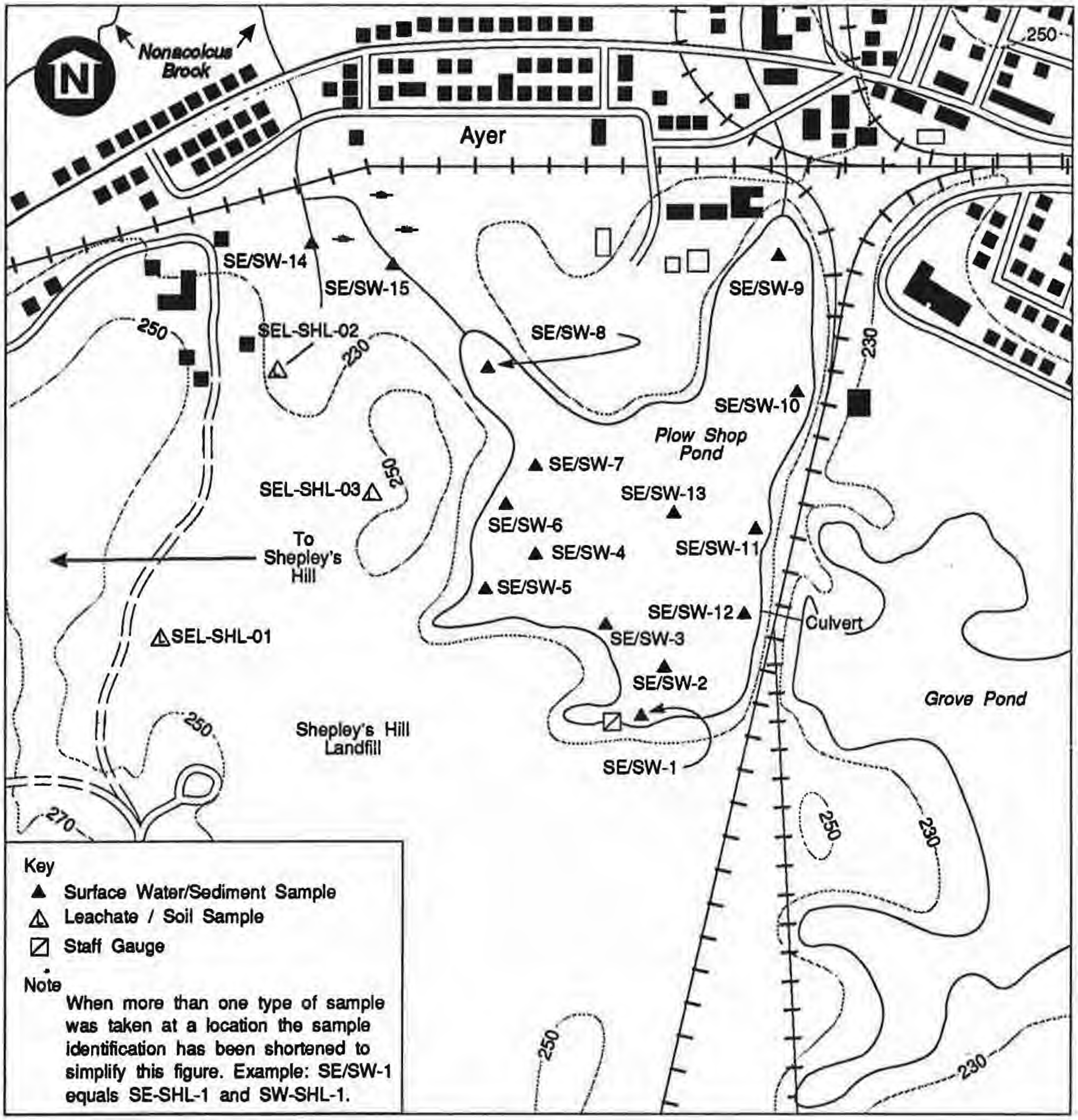
2.1.5 Soil Sampling

Three leachate soil samples were collected at Shepley's Hill Landfill as part of the RI. Sampling locations were selected by the site geologist, and all showed the staining and discoloration associated with leachate seeps (see Figure 2-4). Samples were collected only from the surface of the soil, including as much leachate residue as was available. These samples were analyzed for Target Compound List (TCL) organics, Target Analyte List (TAL) metals, and other general analytical parameters and were collected using the following procedures:

- Care was taken that the appropriate number of pre-cleaned sample bottles, including preservatives, were transported to field.
- Labels were placed on pre-cleaned sample bottles prior to collection. Sample labels were filled out with waterproof ink and included the sampler name, sample identification, sample location, date, and analysis to be performed. The actual time of collection was added after collection.
- E & E personnel used a clean, disposable, stainless steel spoon to scrape leachate soil samples from the ground surface over an area large enough to fill the required volume of samples.
- Leaves, roots, sticks, and rocks were avoided.
- Soils for VOA analysis were collected first and placed directly into their containers. The order of sample collection following volatile collection was, typically, extractables, metals, explosives, TOC, and grain size.
- Stainless steel spoons were decontaminated to avoid cross-contamination.
- Any observable physical characteristics of the soil as it was being sampled (e.g., color, odor, physical state) were recorded in the field log book.
- All pertinent weather information at the time of sampling, such as air temperature, wind and sky conditions, and precipitation, was recorded in the field log book.

2.1.6 Surface Water and Sediment Sampling

To determine the extent and source(s) of contamination in Plow Shop Pond and in Nonacoicus Brook (immediately downstream from Plow Shop Pond and Shepley's Hill Landfill), E & E collected 15 surface water and 15 sediment samples. Samples were collected from the brook and from points distributed throughout Plow Shop Pond, but concentrated along the western side adjacent to Shepley's Hill Landfill (see Figure 2-4).



Source: USGS, 1966, Revised 1979

Figure 2-4 SHEPLEY'S HILL LANDFILL / PLOW SHOP POND SAMPLING LOCATIONS

Surface water samples were analyzed for TCL organics, TAL metals, and other general analytical parameters. In addition, pH, conductivity, and dissolved oxygen were measured in the field. Sediment samples were analyzed for TCL organics, TAL metals, and other general analytical parameters. In addition, certain sediment samples were measured for grain size distribution (see Appendix F). Surface water and sediment sampling rationale are presented in Table 2-3.

2.1.6.1 Surface Water Sampling

E & E collected surface water from Plow Shop Pond and from Nonacoicus Brook, adjacent to Shepley's Hill Landfill. When necessary, a boat was used to reach sample locations. Sampling was performed in accordance with the following procedures:

- o Care was taken that the appropriate number of pre-cleaned sample bottles, including preservatives, were transported to the field for sample collection.
- o Labels were placed on pre-cleaned sample bottles prior to collection. Sample labels were filled out with waterproof ink and included sampler name, sample identification, sample location, date, preservatives added, and analytical purpose. The actual time of collection was added after the sample was collected.
- o A pre-cleaned, wide-mouthed glass bottle used for sample collection was dipped into the brook or pond and rinsed three times. The bottle then was dipped to collect the sample and the water transferred into the respective sampling containers, which also were triple rinsed with sample water. Water samples contained only liquids (no sludges or sediments). Preservatives were not added prior to rinsing. The VOA bottle was immersed directly into the medium sampled, then filled, preserved, and capped.
- o The sample was collected in such a manner as to prevent agitation of the water, which promotes the loss of volatile organics and increases the dissolved oxygen content.
- o VOA sample bottles were filled first. The order of collection following VOAs was, typically, extractables, metals, explosives, and water quality parameters.
- o All VOA sample containers were completely filled and inverted and inspected to ensure that they did not contain any bubbles.
- o To avoid agitation of the sample and possible cross contamination, preservation of the sample to the appropriate pH was checked by using a separate bottle prior to actual sampling for volatile analysis. A representative sample for the matrix and site was collected, an appropriate amount of preservative was added (i.e., two to three drops for VOAs), the container

Table 2-3

SHEPLEY'S HILL LANDFILL
SURFACE WATER/SEDIMENT SAMPLE RATIONALE

Sample ID Designation	Location and Rationale
SW-SHL-1/SE-SHL-1	Southwestern edge of Plow Shop Pond near to shore; to monitor potential migration of contaminants from southern portion of landfill.
SW-SHL-2/SE-SHL-2	Southwestern edge of Plow Shop Pond, farther from shore; to monitor potential migration of contaminants toward center of pond.
SW-SHL-3/SE-SHL-3	Southwestern edge of Plow Shop Pond, near to shore; to monitor potential migration of contaminants from southern portion of landfill.
SW-SHL-4/SE-SHL-4	Southwestern edge of Plow Shop Pond, farther from shore; to monitor potential migration of contaminants toward center of pond.
SW-SHL-5/SE-SHL-5	Western edge of Plow Shop Pond, near to shore; to monitor potential migration of contaminants from southern and northern portions of landfill.
SW-SHL-6/SE-SHL-6	Western edge of Plow Shop Pond, near to shore; to monitor potential migration of contaminants from northern portion of landfill.
SW-SHL-7/SE-SHL-7	Western edge of Plow Shop Pond, farther from shore; to monitor potential migration of contaminants toward center of pond.
SW-SHL-8/SE-SHL-8	Western edge of Plow Shop Pond near outlet; to monitor potential migration of contaminants toward outlet.
SW-SHL-9/SE-SHL-9	Northeastern edge of Plow Shop Pond near northern outlet; to monitor potential migration of contaminants from alternate sources such as the railroad.
SW-SHL-10/SE-SHL-10	Eastern edge of Plow Shop Pond along railroad tracks near to shore; to monitor potential migration of contaminants from alternate sources such as the railroad.
SW-SHL-11/SE-SHL-11	Eastern edge of Plow Shop Pond along railroad tracks near to shore; to monitor potential migration of contaminants from alternate sources such as the railroad.
SW-SHL-12/SE-SHL-12	Eastern edge of Plow Shop Pond near discharge from Grove Pond under the railroad embankment; to monitor influx from Grove Pond.
SW-SHL-13/SE-SHL-13	Center of Plow Shop Pond; to assess overall conditions.
SW-SHL-14/SE-SHL-14	Drainage swale in wetland area between landfill northwestern edge and railroad tracks; to monitor potential migration of contaminants from northern portion of landfill.
SW-SHL-15/SE-SHL-15	Nonacoicus Brook in wetland area between Plow Shop Pond outlet and railroad tracks; to monitor potential migration of contaminants from Plow Shop Pond and from northern portion of landfill.

SW: Surface water sample
SE: Sediment sample from same location

RC424

Source: E & E, 1991

shaken, and the pH tested with pH paper. Once the proper level of preservative was determined in the test bottle, that amount of preservative was added to the rinsed VOA sample bottle. For other analyses, the proper preservative was added, the sample capped and shaken, and the pH checked by pouring a very small amount of sample into a separate disposable container and using pH paper on the sample aliquot.

- Other samples were collected in the wide-mouthed glass bottle and transferred into 1/2-gallon glass bottles and other appropriate bottles required for chemical analyses. The wide-mouthed bottle was refilled as many times as necessary to fill all required sample bottles.

- The temperature, pH, dissolved oxygen, and specific conductance of the water were measured in the field prior to sample collection.

- Any observable physical characteristics of the water (e.g., color, odor, turbidity) were recorded in the field log book as the water was being sampled.

- Sample bottles were wiped dry after being capped and then placed in plastic bags to be shipped for analyses.

- Weather conditions at the time of sampling (e.g., air temperature, wind and sky conditions, precipitation) were recorded in the field log book.

2.1.6.2 Sediment Sampling

Sediment samples were collected in conjunction with the surface water locations discussed above. The following procedures were employed:

- Care was taken that the appropriate number of pre-cleaned sample bottles were transported to the field.

- Labels were placed on pre-cleaned sample bottles prior to collection. Sample labels were filled out with waterproof ink and included sampler name, sample identification, sample location, date, and analysis to performed. The actual time of collection was added after the sample was collected.

- At the brook sample locations, the sampling area was cleaned of vegetation and debris by using a stainless steel spoon. The sediment was then collected and placed into a stainless steel bowl.

- For the pond samples, an Ekman sampling device was used to collect bottom sediment samples after the surface water samples had been collected. The Ekman sampler is a clamshell-shaped device activated by a weight dropped along a rope attached to the sampler. The pond sampling, both surface water and sediment, was conducted while in a small boat. The Ekman sampler, with clamshell scoops held open by small cables attached to the spring-loaded triggering device, was slowly lowered to the pond bottom. With the sampler resting on the pond bottom, the weight was dropped rapidly along the rope to close the clamshell scoops and collect bottom sediment. The sampler was then slowly pulled up to the boat, and held along side the boat to allow excess water to drain out of the sampler back into the pond. The sampler was then brought into the boat, the clamshell scoops opened, and the collected sediment placed into a stainless steel bowl prior to distribution into the appropriate sample bottles.

- o All samples, to the extent possible, contained no less than 30 percent solids. Exceptions may have occurred when sampling the soft organic muds which line the bottom of Plow Shop Pond.
- o From the stainless steel bowl, VOA samples were collected first and placed directly into the respective containers. The order of sample collection following VOA and TPHC collection was extractables, metals, explosives, and TOC.
- o After the VOA samples were collected, samplers used a stainless steel spoon to homogenize the sediment remaining in the stainless steel bowl. From the homogenized sediment, samples were taken to fill containers for the remaining sample analyses (e.g., extractables, metals, explosives, and TOC).
- o To prevent cross-contamination, stainless steel spoons were not reused.
- o Any observable physical characteristics of the sediment as it was being sampled (e.g., color, odor, physical state) were recorded in the field log book.
- o All pertinent weather information at the time of sampling, such as air temperature, wind and sky conditions, and precipitation, was recorded in the field log book.

2.1.7 Groundwater Sampling

Sampling of the 26 wells at Shepley's Hill Landfill (including the 3 POL wells) consisted of the following activities:

- o measuring the depth to water level and total depth of the well (to calculate well volume),

- o purging static water, and
- o collecting samples.

These groundwater sampling activities followed USATHAMA's Quality Assurance Program (January 1990) and are described in the following sections.

2.1.7.1 Measurement of Water Level and Well Volume

Prior to sampling, the static water level and total depth of each well were measured with an audible electronic water level meter. Care was taken to decontaminate equipment between each use to avoid cross-contamination of wells. The number of linear feet of static water (difference between static water level and total depth of well) was calculated, and used to determine the volume of static water in the well.

2.1.7.2 Purging Static Water

Before collecting a groundwater sample, E & E first purged the static water to ensure that a representative groundwater sample was taken. A minimum of five times the static water volume (including saturated annulus) was purged from the well prior to collection of the volatile hydrocarbon samples. At wells that were extremely slow in recharging, purging the well dry was deemed adequate, even if this occurred prior to purging five static water volumes.

Purging was performed using dedicated Teflon bailers or submersible pumps. The water removed from the well during the purging process was initially containerized and observed visually and with monitoring instruments. If visual contamination was observed or if the headspace analysis of the purge water was greater than 10 parts per million (ppm) over background, the drums were retained for RCRA classification and disposal in accordance with the Fort Devens Hazardous Materials Plan (Prior, 1991). If the OVA readings were less than 10 ppm above background, the purge water was disposed of at the well site.

2.1.7.3 Sample Collection

Groundwater samples were analyzed for TCL organics, TAL metals, and other general analytical parameters. Sampling personnel took precautions against cross-contamination by dedicating a Teflon bailer and rope to each well. Collection of groundwater samples from the monitoring well was conducted in the following manner:

- o Care was taken that the appropriate number of pre-cleaned sample bottles, including preservatives, were transported to the field for sample collection.
- o Labels were placed on pre-cleaned sample bottles prior to sample collection. Sample labels were filled out with waterproof ink

and included sample name, sample identification, the sample location, date, time, preservatives added, and analytical purpose.

- The pre-cleaned glass sampling bottles were triple rinsed with the sample water in order to fill up any unused ionic sites on the glass surface. Water samples contained only liquids (no sludges, etc.).

- The samples were collected in such a manner as to prevent agitation of the water, which promotes the loss of volatile organics and increases the dissolved oxygen content.

- Samples analyzed for volatile organics did not have any headspace (or bubbles) in the sample jar, and were handled as little as possible. A few drops of hydrochloric acid were added to VOA samples to reduce the pH to less than 2, to extend the holding time to 14 days. To determine the amount of hydrochloric acid to add to the vials, a test vial of water was acidified with the same quantity of acid as the samples and the pH of this test vial was checked with pH paper in the field.

- The order of collection was, typically, VOAs, extractables, metals, explosives, and anions/cations.

- The temperature, pH, and specific conductance of the water was measured in the field.

- Any observable physical characteristics of the water (e.g., color, odor, turbidity) were recorded in the field log book as the water was being sampled.

- Sample bottles were wiped dry after being capped and were then placed in plastic bags to be shipped for analyses.

- Weather conditions at the time of sampling (e.g., air temperature, wind and sky conditions, and precipitation) were recorded in the field log book.

2.1.8 Surveying

Installation-wide water level measurements were included as part of the RI. Besides the 17 new wells installed under the RI and SI programs, 62 existing monitoring wells were surveyed for elevation and location. Table 2-4 provides a complete list of wells at Fort Devens as of December 1991. These wells consist of both monitoring and water production wells. Monitoring wells have been located on the Fort Devens base map. Map coordinates were transferred to the USATHAMA IRDMIS (PRI 1991). These data will support the development of a Fort Devens groundwater contour elevation map throughout at least the Main Cantonment Area and North Post.

Table 2-4

LOCATION AND NUMBER OF MONITORING WELLS AND WATER SUPPLY WELLS AT FORT DEVENS DECEMBER 1991

Well Type	Location/Name	Number of Wells	Remarks
Monitoring Wells	Building 3602	4	
	Building 2602	4	2 older wells, 2 new wells
	Building 2680	3	
	Building 3622	4	
	POL Storage	3	
	Building 1404	2	
	Shepley's Hill Landfill	23	
	Cold Spring Brook Landfill	7	CSB-5 destroyed, not counted
	Waste Water Treatment Plant	16	6 old wells, 10 new wells
	AAFES Gas Station	6	AAFES-04 destroyed, not counted
	Building 202	3	
	EOD Range	4	
	Mass National Guard Area	7	installed 12/91
	South Post UST Sites	12	installed 12/91, 3 sites
Water Supply Wells	Sheboken Well	1	On Sheridan Road south of Mirror Lake
	Patton Well	1	On Patton Road north of Mirror Lake
	McPherson Well	1	On McPherson Road north of Verbeck Gate
	Grove Pond Wellfield	1	South of Grove Pond, off Mass National Guard area
	South Post Well	1	On Dixie Road southeast of Cranberry Pond
TOTAL NUMBER OF WELLS		103	

RC424

Source: E & E, 1991

All monitoring wells existing prior to December 1991, were surveyed for horizontal location and vertical elevation as per USATHAMA geotechnical requirements (USATHAMA 1987). Elevations at each well were measured at ground/well pad surface, highest point of well riser, and highest point of well protective casing (as applicable). Survey work was performed by Gordon Soderholm and Associates, P.C. of Depew, N.Y., using a professionally licensed surveyor and a crew trained in accordance with OSHA regulations (29 CFR 1910.120(e)).

2.1.9 Groundwater Level Measurements

Prior to the start of the RI, the Army identified 83 of the 103 wells at Fort Devens, including the 17 wells to be installed during RI/SI programs (see Table 2-4). This does not include the multiple well points at the Grove Pond "Well" or more accurately "wellfield." All monitoring wells identified by the Army, with the exception of those installed after August 1991, were surveyed and the water levels in them measured during three periods separated by intervals of not less than 3 months.

At Shepley's Hill Landfill, 26 wells were identified, surveyed, and included in the groundwater measurement schedule. Three of these wells are located immediately South of the landfill, at the Petroleum, Oil, and Lubricant (POL) Storage area, the remaining 23 wells are located on the perimeter of the landfill. Groundwater measurements at these wells were taken on 30 August 1991, on 12 December 1991, and on 18 and 19 March 1992.

A water level gauge was also installed in Plow Shop Pond to allow comparison of surface water elevations with water table elevations beneath the landfill.

Water levels were measured using electronic water level indicators that have audible alarms and that are accurate to within 0.01 foot. The depth to groundwater was measured from the highest point on the rim of the well casing or riser. These same points at each well were surveyed for vertical control. To the extent practicable, each round of groundwater measurements was made over a single consecutive 10-hour period.

The depths to groundwater have been converted to elevations for use in reports. To enter the data into IRDMIS, depth below ground surface measurements were calculated. The groundwater contour maps developed from monitoring well water levels in all wells provide information on flow directions and for the flow velocity calculations.

At wells where the well riser was absent or inaccessible, measurements were taken from the highest point of the wells' outer, protective casing.

Water level measurements are provided in Appendix J.

2.1.10 Aquifer Testing

In-situ hydraulic conductivity values for the geologic units screened by the monitoring wells was obtained by slug testing the newly completed monitoring wells using the methodology described in Appendix B. Slug testing involves displacing water in a monitoring well and measuring the rate at which the water level recovers to static conditions.

The slugs were made from new PVC casing. After one end was sealed, quartz sand was added to the inside of casing to act as a weight. The other end of the casing was then sealed. The sizes of the slugs used were 5-foot or 2-foot lengths by 1.25-inch outside diameter for the 2-inch monitoring wells and 5-foot length by 1.5-inch outside diameter for 4-inch monitoring wells.

At each of the 26 Shepley's Hill Landfill monitoring wells (including 3 POL wells), OVA readings were taken immediately upon opening the well cap. Depth to water and total well depth were measured using an audible electronic water level meter. These measurements were used to determine the length of the water column and determine the appropriate slug length. The water level, total depth, and slug size were recorded on a separate data sheet for each well. Some wells did not contain sufficient water (less than 3 feet) to run a slug test.

An in-situ Hermit 2000 Data Logger and pressure transducer system (e.g., 10 or 20 pounds-per-square-inch transducers) were used to record each test.

All instruments to be placed in a monitoring well were rinsed with distilled water before placement. The transducer probe was lowered to the bottom of the monitoring well and then raised a minimum of several inches, the amount depending on the depth of water present in the well. The rope connected to the slug was carefully measured to a length that allows the slug to be completely submerged while allowing enough room for the transducer probe below.

At each well location, the test number was entered into the data logger and recorded on the data sheet. The slug was lowered into the well but above the water level. The slug was then lowered quickly but steadily into the water. The data logger measured falling head values during the "slug in" testing. After a minimum recovery of 90 percent of original static water level, or a 1-hour run time, the head level, drawdown, and time were noted. "Slug out" testing was then performed by removing the slug. After 90 percent recovery was obtained or 1 hour had passed, the head value, drawdown, and time were noted and the test was stopped. All instruments were rinsed with distilled water upon removal from the well.

However, not all of the wells were successfully slug tested. The two primary causes that inhibited successful slug testing were the following:

- o lack of the appropriate depth of water in the well, and
- o too high a hydraulic conductivity resulting in very rapid recoveries.

2.1.11 Air Survey

As part of the RI at Shepley's Hill Landfill, an air quality survey was conducted to determine the ambient air concentrations of respirable particulate matter (PM-10) and VOCs upwind and downwind of the landfill. A narrative description of the results of the air survey and all supporting data can be found in Appendix G.

The air quality survey was conducted in the following four stages: meteorological monitoring, sample site selection, PM-10 sampling, and VOC sample collection.

2.1.11.1 Meteorological Monitoring

The purpose of meteorological monitoring was to collect data that could be used to select appropriate sampling locations, and would document the meteorological conditions under which the air samples were taken. E & E monitored the following meteorological parameters: temperature, relative humidity, wind speed, wind direction, and barometric pressure. These parameters were monitored for the duration of the air quality survey. The standard deviation of wind direction, sigma theta, was calculated in real time from the wind direction measurements. Meteorological data are presented in Appendix G.

The meteorological monitoring equipment consisted of a temperature/relative humidity sensor, a wind speed sensor, and a wind direction sensor mounted on a cross-arm atop a 5-meter aluminum tower secured by guy wires. A weather-proof box at the base of the tower housed an Odessa Engineering DSM-3260 data storage module and the barometric pressure sensor. The sensors were connected to a junction box mounted on the tower, which in turn was connected by a main cable to the data storage module. The system was powered by a 9-volt deep cycle marine battery. The data were accessed with a lap-top computer and Odessa Engineering's ENVICOM software.

The meteorological station was sited using the criteria set forth in the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV--Meteorological Measurements (USEPA 1989h). In this document, EPA recommends that a meteorological tower should be sited in "open terrain," which is defined as an area where the horizontal distance between the instruments and any obstruction is at least 10 times the height of that obstruction. The meteorological station was sited in the middle of Shepley's Hill Landfill (see Figure 2-5) in accordance with these criteria.

2.1.11.2 Sample Site Selection

Sampling locations were selected based upon the on-site meteorological monitoring data and the physical constraints of the site. The type of sample collected also influenced the choice of sample locations. In general, there must be free, unobstructed flow around the sampler in order to obtain a representative sample. Obstructions can be in the form of changes in topography, vegetation, and buildings. E & E attempted to site all samplers using the following criteria:

- o sampler intakes should be approximately in the breathing zone (1.5 to 2 meters above the ground),
- o samplers should be located at a horizontal distance of at least twice the height of any nearby obstructions,
- o samplers should have unrestricted airflow in an arc of 270 degrees around the sampler, and
- o samplers should be placed at a minimum distance of 25 meters from a roadway.

Data from the on-site meteorological monitoring were reviewed to determine the prevailing wind patterns at the landfill and the nature and extent of any diurnal wind shifts. Since the Shepley's Hill Landfill is wooded on all sides, downwind samplers were placed on the landfill as far downwind as possible while still meeting the siting criteria. The locations of the downwind particulate matter and VOC samplers are shown in Figure 2-5. The upwind samplers were located to the west of Shepley's Hill in a field next to the elementary school.

2.1.11.3 Respirable Particulate Matter (PM-10) Sampling

Metal contamination has been associated with the Shepley's Hill Landfill. The air pathway for exposure to metals is through inhalation of PM-10. PM-10 is defined as particulate matter with a diameter of 10 microns or less. The EPA reference method for determination of the ambient concentration of PM-10 is given in 40 CFR 50 Appendix J. This method requires drawing an air sample at a constant flow rate first through a size-selective inlet, where particles greater than 10μm are removed, and then through a filter medium. The filter medium can be weighed to determine the total mass of PM-10. The 24-hour sample is accurately timed and the mass concentration of PM-10 can then be determined by the total volume of air sampled. The equipment used to sample PM-10 at Fort Devens was the General Metal Works HVPM-10 which consists of a high volume blower and filter housing, mass flow

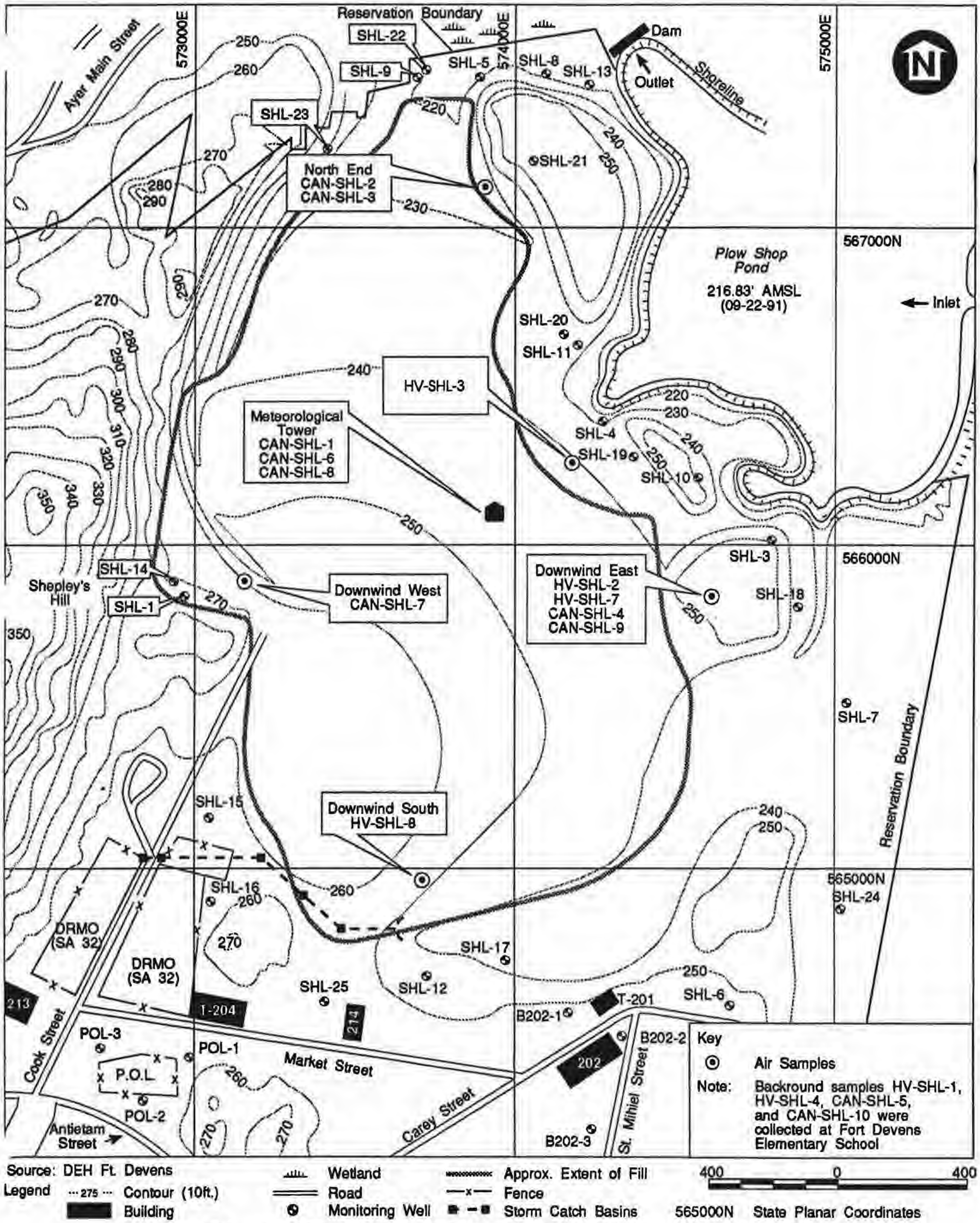


Figure 2-5 LOCATION OF AIR SAMPLES AT SHEPLEY'S HILL LANDFILL

controller, size selective inlet, digital timer, and flow event recorder. The filter media used in this equipment is an 8 x 10-inch glass fiber filter.

The HVPM-10 samplers were calibrated on site before being deployed in the field. Calibration of a high volume sampler refers to calibration of the sampler's flow-rate indicator. Once calibrated, the flow rate indicator provides an accurate reading of the sample flow rate from which the volume of the sampled air can be calculated (EPA-60/4-77-027a 1983). The calibration procedure employed consisted of the following steps:

- o Calibration equipment was assembled and the calibration orifice on the sampler was installed.
- o The sampling system was checked to ensure that there were no leaks.
- o An 18-hole plate was installed in the orifice device.
- o The sampler was turned on and allowed to warm up.
- o Ambient pressure (Ta), barometric pressure (Pa), seasonal average temperature (Ts), seasonal average pressure (Ps), orifice serial number and calculated flow rate (Qa), calibration curve slope (m), y-intercept (b), and linear regression (r) were all recorded.
- o Manometer deflection (ΔP H2O) was recorded.
- o Event recorder response (I) was recorded.
- o The last five steps were repeated with 13-, 10-, 7-, and 5-holed plates, then the sampler was turned off.
- o Qa was calculated: $Qa=1/m\{\sqrt{\Delta H2O(Ta/Pa)}\}-b$.
- o The recorder response was corrected to actual conditions: $IC-I[\sqrt{(Ta/Pa)}]$.
- o Calibration was corrected to seasonal conditions: $ms=m/[\sqrt{(Ts/Ps)}]$, $bs=b/[\sqrt{(Ts/Ps)}]$.
- o The mass flow controller set point flow rate (SFR) was calculated: SFR=1.13(Ps/standard pressure(Pstd))(standard temperature(Tstd)/Ts).
- o The mass flow controller set point recorder response was calculated (SSP): $SSP=\{[m(SFR)+b][\sqrt{(Ps/Ts)}]\}$.
- o The filter was installed, the sampler turned on, and the mass flow controller was set to the calibrated set point.

The calibration sheets for each of the PM-10 samplers used at Fort Devens are presented in Appendix G.

PM-10 samples were collected during two sampling events. Two PM-10 samples were collected downwind of the landfill and one upwind (background) sample was collected for each sampling event. The samplers were programmed to run for 24 hours for each sample.

2.1.11.4 VOC Sample Collection

Ambient VOC samples were collected in 6-liter SUMMA polished stainless steel canisters in accordance with EPA Method TO-14, "Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA Passivated Canister Sampling and Gas Chromatographic Analysis." This method is found in EPA document 600/4-84-041, Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. Samples were drawn through Scientific Instrumentation Specialists model AGS-1/D automated canister samplers. The AGS-1/D consists of a pump, timer, and flow controller. The AGS-1/D was used to collect a pressurized sample of approximately 14 liters over a period of 8 hours.

E & E used the following sampling and calibration procedures:

- Each sampler was connected to a 12-volt battery.
- The sampler flow rate was measured with a Buck Primary Gasflow Calibrator and the flow rate was adjusted to approximately 30 cc/minute and recorded.
- A 6-liter canister was connected to the sampler. Canisters were certified clean by an analytical laboratory.
- An 8-hour sampling period was programmed on the sampler timer.
- The valve was opened on the canister and initial pressure was recorded.

When sampling was completed:

- Final pressure in the canister was recorded.
- The valve on the canister was closed.
- The final flow rate was checked using a Buck Primary Gasflow Calibrator and the rate was recorded.

VOC samples were collected during two sampling events. Four VOC samples were collected downwind of the landfill and one background sample was collected upwind during each of the two sampling events.

2.1.12 Ecological Assessment

Ecological investigation of the Shepley's Hill Landfill site was required to provide information for use in the baseline risk assessment (human health evaluation and environmental evaluation). The primary objective of the ecological investigation was to identify and evaluate existing aquatic, terrestrial, and wetland communities. Emphasis was placed on sensitive environments or species that may come in contact with site contaminants, such as State- or federally-designated wetlands, critical habitats, and endangered species. Based on E & E's preliminary evaluation of available information on site ecology and a site visit, the ecological resources potentially impacted by the Shepley's Hill Landfill were identified for further characterization. These resources included aquatic and wetland communities in the vicinity of Plow Shop Pond, as well as terrestrial vegetation and wildlife species living on or in the vicinity of the landfill.

Ecological characterization of the site was based on collection and analysis of existing site data, in conjunction with a field investigation of the landfill. A two-member field team surveyed each of the two landfill sites during the week of 12 through 16 August 1991.

The appropriate State and Federal agencies were consulted to determine if any rare, threatened, or endangered species or specially designated ecosystems occur on or near the sites, and to establish if there are recreationally important fish species found in Plow Shop Pond. Mr. Thomas Poole of the Fort Devens Natural Resource Office provided site specific information from the Draft Environmental Impact Statement for Fort Devens on "protected species or species imported for recreational purposes" as well as general information on site vegetation, fish, and wildlife, including species lists.

Literature and map resources were reviewed prior to the initiation of field work. These resources included U.S. Army site maps, U.S. Army aerial photographs, USGS Ayer and Shirley topographic quadrangle maps, the USFWS Ayer and Shirley quadrangle National Wetlands Inventory (NWI) maps, the Atlas of Estimated Habitats of State-Listed Rare Wetlands Wildlife (Massachusetts Natural Heritage and Endangered Species Program (MNHESP) 1992), the Soil Survey of Middlesex County (USDA 1924), and the Soil Survey of Worcester County (USDA 1985).

This information was supplemented by a field ecological survey of the site. This survey included a wetland delineation and functional assessment. Wetlands were delineated using procedures described in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineation 1989) and the New England Division of the Army Corps of Engineers (USACE) wetlands delineation guidance document (USACE 1991). Vegetation, soils, and hydrology were sampled at one wetland point and one adjacent upland point for each wetland plant community. The jurisdictional boundaries of federally-regulated wetlands were flagged on site. Jurisdictional boundaries of state-regulated wetlands frequently are different than boundaries of federally-regulated wetlands because Massachusetts defines wetlands on the basis of vegetation and hydrology only. For this reason, wetland boundaries flagged on site may not correspond to jurisdictional boundaries of state-regulated wetlands.

Wetland functions were assessed for wetlands associated with each landfill site using Wetland Inventory Data forms (Hollands and McGee 1985). These data forms were designed by Hollands and McGee (1985) in response to requirements promulgated under the Massachusetts Protection Act (MGL Chapter 131, Section 40) to assess the functions of wetlands. The Wetland Inventory Data forms are provided in Appendix E.

In addition to the wetland delineation, the ecological survey of the site included a walkover survey. Wildlife use of each landfill site was evaluated using literature sources as well as observations. Species lists were generated from two sources: a review of New England Wildlife: Habitat, Natural History, and Distribution (DeGraaf and Rudis 1986) for relatively common species that occur within Middlesex and Worcester counties, Massachusetts; and personal communication with Thomas Poole of the Fort Devens Natural Resources Office who provided information from tables prepared for a USACE draft Environmental Impact Statement (undated) for Fort Devens (Poole 1991). These species lists were augmented by wildlife sightings made during the five-day field survey. Wildlife sightings included direct observations as well as identifications based on vocalizations, tracks, burrows, browse, and scat. General wildlife values (e.g., food and cover availability) of each cover type were also noted. Dominant species in the overstory, understory, and herbaceous layers were identified and vegetation cover types were mapped using information from the survey, agency contacts, and aerial photographs. Cover types were designated based on dominant vegetation species and successional growth stage. Indications of possible stress due to chemical contamination, such as sparse or dead vegetation, were also noted, along with observations of potential wildlife utilization of the landfill as habitat or of landfill seeps as drinking water sources.

Although the Shepley's Hill Landfill site contains known locations or observations of resident and transient species of concern (including the grasshopper sparrow, upland sandpiper, and bald eagle), systematic population surveys were not conducted in this stage of the work. Field collection and identification of fish and benthic invertebrates was not performed (see Section 9.2).

2.2 COLD SPRING BROOK LANDFILL

2.2.1 Geophysical Surveys

Detail of the Cold Spring Brook Landfill history is unknown, and prior to this RI, the full extent of the filled area was uncertain. To determine this extent, two complementary surveys were performed using both an EM-31 terrain conductivity meter and a proton procession magnetometer.

In order to conduct these surveys, E & E created a square grid of 20-foot by 20-foot intervals over the suspected extent of the fill and overlapping onto areas where fill might be present. Each grid line was cleared of vegetation sufficiently to permit access. The magnetic field/magnetic gradient and average conductivity were then noted at each grid node. The data was then interpreted by the field and office geologists, and the extent of fill estimated.

Please refer to Appendix H for a complete report of these surveys.

2.2.2 Soil Sampling

Surface soil samples were collected at Cold Spring Brook to support the ecological risk assessment. Due to the landfill's surface reverting to a quasi-natural state (i.e., semi-climax vegetation without the kind of maintenance found at Shepley's Hill Landfill) potential exposure of the biota to contaminants in the surface soils posed a concern. Three locations for sample collection were selected (see Figure 2-6). Soil samples were taken at three points, each of which was within either the western, eastern, or middle third of the landfill area. Actual sampling points were selected on the basis of the presence of moderately fine-grained soils, i.e., sand and silt. These samples were analyzed for TCL organics, TAL metals, and other general analytical parameters.

Surface soil samples were collected from a depth of 0 to 6 inches below ground surface at each sampling location. Soil samples were collected according to the following procedures:

- o Care was taken that the appropriate number of pre-cleaned sample bottles, including preservatives, were transported to the field.
- o Labels were placed on pre-cleaned sample bottles prior to collection. Sample labels were filled out with waterproof ink and included the sampler name, sample identification, sample location, date, and analysis to be performed. The actual time of collection was added after collection.
- o E & E personnel used a clean stainless steel spoon to scrape soil samples from the ground surface over an area large enough to fill the required volume of samples.
- o Leaves, roots, sticks, and rocks were avoided.
- o Soils for VOA analysis were collected first and placed directly into their containers. The matrix for the remaining samples was homogenized in a stainless steel bowl prior to being placed in the sample jars. The order of sample collection following volatile collection was, typically, extractables, metals, and TOC.

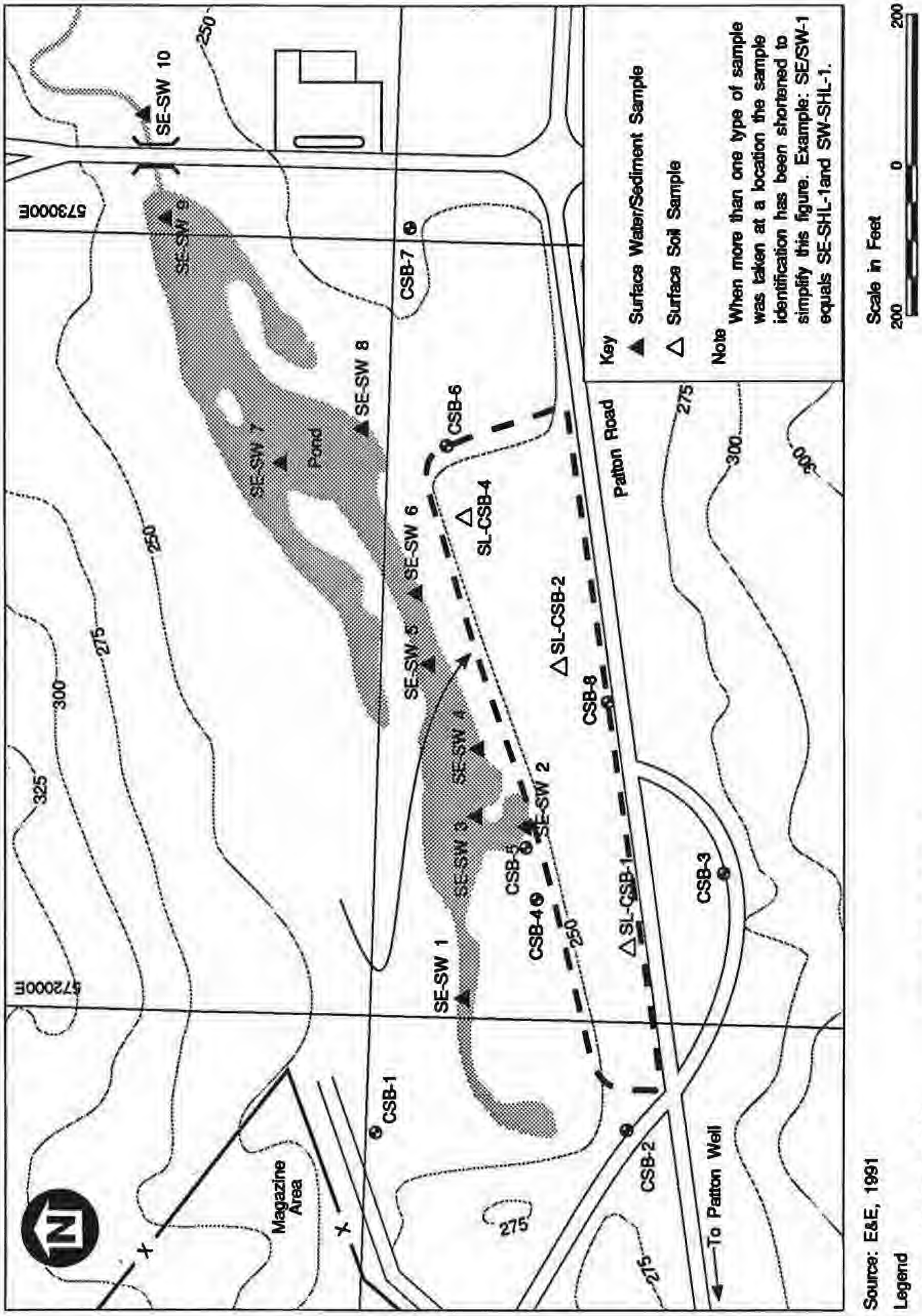


Figure 2-6 COLD SPRING BROOK LANDFILL AREA AND SAMPLING LOCATIONS

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- o Stainless steel spoons were decontaminated to avoid cross-contamination.

- o Any observable physical characteristics of the soil as it was being sampled (e.g., color, odor, physical state) were recorded in the field log book.

- o All pertinent weather information at the time of sampling, such as air temperature, wind and sky conditions, and precipitation, was recorded in the field log book.

2.2.3 Surface Water and Sediment Sampling

To determine the extent and source(s) of contamination in Cold Spring Brook, 10 surface water and 10 sediment samples were collected. Soil samples were taken at three points, each of which was within the western, eastern, or middle third of the landfill area. Actual sampling points were selected on the basis of the presence of moderately fine-grained soils, i.e., sand and silt. See Figure 2-6 for sampling locations.

Surface water samples were analyzed for TCL organics, TAL metals, explosives, and other general analytical parameters. The general analytical parameters analyzed for at Cold Spring Brook Landfill were: TPHC, chloride, total kjeldahl nitrogen (TKN), nitrate, sulfate, total phosphorus, hardness, alkalinity, and total suspended solids. In addition, pH, conductivity and dissolved oxygen were measured in the field. Sediment samples were analyzed for TCL organics, TAL metals, explosives, and other general analytical parameters. The general parameters analyzed for were TPHC and TOC. In addition, sediment samples were measured for grain size distribution (see Appendix F). The rationale for choosing sampling locations for surface water and sediment samples is presented in Table 2-5.

2.2.3.1 Surface Water Sampling

E & E collected surface water samples from Cold Spring Brook Landfill. As necessary, a boat was used to reach sample locations. The samples were collected in accordance with the following procedures:

- o Care was taken that the appropriate number of pre-cleaned sample bottles, including preservatives, were transported to the field for sample collection.

- o Labels were placed on pre-cleaned sample bottles prior to collection. Sample labels were filled out with waterproof ink and included sampler name, sample identification, sample location, date, preservatives added, and analytical purpose. The actual time of collection was added after the sample was collected.

Table 2-5

**COLD SPRING BROOK LANDFILL
SURFACE WATER/SEDIMENT
RATIONALE FOR CHOOSING SAMPLING LOCATIONS**

Sample ID Designation	Location and Rationale
SW-CSB-1/SE-CSB-1	Upstream of landfill on western edge of Cold Spring Brook Pond; to monitor conditions where the upstream flow from the magazine area enters the pond.
SW-CSB-2/SE-CSB-2	Southern edge of Cold Spring Brook Pond near to shore; to monitor potential migration of contaminants from western portion of landfill.
SW-CSB-3/SE-CSB-3	Equidistant from north and south shores of Cold Spring Brook Pond; to monitor potential migration of contaminants toward center of pond.
SW-CSB-4/SE-CSB-4	Southern edge of Cold Spring Brook Pond near to shore; to monitor potential migration of contaminants from western portion of landfill and from drums at base of landfill.
SW-CSB-5/SE-CSB-5	Equidistant from north and south shores of Cold Spring Brook Pond; to monitor potential migration of contaminants toward center of pond.
SW-CSB-6/SE-CSB-6	Southern edge of Cold Spring Brook Pond near to shore; to monitor potential migration of contaminants from eastern portion of landfill.
SW-CSB-7/SE-CSB-7	Equidistant from north and south shores of Cold Spring Brook Pond; to monitor potential migration of contaminants toward center of pond and downstream of landfill.
SW-CSB-8/SE-CSB-8	Southern edge of Cold Spring Brook Pond near to shore, at northeastern corner of landfill; to monitor potential migration of contaminants from eastern portion of landfill.
SW-CSB-9/SE-CSB-9	Eastern edge of Cold Spring Brook Pond near Patton Road; to monitor potential migration of contaminants downstream.
SW-CSB-10/SE-CSB-10	Cold Spring Brook to the east of Patton Road; to monitor potential migration of contaminants downstream.

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SW: Surface Water Sample
SE: Sediment Sample

Source: E & E, 1991

- o A pre-cleaned, wide-mouthed glass bottle used for sample collection was dipped into the creek or pond and rinsed three times. The bottle then was dipped to collect the sample and the water transferred into the respective sampling containers, which also were triple rinsed with sample water. Water samples contained only liquids (no sludges or sediments). Preservatives were not added prior to rinsing. The VOA bottle was immersed directly into the medium sampled, then filled, preserved, and capped.

- o The sample was collected in such a manner as to prevent agitation of the water, which promotes the loss of volatile organics and increases the dissolved oxygen content.

- o VOA sample bottles were filled first. The order of collection following VOAs was, typically, TPH, extractables, metals, explosives, and water quality parameters.

- o All VOA sample containers were completely filled and inverted and inspected to ensure that they did not contain any bubbles.

- o To avoid agitation of the sample and possible cross contamination, preservation of the sample to the appropriate pH was checked by using a separate bottle prior to actual sampling for volatile analysis. A representative sample for the matrix and site was collected, an appropriate amount of preservative was added (i.e., two to three drops for VOAs), the container shaken, and the pH tested with pH paper. Once the proper level of preservative was determined in the test bottle, that amount of preservative was added to the rinsed VOA sample bottle. For other analyses, the proper preservative was added, the sample capped and shaken, and the pH checked by pouring a very small amount of sample into a separate disposable container and using pH paper on the sample aliquot.

- o Other samples were collected in a pre-cleaned, wide-mouthed bottle and transferred into 1/2-gallon glass bottles and other appropriate bottles required for chemical analyses. The wide-mouthed bottle was refilled as many times as necessary to fill all required sample bottles.

- o The temperature, pH, dissolved oxygen, and specific conductance of the water were measured in the field, prior to sample collection.

- o Any observable physical characteristics of the water (e.g., color, odor, turbidity) were recorded in the field log book as the water was being sampled.

- o Sample bottles were wiped dry after being capped and then placed in plastic bags to be shipped for analysis.

- o Weather conditions at the time of sampling (e.g., air temperature, wind and sky conditions, precipitation) were recorded in the field log book.

2.2.3.2 Sediment Sampling

Sediment samples were collected in conjunction with the surface water locations discussed above. The following procedures were employed:

- o Care was taken that the appropriate number of pre-cleaned sample bottles were transported to the field.

- o Labels were placed on pre-cleaned sample bottles prior to collection. Sample labels were filled out with waterproof ink and included the sampler name, sample identification, sample location, date, and analysis to performed. The actual time of collection was added after the sample was collected.

- o An Ekman sampling device was used to collect bottom sediment samples after the surface water samples had been collected. The Ekman sampler is a clamshell-shaped device activated by a weight dropped along a rope attached to the sampler. The pond sampling, both surface water and sediment, was conducted while in a small boat. The Ekman sampler, with clamshell scoops held open by small cables attached to the spring-loaded triggering device, was slowly lowered to the pond bottom. With the sampler resting on the pond bottom, the weight was dropped rapidly along the rope to close the clamshell scoops and collect bottom sediment. The sampler was then slowly pulled up to the boat, and held along side the boat to allow excess water to drain out of the sampler back into the pond. The sampler was then brought into the boat, the clamshell scoops opened, and the collected sediment placed into a stainless steel bowl prior to distribution into the appropriate sample bottles.

- o All samples, to the extent possible, contained no less than 30 percent solids.

- o From the stainless steel bowl, VOA and TPH samples were collected first and placed directly into the respective containers.

- o After the VOA and TPH samples were collected, samplers used a stainless steel spoon to homogenize the sediment remaining in the stainless steel bowl. From the homogenized sediment, samples were taken to fill containers for the remaining sample analyses (e.g., extractable metals, explosives, and TOC).

- o To prevent cross-contamination, stainless steel spoons were not reused.

- o Any observable physical characteristics of the sediment as it was being sampled (e.g., color, odor, physical state) were recorded in the field log book.

- o All pertinent weather information at the time of sampling, such as air temperature, wind and sky conditions, and precipitation, was recorded in the field log book.

2.2.4 Groundwater Sampling

Sampling of the seven wells at Cold Spring Brook Landfill (see Figure 2-7) consisted of the following activities:

- o measuring the depth to water level and total depth of the well (to calculate well volume),

- o purging static water, and

- o collecting samples.

These groundwater sampling activities followed USATHAMA's Quality Assurance Program (January 1990) and are described in the following sections.

2.2.4.1 Measurement of Water Level and Well Volume

Prior to sampling, the static water level and total depth of each well were measured with an audible electronic water level meter. Care was taken to decontaminate equipment between each use to avoid cross-contamination of wells. The number of linear feet of static water (difference between static water level and total depth of well) was calculated, and used to figure the volume of static water in each well.

2.2.4.2 Purging Static Water

Before collecting a groundwater sample, E & E first purged the static water to ensure that a representative groundwater sample was taken. A minimum of five times the static water volume (including saturated annulus) was purged from the well prior to collection of the VOC samples. At wells that were extremely slow in recharging, purging the well dry was deemed adequate, even if this occurred prior to purging five static water volumes.

Purging was performed using dedicated Teflon bailers or submersible pumps. The water removed from the well during the purging process was initially containerized and observed visually and with monitoring instruments. If visual contamination was observed or if the headspace analysis of the purge water was greater than 10 parts per million (ppm) over background, the drums were retained for RCRA classification and disposal in accordance with the Fort Devens Hazardous Materials Plan (Prior, 1991). If the OVA readings were less than 10 ppm above background, the purge water was disposed of at the well site.

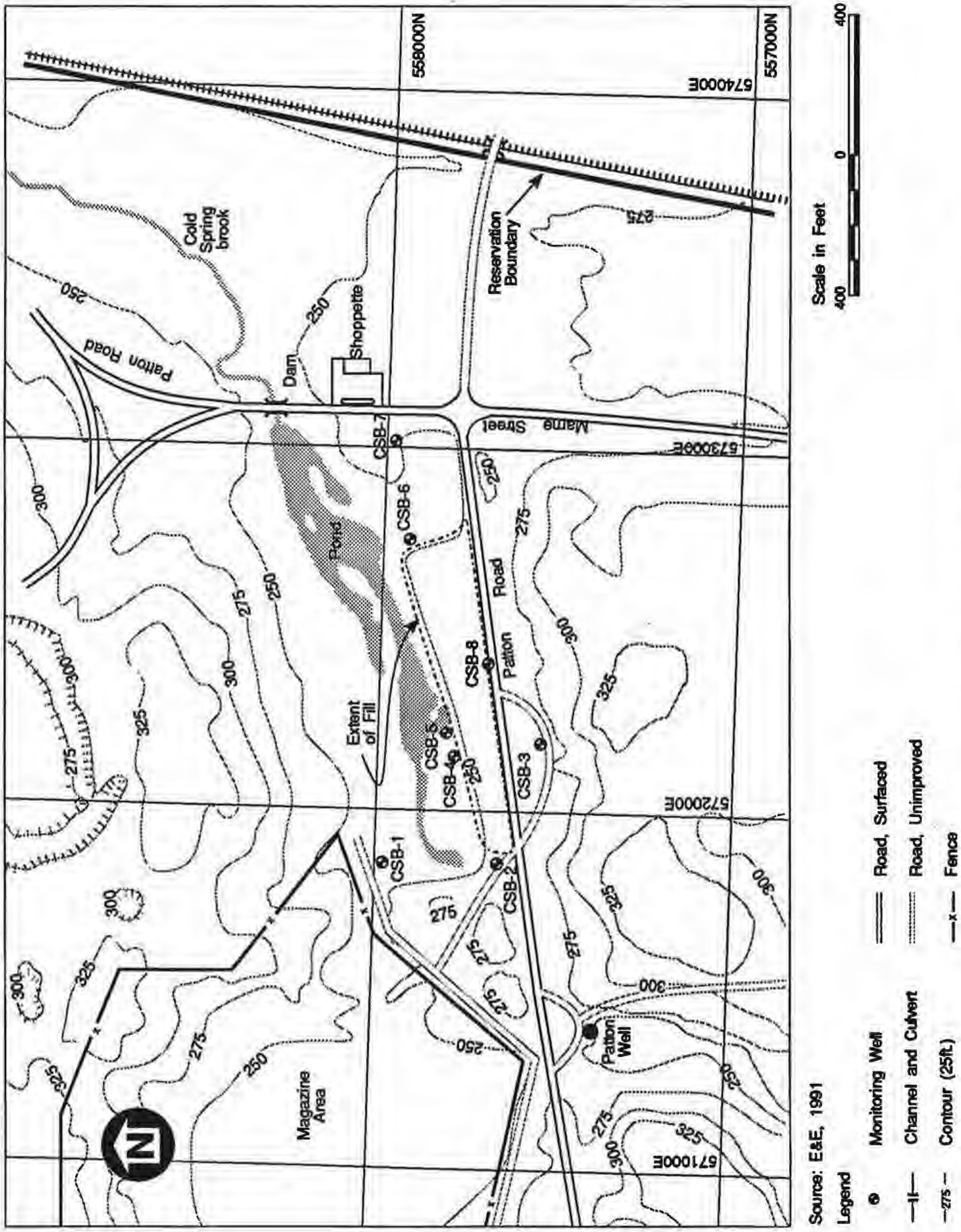

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Figure 2-7 LOCATIONS OF MONITORING WELLS ON COLD SPRING BROOK LANDFILL

2.2.4.3 Sample Collection

Groundwater samples were analyzed for TCL organics, TAL metals, explosives, and other general analytical parameters. The other general parameters analyzed for include: chloride, fluoride, sulfate, nitrate, nitrite, bromide, TKN, and TPHC. Sampling personnel took precautions against cross-contamination by dedicating a Teflon bailer and rope to each well. Collection of groundwater samples from the monitoring well was conducted in the following manner:

- o Care was taken that the appropriate number of pre-cleaned sample bottles, including preservatives, were transported to the field for sample collection.

- o Labels were placed on pre-cleaned sample bottles prior to sample collection. Sample labels were filled out with waterproof ink and included sample name, sample identification, the sample location, date, time, preservatives added, and analytical purpose.

- o The pre-cleaned glass sampling bottles were triple rinsed with the sample water in order to fill up any unused ionic bonds on the glass surface. Water samples contained only liquids (no sludges, etc.).

- o The samples were collected in such a manner as to prevent agitation of the water, which promotes the loss of volatile organics and increases the dissolved oxygen content.

- o Samples analyzed for volatile organics did not have any headspace (or bubbles) in the sample jar, and were handled as little as possible. A few drops of hydrochloric acid were added to VOA samples to reduce the pH to less than 2, to extend the holding time to 14 days. To determine the amount of hydrochloric acid to add to the vials, a test vial of water was acidified with the same quantity of acid as the samples and the pH of this test vial was checked with pH paper in the field.

- o The order of collection was, typically, VOA, TPHC, extractables, metals, explosives, and anions/cations.

- o The temperature, pH, and specific conductivity of the water was measured in the field, prior to sample collection.

- o Any observable physical characteristics of the water (e.g., color, odor, turbidity) were recorded in the field log book as the water was being sampled.

- o Sample bottles were wiped dry after being capped and placed in plastic bags to be shipped for analyses.

- o Weather conditions at the time of sampling (e.g., air temperature, wind and sky conditions, and precipitation) were recorded in the field log book.

2.2.5 Surveying

Installation-wide water level measurements were included as part of the RI. Besides the 17 new wells installed under the RI and SI programs, 66 existing wells were surveyed for elevation and location. Table 2-3 provides a complete list of wells at Fort Devens. These wells consist of both monitoring and water production wells. Monitoring wells have been located on the Fort Devens base map. Map coordinates were transferred to the USATHAMA IRDMIS (USATHAMA 1987). These data will support the development of a Fort Devens groundwater contour elevation map throughout the Main Cantonment Area and North Post.

All wells were surveyed for horizontal location and vertical elevation as per USATHAMA geotechnical requirements. Elevations at each well were measured at ground surface, the highest point of the well riser, and the highest point of the well protective casing (as applicable). Survey work was performed by Gordon Soderholm and Associates, P.C. of Depew, N.Y., using a professionally licensed surveyor and a crew trained in accordance with OSHA regulations.

2.2.6 Groundwater Level Measurements

Prior to the start of the RI, the Army identified 83 wells at Fort Devens, including the 17 wells to be installed during RI/SI programs (see Table 2-3). This does not include the multiple well points at the Grove Pond "Well" or more accurately "wellfield." All wells identified by the Army were surveyed and the water levels in them measured during three periods separated by intervals of not less than 3 months.

At Cold Spring Brook Landfill, 7 wells were identified, surveyed, and included in the groundwater measurement schedule. Groundwater measurements at these wells were taken on 30 August 1991, on 12 December 1991, and on 19 March 1992.

A water level gauge was also installed in Cold Spring Brook to allow comparison of surface water elevations with water table elevations beneath the landfill.

Water levels were measured using electronic water level indicators having audible alarms and accurate to within 0.01 foot. The depth to groundwater was measured from the highest point on the rim of the well casing or riser. These same points at each well were surveyed for vertical elevation. To the extent practicable, each round of groundwater measurements was made over a single, consecutive 10-hour period.

The depths to groundwater have been converted to elevations for use in reports. To enter the data into the IRDMIS, E & E calculated the depth below ground surface. The groundwater contour maps developed from monitoring well water levels in all wells provide information on flow direction and for the flow velocity calculation.

At wells where the well riser was absent or inaccessible, measurements were taken from the highest point of each well's outer, protective casing.

Water level measurements are provided in Appendix J.

2.2.7 Aquifer Testing

In-situ hydraulic conductivity values for the geologic units screened by the monitoring wells was obtained by slug testing the monitoring wells using the methodology described in Appendix B. Figure 2-7 shows Cold Spring Brook well locations where aquifer tests were performed. Slug testing involves displacing water in a monitoring well and measuring the rate at which the water level recovers to static conditions.

The slugs were made from new PVC casing. After one end was sealed, quartz sand was added to the inside of the casing to act as a weight. The other end of the casing was then sealed. The sizes of the slugs used were 5-foot or 2-foot lengths by 1.25-inch outer diameter for the 2-inch monitoring wells and 5-foot length by 1.5-inch outside diameter for 4-inch monitoring wells.

At each of the seven Cold Spring Brook Landfill monitoring wells, OVA readings were taken immediately upon opening the well cap. Depth to water and total well depth were measured using an audible electronic water level meter. These measurements were used to determine the length of the water column and to determine the appropriate slug length. The water level, total depth, and slug size were recorded on a separate data sheet for each well. Some wells did not contain sufficient water (less than 3 feet) to run a slug test.

An in-situ Hermit 2000 Data Logger and pressure transducer system (e.g., 10 or 20 pounds-per-square-inch transducers) were used to record each test.

All instruments to be placed in a monitoring well were rinsed with distilled water before placement. The transducer probe was lowered to the bottom of the monitoring well and then raised a minimum of several inches, the amount depending on the depth of water present in the well. The rope connected to the slug was carefully measured to a length that allows the slug to be completely submerged while allowing enough room for the transducer probe below.

At each well location, the test number was entered into the data logger and recorded on the data sheet. The slug was lowered into the well but above the water level. The slug was then lowered quickly but steadily into the water. The data logger measured falling head values during the "slug in" testing. After a minimum recovery of 90 percent of original static water level, or a 1 hour run time, the head level, drawdown, and time were noted. "Slug out" testing was then performed by removing the slug. After 90 percent recovery was obtained or 1 hour had passed, the head value, drawdown, and time were noted and the test was stopped. All instruments were rinsed with distilled water upon removal from the well.

However, not all of the wells were successfully slug tested. The two primary reasons are as follows:

- o lack of the appropriate depth of water in the well, and
- o too high a hydraulic conductivity resulting in very rapid recoveries.

2.2.8 Air Survey

As part of the RI at Cold Spring Brook Landfill, an air quality survey was conducted to determine the ambient air concentrations of respirable particulate matter (PM-10) and VOCs upwind and downwind of the landfill. A narrative description of the results of the air survey and all supporting data can be found in Appendix G.

The air quality survey was conducted in the following four stages: meteorological monitoring, sample site selection, PM-10 sampling, and VOC sample collection.

2.2.8.1 Meteorological Monitoring

The purpose of meteorological monitoring was to collect data that could be used to select appropriate sampling locations, and would document the meteorological conditions under which the air samples were taken. E & E monitored the following meteorological parameters: temperature, relative humidity, wind speed, wind direction, and barometric pressure. These parameters were monitored for the duration of the air quality survey. The standard deviation of wind direction, sigma theta, was calculated in real time from the wind direction measurements. Meteorological data are presented in Appendix G.

The meteorological monitoring equipment consisted of a temperature/relative humidity sensor, a wind speed sensor, and a wind direction sensor mounted on a cross-arm atop a 5-meter aluminum tower secured by guy wires. A weather-proof box at the base of the tower housed an Odessa Engineering DSM-3260 data storage module and the barometric pressure sensor. The sensors were connected to a junction box mounted on the tower, which in turn was connected by a main cable to the data storage module. The system was powered by a 9-volt deep cycle marine battery. The data were accessed with a lap-top computer and Odessa Engineering's ENVICOM software.

The meteorological station was sited using the criteria set forth in the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV-- Meteorological Measurements prepared by the EPA in 1989. In this document, EPA recommends that a meteorological tower should be sited in "open terrain," which is defined as an area where the horizontal distance between the instruments and any obstruction is at least 10 times the height of that obstruction. The meteorological station was sited in the middle of Shepley's Hill Landfill (see Figure 2-5) in accordance with these criteria.

2.2.8.2 Sample Site Selection

The Cold Spring Brook Landfill is in a low-lying, densely-vegetated area that prevented sampler placement according to the conventions followed at Shepley's Hill Landfill (Section 2.1.11.2). At Cold Spring Brook, samplers were placed directly on the landfill (see Figure 2-8). The PM-10 sampler was placed within the only clearing on the site and the VOC sampler was placed in proximity to monitoring well CSB-04. The dense vegetation covering the site yields low wind speeds, thus decreasing the dispersion of pollutants leaving the site. Sampling directly on the landfill helped in determining whether any contaminants were emitted from the landfill area. However, downwind transport could not be quantified by sampling.

2.2.8.3 Respirable Particulate Matter (PM-10) Sampling

Metal contamination has been associated with the Cold Spring Brook Landfill. The air pathway for exposure to metals is through inhalation of PM-10. PM-10 is defined as particulate matter with a diameter of 10 microns or less. The EPA reference method for determination of the ambient concentration of PM-10 is given in 40 CFR 50 Appendix J. This method requires drawing an air sample at a constant flow rate first through a size-selective inlet, where particles greater than 10μm are removed, and then through a filter medium. The filter medium can be weighed to determine the total mass of PM-10. The 24-hour sample is accurately timed and the mass concentration of PM-10 can then be determined by the total volume of air sampled. The equipment used to sample PM-10 at Fort Devens was the General Metal Works HVPM-10, which consists of a high volume blower and filter housing, mass flow controller, size selective inlet, digital timer, and flow event recorder. The filter media used in this equipment is an 8 x 10 inch glass fiber filter.

The HVPM-10 samplers were calibrated on site before being deployed in the field. Calibration of a high volume sampler refers to calibration of the sampler's flow-rate indicator. Once calibrated, the flow rate indicator provides an accurate reading of the sample flow rate from which the volume of the sampled air can be calculated (EPA-60/4-77-027a 1983). The calibration procedure employed consisted of the following steps:

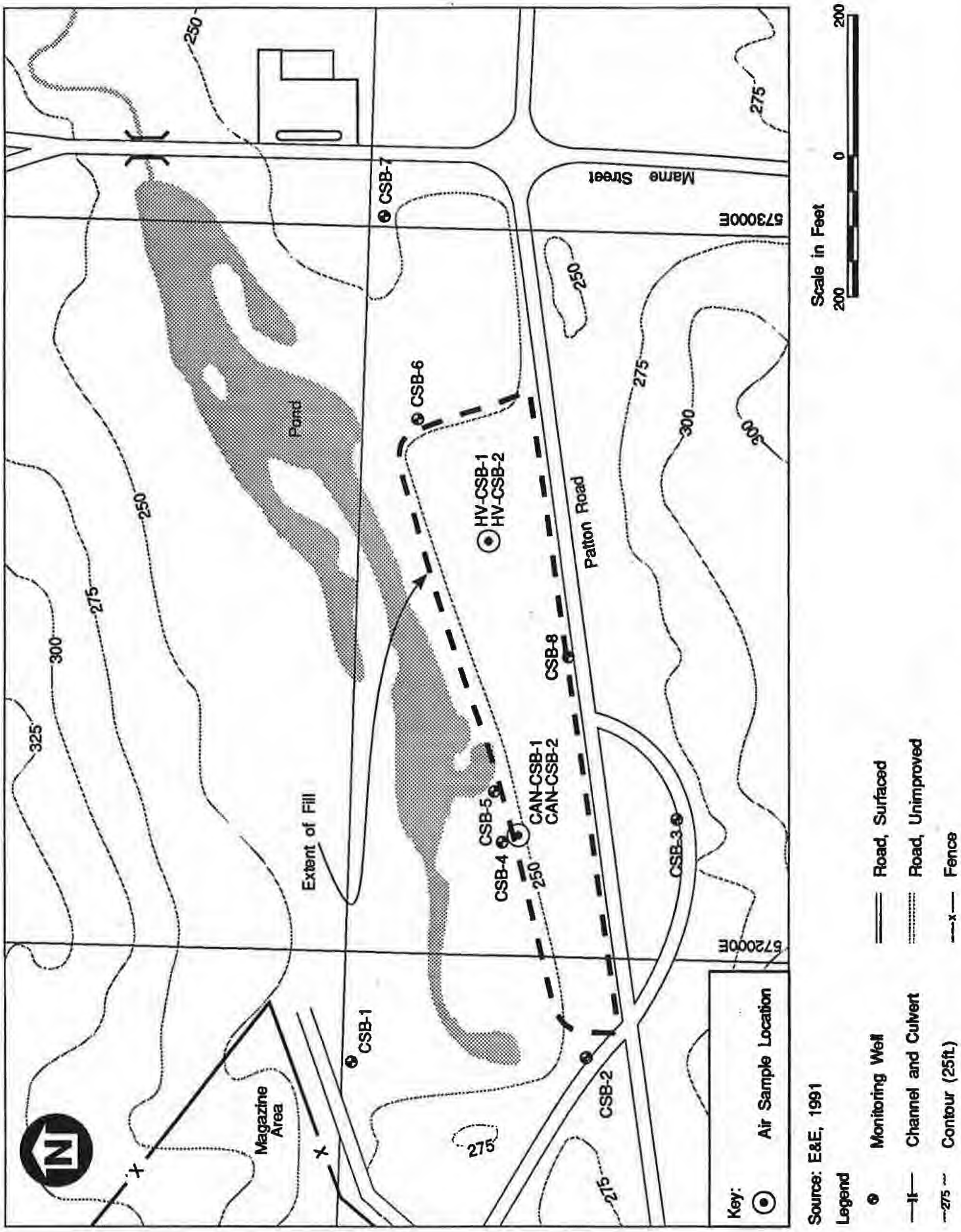

Figure 2-8 LOCATION OF AIR SAMPLES AT COLD SPRING BROOK LANDFILL

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- o Calibration equipment was assembled and the calibration orifice on the sampler was installed.
- o The sampling system was checked to ensure that there were no leaks.
- o An 18-hole plate was installed in the orifice device.
- o The sampler was turned on and allowed to warm up.
- o Ambient pressure (Ta), barometric pressure (Pa), seasonal average temperature (Ts), seasonal average pressure (Ps), orifice serial number and calculated flow rate (Qa), calibration curve slope (m), y-intercept (b), and linear regression (r) were all recorded.
- o Manometer deflection (ΔP H2O) was recorded.
- o Event recorder response (I) was recorded.
- o The last five steps were repeated with 13-, 10-, 7-, and 5-holed plates, then the sampler was turned off.
- o Qa was calculated: $Qa=1/m\{\sqrt{\Delta H2O(Ta/Pa)}\}-b$.
- o The recorder response was corrected to actual conditions: $IC=I[\sqrt{(Ta/Pa)}]$.
- o Calibration was corrected to seasonal conditions: $ms=m/[\sqrt{(Ts/Ps)}]$, $bs=b/[\sqrt{(Ts/Ps)}]$.
- o The mass flow controller set point flow rate (SFR) was calculated: SFR=1.13(Ps/standard pressure(Pstd))(standard temperature(Tstd)/Ts).
- o The mass flow controller set point recorder response was calculated (SSP): $SSP=\{[m(SFR)+b][\sqrt{(Ps/Ts)}]\}$.
- o The filter was installed, the sampler turned on, and the mass flow controller was set to the calibrated set point.

The calibration sheets for each of the PM-10 samplers used at Fort Devens are presented in Appendix G.

PM-10 samples were collected during two sampling events. The samplers were programmed to run for 24 hours for each sample.

2.2.8.4 VOC Sample Collection

Ambient VOC samples were collected in 6-liter SUMMA polished stainless steel canisters in accordance with EPA Method TO-14, "Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using

SUMMA Passivated Canister Sampling and Gas Chromatographic Analysis." This method is found in EPA document 600/4-84-041, Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. Samples were drawn through Scientific Instrumentation Specialists model AGS-1/D automated canister samplers. The AGS-1/D consists of a pump, timer, and flow controller. The AGS-1/D was used to collect a pressurized sample of approximately 14 liters over a period of 8 hours.

E & E used the following sampling and calibration procedures:

- o Each sampler was connected to a 12-volt battery.
- o The sampler flow rate was measured with a Buck Primary Gasflow Calibrator and the flow rate was adjusted to approximately 30 cc/minute and recorded.
- o A 6-liter canister was connected to the sampler. Canisters were certified clean by an analytical laboratory.
- o An 8-hour sampling period was programmed on the sampler timer.
- o The valve was opened on the canister and initial pressure was recorded.

When sampling was completed:

- o Final pressure in the canister was recorded.
- o The valve on the canister was closed.
- o The final flow rate was checked using a Buck Primary Gasflow Calibrator, and the rate was recorded.

VOC samples were collected during two sampling events.

2.2.9 Ecological Assessment

Ecological investigation of the Cold Spring Brook Landfill site was required to provide information for use in the baseline risk assessment (human health evaluation and environmental evaluation). The primary objective of the ecological investigation was to identify and evaluate existing aquatic, terrestrial, and wetland communities. Emphasis was placed on sensitive environments or species that may come in contact with site contaminants, such as State- or federally-designated wetlands, critical habitats, and endangered species. Based on E & E's preliminary evaluation of available information on site ecology and a site visit, the ecological resources potentially impacted by the Cold Spring Brook Landfill were identified for further characterization. These resources included aquatic and wetland communities in the vicinity of Cold Spring Brook, as well as terrestrial vegetation and wildlife species living on or in the vicinity of the landfill.

Ecological characterization of the site was based on collection and analysis of existing site data, in conjunction with a field investigation of the landfill. A two-member field team surveyed each of the two landfill sites during the week of 12 through 16 August 1991.

The appropriate State and Federal agencies were consulted to determine if any rare, threatened, or endangered species or specially designated ecosystems live on or near the sites, and to establish if there are recreationally important fish species found in Cold Spring Brook. The Fort Devens Natural Resource Office was consulted for site-specific information on protected or recreationally-important species as well as for general information on site vegetation, fish, and wildlife, including species lists.

Literature and map resources were reviewed prior to the initiation of fieldwork. These resources included U.S. Army site maps, U.S. Army aerial photographs, USGS Ayer and Shirley topography quadrangle maps, the USFWS Ayer and Shirley quadrangle National Wetlands Inventory (NWI) maps, the Atlas of Estimated Habitats of State-Listed Rare Wetlands Wildlife (MNHESP 1992), the Soil Survey of Middlesex County (USDA 1924), and the Soil Survey of Worcester County (USDA 1985).

This information was supplemented by a field ecological survey of the site. This survey included a wetland delineation and functional assessment. Wetlands were delineated using procedures described in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineation 1989) and the New England Division of the USACE wetland delineation guidance document (USACE 1991). Vegetation, soils, and hydrology were sampled at one wetland point and one adjacent upland point for each wetland plant community. The boundaries of jurisdictional wetlands were flagged on-site. Wetland functions were assessed for wetlands associated with each landfill site using Wetland Inventory Data forms (Hollands an McGee 1985). These data forms were designed by Hollands and McGee (1985) in response to requirements promulgated under the Massachusetts Protection Act (MGL Chapter 131, Section 40) to assess the functions of wetlands. An example of the Wetland Inventory Dataform is provided in Appendix E.

In addition to the wetland delineation, the ecological survey of the site included a walkover survey. Wildlife use of each landfill site was evaluated using literature sources as well as field observations. Species lists were generated by reviewing New England Wildlife: Habitat, Natural History, and Distribution (DeGraaf and Rudis 1986) for relatively common species that occur within Middlesex and Worcester counties, Massachusetts. These species lists were augmented by wildlife sightings made during the five-day field survey. Wildlife sightings included direct observations as well as identifications based on vocalizations, tracks, burrows, browse, and scat. General wildlife values (e.g., food and cover availability) of each cover type were also noted. Dominant species in the overstory, understory, and herbaceous layers were identified and vegetation cover types were mapped using information from the survey, agency contacts, and aerial photographs. Cover types were designated based on dominant vegetative species and successional growth stage. Indications of possible stress due to chemical contamination, such as sparse or dead vegetation, were also noted, along with observations of potential wildlife utilization of the landfill as habitat or of landfill seeps as drinking water sources.

Systematic population surveys were not conducted in this stage of the work. Field collection and identification of fish and benthic invertebrates was not performed.

2.3 QUALITY CONTROL PROCEDURES

2.3.1 Field QC Samples

Various types of field QC samples were used to check the effectiveness of field handling methods. The type of QC samples and analytical requirements which were proposed for the RI sites are summarized on Table 2-6. They were analyzed in the laboratory as samples, and their purpose was to assess the sampling and transport procedures as possible sources of sample contamination and to determine overall sampling and analytical precision.

Field QC samples and the frequency of collection are described 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 at ADL prior to the sampling event and shipped with the sample bottles. Trip blanks were prepared by adding organic-free water to a 40-ml volatile organic analysis (VOA) vial containing 2 to 3 drops of concentrated hydrochloric acid. One trip blank was used with every cooler of samples, or one trip blank per 10 volatile organic samples (regardless of matrix) was used, whichever was greater. Each trip blank was transported to the sampling location, handled like a sample, and returned 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 properly prepared and 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.

Rinsate blanks were collected at a frequency of 1 per 20 samples or per decontamination event as specified in the RI Field Sampling Plan. Rinsate blanks were not collected with sampling activities using dedicated equipment.

Table 2-6

SUMMARY OF ALL RI ANALYTICAL REQUIREMENTS

Site Name	Analysis	Number of Samples	Dup	QA/QC Samples Trip(*)	Rin	MS/ MSD(**)	MS/Lab	Total Number Samples
Shepley's Hill AOC 4,5,18	TCL (28 groundwater wells)	56	3	2	0	2	0	61
	TCL (surface water)	18	1	2	0	0	0	21
	TCL (pond sediment)	15	1	0	1	1	0	18
	TCL (leachate soil)	3	0	0	1	0	0	4
	TAL (28 groundwater wells)	56	3	0	0	0	2	61
	TAL (surface water)	18	1	0	0	0	0	19
	TAL (pond sediment)	15	1	0	1	0	1	18
	TAL (leachate soil)	3	0	0	1	0	0	4
	Explosives (28 groundwater)	56	3	0	0	2	0	61
	Explosives (surface water)	18	1	0	0	0	0	19
	Explosives (pond sediment)	15	1	0	1	1	0	18
	Explosives (leachate soil)	3	0	0	1	0	0	4
	Air Quality Particulates	7	1	0	0	0	0	8
	Air Quality Organics	7	1	0	0	0	0	8
	TOC (pond sediment)	15	1	0	1	0	0	17
	TOC (well borings)	12	0	0	0	0	0	12
	Ions (28 groundwater)[a]	56	3	0	0	0	0	59
	Water Quality (surface water)[b]	18	1	0	0	0	0	19
Cold Spring Brook Landfill AOC 40	TCL (8 groundwater wells)	16	1	2	0	1	0	20
	TCL (surface water)	10	1	2	0	0	0	13
	TCL (pond sediment)	10	1	0	1	1	0	13
	TCL (surface soil)	3	1	0	1	1	0	6
	TAL (8 groundwater wells)	16	1	0	0	0	1	18
	TAL (surface water)	10	1	0	0	0	0	11
	TAL (pond sediment)	10	1	0	1	0	1	13
	TAL (surface soil)	3	1	0	1	0	1	6
	Explosives (8 groundwater)	16	1	0	0	1	0	12
	Explosives (surface water)	10	1	0	0	0	0	11
	Explosives (pond sediment)	10	1	0	1	1	0	19
	TOC (surface soil)	3	1	0	1	1	0	16
	Air Quality Particulates	1	1	0	0	0	0	2
	Air Quality Organics	1	1	0	0	0	0	2
	TOC (pond sediment)	10	1	0	1	0	0	12
	Ions (8 groundwater wells)[a]	16	1	0	0	0	0	17
	TPHC (8 groundwater wells)	16	1	0	0	0	0	17
	TPHC (surface water)	10	1	0	0	0	0	11
	TPHC (pond sediment)	10	1	0	1	0	0	12
	Water Quality (surface water)[b]	10	1	0	0	0	0	11

RC424

TAL: Target Analyte List
TCL: Target Compound List
TOC: Total Organic Carbon
TPHC: Total Petroleum Hydrocarbons

* Trip blanks will be analyzed only for VOAs. The trip blank for air quality particulates is a filter blank.

**MS/MSD samples are for pesticide/PCB and explosives analysis only. Only methods that do not use USATHAMA surrogates will be collected for MS/MSD analysis.

a Anions/Cations: bicarbonate, chloride, sulfate, nitrate, dissolved oxygen, and total nitrogen (Cations: calcium, potassium, and magnesium are included in TAL).

b Water quality parameters include chlorides, total nitrogen, nitrate-nitrogen, sulfates, total phosphorous, hardness, alkalinity, and total suspended solids.

Source: E & E, 1991

Field Duplicates consist of a set of two samples collected independently at a sampling location during a single sampling event. Field duplicates were sent to the laboratory and were indistinguishable from other analytical samples, so that personnel performing the analyses were not able to determine which samples were field duplicates. Field duplicates assess the consistency of the overall sampling and analytical system. Duplicates were collected for every 20 samples of each type of matrix as specified in the RI Field Sampling Plan.

Matrix Spike/Spike Duplicates are actual field samples specified by the field personnel for additional laboratory QC samples. The QC samples are to determine the potential effects of matrix interferences on sample analytical results. A set of laboratory matrix QC samples were analyzed for each type of matrix at Fort Devens. Extra sample volume was normally submitted by field personnel, but all other procedures were handled by ADL.

For a discussion of laboratory QC samples, refer to sections 10.2 and 10.3 of the Quality Assurance Project Plan (QAPjP).

2.3.2 Decontamination

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, and after the completion of all monitoring wells. 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 consisted of:

- high-pressure cleaning;
- scrubbing with brushes, if soil remained on equipment; and
- high-pressure rinse.

Split spoons and other non-disposable equipment were decontaminated between each split spoon sampling event. If there was no evidence of contamination and no subsurface soil samples were collected, the split spoons were decontaminated as follows:

- scrubbing with brushes,
- triple rinsing with USATHAMA-approved water, and
- air drying.

A temporary decontamination pad was constructed at Shepley's Hill Landfill using an area approximately 12 feet by 12 feet with a defined perimeter approximately 6 inches high, 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.

If any evidence of contamination was noted on material generated during field activities or decontamination procedures, the material was drummed on-site and labeled.

All drummed material generated from the E & E field activities was properly labeled with the following information:

- o Site Name,
- o Location,
- o Contents,
- o ID,
- o Date of Accumulation,
- o Sample ID, and
- o Sampler.

This material was stored in a secure storage area at Fort Devens.

2.3.3 Sample Preservation and Handling

The volumes and containers required for typical sampling activities are shown in Tables 5-1 and 5-2 of the QAPjP. Pre-washed sample containers obtained from a reliable supplier were provided by ADL. All containers were prepared in accordance with the current EPA bottle-washing procedures required for CERCLA investigations.

2.3.4 Laboratory Quality Procedures

Sampling and analysis of all matrices during the Fort Devens RIs were carried out in accordance with the requirements of the USATHAMA Quality Assurance Program (USATHAMA, January 1990) and specifications in the Fort Devens QAPjP (E & E, 1991). Samples were handled properly and conveyed to the subcontractor laboratory in accordance with specified chain-of-custody (COC) procedures. The QAPjP describes sample management procedures, including sample container and preservation requirements, chain-of-custody program protocol and records, and sample tracking and shipping. Data validation was performed by E & E as discussed in the QAPjP. E & E has received complete QA packages for all samples from ADL, and E & E has performed an independent review of these data.

During chemical analyses, the subcontractor laboratory QA/QC Coordinator, on a weekly basis, provided the QA Contractor/Manager with all system and performance audit reports; COC logs; holding time/ extraction analysis reports; batching reports; instrument logs; maintenance and calibration records; and complete analytical QC documentation as submitted to USATHAMA (control charts, method blanks, surrogate recovery, and matrix spike results). ADL provided copies of all corrective actions to E & E for approval. While ADL provided operational control of the laboratory, E & E's QA Coordinator/Manager retained ultimate responsibility for data quality.

3. RESULTS OF FIELDWORK - PHYSICAL CHARACTERISTICS

By analyzing the results of E & E's extensive field investigation and combining these results with information obtained from earlier investigations, E & E can present a more accurate description of the physical characteristics of Shepley's Hill Landfill and Cold Spring Brook Landfill. Improved understanding of each site's physical setting is essential to determining contaminant fate and transport (discussed in Section 6), which in turn forms the basis for the human health and ecological risk assessment (Sections 8 and 9, respectively). The physical characteristics discussed in this section include each landfill's ecology, geology, soils, groundwater, hydrology, surface water hydrology, sediments, and meteorology.

With regard to site ecology, E & E evaluates the actual or potential effects of site contaminants on biological resources other than people and domesticated species. The ecological assessment consists of two major activities, the ecological characterization and the ecological risk assessment. The ecological characterization provides a detailed description of the wetland, aquatic, and terrestrial plant communities present on and adjacent to the two landfill sites and the fish and wildlife associated with these communities. A major objective of the ecological characterization is to determine whether or not significant ecological resources that could be impacted by site contaminants are present within the vicinity of either landfill site. The ecological risk assessment (Section 8) evaluates the actual or potential effects of site contaminants on ecological resources by qualitatively or quantitatively characterizing the risks of specific contaminants for specific environmental receptors.

The results of the ecological assessment can be used to support remediation action for the two landfill sites. For example, the ecological assessment determines whether or not actual or potential effects of site contaminants to ecological resources warrant remedial action. Also, the ecological assessment can identify potential deleterious effects to ecological resources that may result from remedial actions. The determination of suitable remedial actions may require further sampling of fauna in aquatic and wetland areas.

This ecological assessment was conducted in accordance with three EPA guidance documents: Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual (USEPA 1989d), Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA 1989b), and Guidance for Ecological Risk Assessments (USEPA 1989e). Additional EPA guidance, Ecological Assessment of Superfund Sites: An Overview (USEPA 1991d) was issued during report preparation (December 1991) and provides an updated framework for this section of the report.

3.1 SHEPLEY'S HILL LANDFILL

3.1.1 Ecological Characterization of the Shepley's Hill Landfill Site

The purpose of this ecological characterization is to identify, map, and describe the upland, wetland, and aquatic ecosystems that occur within the vicinity of the Shepley's Hill Landfill site. A major objective of the ecological characterization is to determine whether or not significant ecological resources that could be impacted by site contaminants are present within the vicinity of the site. These significant resources include jurisdictional wetlands and other sensitive environments; Federal or State endangered, threatened, or rare species; and economically or recreationally important fisheries or wildlife. Observations of physically stressed plants and animals or the absence of common species known to be sensitive to site contaminants, which may indicate effects attributable to Shepley's Hill Landfill site contaminants, are also discussed in this section. The methodology used during the site ecological field survey is described in Section 2.1.2.

3.1.1.1 Upland Plant Communities

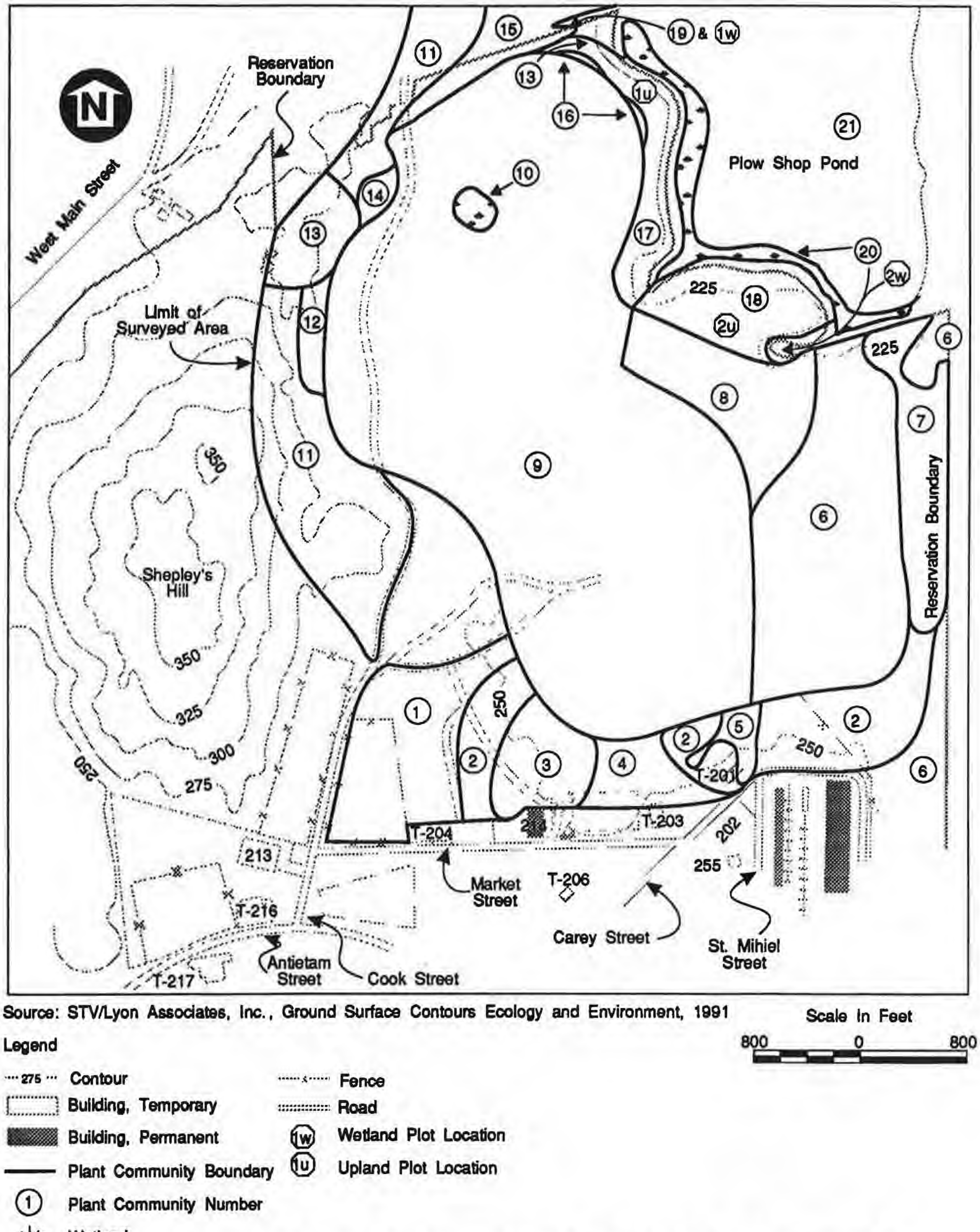
Of the 21 cover types, a total of 17 were distinct upland vegetation plant communities identified within the vicinity of the Shepley's Hill Landfill site. The boundaries between these cover types are depicted in Figure 3-1. Plant species identified within the Shepley's Hill Landfill site as well as the Cold Spring Brook Landfill site are listed in Table 3-1. Mammals, birds, reptiles, and amphibians that were observed during the field surveys or that are likely to occur in the area, based on range maps in DeGraaf and Rudis (1987), are listed in Tables 3-2, 3-3, and 3-4, respectively. Table 3-5 summarizes the dominant plants present within each cover type.

Two areas with numerous standing dead trees were noted within the Shepley's Hill Landfill site. One area is within cover type 13 while the other is within cover type 17. These stressed vegetation areas are discussed in detail in Section 3.1.1.4.

Each upland plant cover type present within the Shepley's Hill Landfill site is described below in terms of plant species composition, vegetation structure, edaphic conditions, and land use. The value of each area for wildlife is also evaluated.

Cover Type 1: Mature White Pine Forest

This forest is dominated by pole- to sawtimber-sized eastern white pine (Pinus strobus) trees, red maple (Acer rubrum) saplings, dwarf blueberry (Vaccinium cespitosum) shrubs, and bracken fern (Pteridium aquilinum). Pole-sized white oak (Quercus alba) and scarlet oak (Quercus coccinea) also occur in the forest canopy. This cover type is located in an area of gently rolling terrain with scattered granite outcrops.



Source: STV/Lyon Associates, Inc., Ground Surface Contours Ecology and Environment, 1991

Figure 3-1 COVER TYPE BOUNDARIES FOR ECOLOGICAL ASSESSMENT OF SHEPLEY'S HILL LANDFILL

Table 3-1

VEGETATION SPECIES IDENTIFIED ON THE SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES, FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Red pine	Pinus resinosa
Big-tooth aspen	Populus grandidentata
Red maple	Acer rubrum
Green ash	Fraxinus pennsylvanica
Quaking aspen	Populus tremuloides
Eastern white pine	Pinus strobus
Paper birch	Betula papyrifera
Northern red oak	Quercus rubra
White oak	Quercus alba
American elm	Ulmus americana
American chestnut	Castanea dentata
Hophornbeam	Ostrya virginiana
Black birch	Betula lenta
Gray birch	Betula populifolia
Black cherry	Prunus serotina
Shagbark hickory	Carya ovata
Scotch pine	Pinus sylvestris
Eastern hemlock	Tsuga canadensis
Eastern cottonwood	Populus deltoides
Scarlet oak	Quercus coccinea
Hawthorn	Crataegus ssp.
Sassafras	Sassafras albidum
Choke cherry	Prunus virginiana
Staghorn sumac	Rhus typhina
Smooth sumac	Rhus glabra
Blackberry	Rubus allegheniensis
Black raspberry	Rubus occidentalis
Autumn olive	Elaeagnus umbellata

RC424

Key at end of table

Table 3-1 (Cont.)

VEGETATION SPECIES IDENTIFIED ON THE SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES, FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Gray dogwood	Cornus foemina
Tartarian honeysuckle	Lonicera tatarica
Maple-leaved viburnum	Viburnum acerifolium
Witch hazel	Hamamelis virginiana
Dwarf blueberry	Vaccinium angustifolium
Swamp azalea	Rhododendrum viscosum
Alternate-leaved dogwood	Cornus alternifolia
Black huckleberry	Gaylussacia baccata
Sheep laurel	Kalmia angustifolia
Highbush blueberry	Vaccinum corymbosum
Nannyberry	Viburnum lentago
Buttonbush	Cephalanthus occidentalis
Bristly dewberry	Rubus hispidus
Meadowsweet	Spiraea latifolia
Silky dogwood	Cornus amomum
Smooth alder	Alnus serrulata
American hazelnut	Corylus americana
Maleberry	Lyonia ligustrina
Common greenbrier	Smilax rotundifolia
Poison sumac	Rhus vernix
Northern arrowwood	Viburnum recognitum
Smooth juneberry	Amelanchier laevis
Multiflora rose	Rosa multiflora
Spotted knapweed	Centaurea maculosa
Queen Anne's lace	Daucus carota
Panic grass	Panicum ssp.
Cow vetch	Vicia cracca
Virginia creeper	Parthenocissus quinquefolia
Timothy grass	Phleum pratense

RC424

Key at end of table

Table 3-1 (Cont.)

VEGETATION SPECIES IDENTIFIED ON THE SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES, FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Flat-top goldenrod	Euthamia graminifolia
Early goldenrod	Solidago juncea
Canada goldenrod	Solidago canadensis
Rough-stemmed goldenrod	Solidago rugosa
Black-eyed Susan	Rudbeckia serotina
Sweetfern	Comptonia peregrina
Evening primrose	Oenothera biennis
Butter-and-eggs	Linaria vulgaris
Bladder campion	Silene cucubalus
Stiff aster	Aster linariifolius
Rabbit-foot clover	Trifolium arvense
Crabgrass	Digitaria sp.
Common mullein	Verbascum thapsus
Round-headed bush clover	Lespedeza prucumbens
Yarrow	Achillea millefolium
Indian pipe	Monotropa uniflora
Pink ladyslipper	Cypripedium acaule
Canada mayflower	Maianthemum canadense
Stiff clubmoss	Lycopodium annotinum
Tree clubmoss	Lycopodium obscurum
Ragweed	Ambrosia artemisiifolia
Soft rush	Scirpus validus
Common St. Johnswort	Hypericum perforatum
Wool grass	Scirpus cyperinus
Fescue	Fescue ssp.
Orchard grass	Dactylis glomerata
New England aster	Aster novae-angliae
Hairgrass	Agrostis scabra
Lace grass	Eragrostis capillaris
Bittersweet nightshade	Solanum dulcamara

RC424

Key at end of table

Table 3-1 (Cont.)

VEGETATION SPECIES IDENTIFIED ON THE SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES, FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Skunk cabbage	Symplocarpus foetidus
Pokeweed	Phytolacca americana
Trailing cubutus	Epigaea repens
Wood strawberry	Fragaria vesca
White sweet-clover	Melilotus alba
Rice cut grass	Leersia oryzoides
Horsetails	Equisetum ssp.
Jack-in-the-pulpit	Arisaema atrorubens
Hairy Solomon's seal	Polygonatum pubescens
Goldthread	Coptis groenlandica
Bedstraw	Galium ssp.
Duckweed	Lemna minor
Broad-leaved cattail	Typha latifolia
Swamp milkweed	Asclepias incarnata
Water horehound	Lycopus americanus
Royal fern	Osmunda regalis
Cinnamon fern	Osmunda cinnamomea
Poison ivy	Toxicodendron radicans
Yellow clintonia	Clintonia borealis
Wild sarsaparilla	Aralia nudicaulis
Bracken fern	Pteridium aquilinum
Climbing fern[a]	Lygodium palmatum
Downy rattlesnake plantain	Goodyera pubescens
Pipsissewa	Chimaphila unbellata
Bunchberry	Cornus canadensis
Starflower	Trientalis borealis
Indian cucumber-root	Medeola virginiana
Wood ferns	Dryopteris ssp.
Purple loosestrife	Lythrum salicaria
Swamp loosestrife	Decodon verticillatus
Sedge	Carex ssp.

RC424

Key at end of table

Table 3-1 (Cont.)

VEGETATION SPECIES IDENTIFIED ON THE SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES, FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Enchanter's nightshade	Circaea quadrisulcata
Spotted jewelweed	Impatiens capensis
Sensitive fern	Onoclea sensibilis
Wild grape	Vitus spp.
Marsh fern	Thelypteris thelypteroides
Bur reed	Sparganium ssp.
Sweet-scented water lily	Nymphaea odorata
Boneset	Eupatorium perfoliatum
Path rush	Juncus tenuis
Birdsfoot trefoil	Lotus corniculatus
Small yellow pond lily	Nuphar microphyllum
Spatterdock	Nuphar variegatum
Blue vervain	Verbina hastata
Viper's bugloss	Echium vulgare
Slender-leaved goldenrod	Euthamia tenufolia
Bouncing bet	Saponaria officinalis
Common cinquefoil	Potentilla recta
Foxtail	Alopecurus ssp.
Blue curls	Trichostema dichotomum
Orange grass	Hypericum gentianoides
Common milkweed	Asclepias syriaca
White clover	Trifolium repens
Red clover	Trifolium pratense
Yellow sweet clover	Melilotus officinalis
Curly dock	Rumex crispus
Smooth hawkweed	Hieracium florentinum
Sweet everlasting	Gnaphalium obtusifolium
Staghorn clubmoss	Lycopodium clavatum
Tansy	Tanacetum vulgare
Indian tobacco	Lobelia inflata
Buttonweed	Diodia teres

RC424

Key at end of table

Table 3-1 (Cont.)

VEGETATION SPECIES IDENTIFIED ON THE SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES, FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Bull thistle	Cirsium vulgare
Joe Pye weed	Eupatorium dubium
Wild cucumber	Echinocystis lobata
Interrupted fern	Osmunda claytoniana
White wood aster	Aster divaricatus
Pickerel-weed	Pontederia cordata
Water shield	Brasenia schreberi
Downy false foxglove	Gerardia virginica
Sharp-leaved aster	Aster acuminatus
Brome-like sedge	Carex bromoides
Sallow sedge	Carex lurida
Straw-colored cyperus	Cyperus strigosus
Nodding smartweed	Polygonum lapathifolium
Poverty grass	Aristida dichotoma
Purple lovegrass	Eragrostis spectabilis
Bluegrass	Poa ssp.
Water marigold	Megalodonta beckii
Ground cedar	Lycopodium tristachyum
Felon-herb	Artemisia vulgaris

RC424

Key:

[a]State special-concern species known to occur within Fort Devens Army Installation (U.S. Army Corps of Engineers 1989)

Note: Species identified during the 12 to 17 August 1991 field survey

Source: Ecology and Environment, Inc. 1992

Table 3-2

MAMMAL SPECIES LIKELY TO OCCUR WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Virginia opossum	Didelphis virginiana
Smokey shrew	Sorex fumeus
Masked shrew	Sorex cinereus
Northern water shrew[a]	Sorex palustris
Shorttail shrew[b]	Blarina brevicauda
Hairytail mole	Parascalops breweri
Star-nosed mole	Condylura cristata
Keen's myotis	Myotis keenii
Little brown myotis	Myotis lucifugus
Silver-haired bat	Lasionycteris noctivagens
Eastern pipistrel	Pipistrellus subflavus
Red bat	Lasiurus borealis
Big brown bat	Eptesicus fuscus
Black bear[b]	Ursus americanus
Raccoon[b]	Procyon lotor
Short-tail weasel	Mustela erminea
Long-tail weasel	Mustela frenata
Mink	Mustela vison
River otter	Lutra canadensis
Striped skunk	Mephitis mephitis
Coyote[b]	Canis latrans
Red fox[b]	Vulpes vulpes
Gray fox	Urocyon cinereoargenteus
Bobcat	Lynx rufus
Woodchuck[b]	Marmota monax
Eastern chipmunk[b]	Tamias striatus

RC424

Key at end of table

Table 3-2 (Cont.)

MAMMAL SPECIES LIKELY TO OCCUR WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Eastern gray squirrel[b]	Sciurus carolinensis
Red squirrel	Tamiasciurus hudsonicus
Southern flying squirrel	Glaucomys volens
Beaver[b]	Castor canadensis
White-footed mouse	Peromyscus leucopus
Southern redback vole	Clethrionomys gapperi
Meadow vole[b]	Microtus pennsylvanicus
Pine vole	Pitymys pinetorum
Muskrat[b]	Ondatra zibethica
Meadow jumping mouse	Zapus hudsonius
Norway rat	Rattus norvegicus
House mouse	Mus musculus
Eastern cottontail[b]	Sylvilagus floridanus
White-tailed deer[b]	Odocoileus virginianus

RC424

Key:

[a]State special-concern species known to occur within Fort Devens (U.S. Army Corps of Engineers 1989)

[b]Evidence of these species was observed during the field survey (i.e., scats, tracks, dens, or individuals)

Source: Compiled by Ecology and Environment, Inc. 1992

Table 3-3

BIRDS THAT ARE LIKELY TO BREED OR WINTER WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Pied billed grebe[a]	Podilymbus podiceps
American bittern[a]	Botaurus lentiginosus
Great blue heron[b]	Ardea herodias
Green-backed heron[b]	Butorides striatus
Black-crowned night-heron	Nycticorax nycticorax
Canada goose[b]	Branta canadensis
Wood duck[b]	Aix sponsa
American black duck[b]	Anas rubripes
Mallard	Anas platyrhynchos
Osprey[a]	Pandion haliaetus
Bald eagle[a]	Haliaeetus leucocephalus
Northern harrier[a]	Circus cyaneus
Cooper's hawk[a,b]	Accipiter cooperii
Sharp-skinned hawk[a]	Accipiter striatus
Broad-winged hawk	Buteo platypterus
Red-tailed hawk[b]	Buteo jamaicensis
Rough-legged hawk	Buteo lagopus
American kestrel[b]	Falco sparverius
Peregrine falcon[a]	Falco peregrinus
Ring-necked pheasant	Phasianus colchicus
Ruffed grouse	Bonasa umbellus
Wild turkey	Meleagris gallopavo
Killdeer[b]	Charadrius vociferus
Spotted sandpiper	Actitus macularis
Solitary sandpiper[b]	Tringa solitaria
Upland sandpiper[a]	Bartramia longicauda
American woodcock	Scolopax minor
Ring-billed gull[b]	Larus delawarensis

RC424

Key at end of table

Table 3-3 (Cont.)

BIRDS THAT ARE LIKELY TO BREED OR WINTER WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Herring gull[b]	Larus argentatus
Rock dove[b]	Columba livia
Mourning dove[b]	Zenaida macroura
Black-billed cuckoo	Coccyzus erythrophthalmus
Yellow-billed cuckoo	Coccyzus americanus
Eastern screech owl	Otus asio
Great horned owl[b]	Bubo virginianus
Barred owl	Strix varia
Chimney swift[b]	Chaetura pelagica
Ruby-throated hummingbird	Archilochus colubris
Belted kingfisher[b]	Ceryle alcyon
Downy woodpecker[b]	Picoides pubescens
Hairy woodpecker	Picoides villosus
Northern flicker[b]	Colaptes auratus
Pileated woodpecker[b]	Dryocopus pileatus
Eastern wood-pewee[b]	Contopus virens
Alder flycatcher	Empidonax alnorum
Willow flycatcher	Empidonax traillii
Least flycatcher[b]	Empidonax minimus
Eastern phoebe[b]	Sayornis phoebe
Great crested flycatcher[b]	Myiarchus crinitus
Eastern kingbird[b]	Tyrannus tyrannus
Horned lark	Eremophial alpestris
Purple martin	Progne subis
Tree swallow	Tachycineta bicolor
Barn swallow[b]	Hirundo rustica
Blue jay[b]	Cyanocitta cristata
American crow[b]	Corvus brachyrhynchos
Black-capped chickadee[b]	Parus atricapillus
Tufted titmouse	Parus bicolor
Red-breasted nuthatch	Sitta canadensis

RC424

Key at end of table

Table 3-3 (Cont.)

BIRDS THAT ARE LIKELY TO BREED OR WINTER WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
White-breasted nuthatch[b]	Sitta carolinensis
Brown creeper	Certhia americana
House wren	Troglodytes aedon
Golden-crowned kinglet	Regulus satrapa
Blue-gray gnatcatcher	Polioptila caerulea
Veery	Catharus fuscescens
Wood thrush[b]	Hylocichla mustelina
American robin[b]	Turdus migratorius
Gray catbird[b]	Dumetella carolinensis
Northern mockingbird[b]	Mimus polyglottos
Brown thrasher	Toxostoma rufum
Cedar waxwing[b]	Bombycilla cedrorum
European starling[b]	Sturnus vulgaris
Warbling vireo	Vireo gilvus
Red-eyed vireo	Vireo olivaceus
Nashville warbler	Vermivora ruficapilla
Yellow warbler	Dendroica petechia
Chestnut-sided warbler	Dendroica pensylvanica
Black-throated blue warbler	Dendroica caerulescens
Yellow-rumped warbler	Dendroica coronata
Black-throated green warbler	Dendroica virens
Pine warbler	Dendroica pinus
Prairie warbler	Dendroica discolor
Blackpoll warbler[a]	Dendroica striata
Black and white warbler	Mniotilta varia
American redstart	Setophaga ruticilla
Ovenbird	Seiurus aurocapillus
Nothern waterthrush	Seiurus noveboracensis
Common yellowthroat[b]	Geothlypis trichas
Canada warbler	Wilsonia canadensis
Scarlet tanager	Piranga olivacea

RC424

Key at end of table

Table 3-3 (Cont.)

BIRDS THAT ARE LIKELY TO BREED OR WINTER WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Northern cardinal[b]	Cardinalis cardinalis
Rose-breasted grosbeak	Pheucticus ludovicianus
Indigo bunting	Passerina cyanea
Rufous-sided townhee[b]	Pipilo erythrophthalmus
American tree sparrow	Spizella arborea
Chipping sparrow	Spizella passerina
Field sparrow[b]	Spizella pusilla
Savannah sparrow[b]	Passerculus sandwichensis
Grasshopper sparrow[a,b]	Ammodramus savannarum
Song sparrow[b]	Melospiza melodia
Swamp sparrow	Melospiza georgiana
White-throated sparrow	Zonotrichia albicollis
Dark-eyed junco[b]	Junco hyemalis
Snow bunting	Plectrophenax nivalis
Bobolink	Dolichonyx oryzivorus
Red-winged blackbird	Agelaius phoeniceus
Eastern meadowlark[b]	Sturnella magna
Common grackle[b]	Quiscalus quiscula
Brown-headed cowbird	Molothrus ater
Northern oriole[b]	Icterus galbula
Purple finch	Carpodacus purpureus
House finch[b]	Carpodacus mexicanus
Pine siskin	Carduelis pinus
American goldfinch[b]	Carduelis tristis
Evening grosbeak	Coccothraustes vespertinus
House sparrow[b]	Passer domesticus

RC424

Key:

[a]Endangered, threatened, or special-concern species known to occur within Fort Devens Army Installation (U.S. Army Corps of Engineers 1989)

[b]Species observed during field surveys conducted 12 to 16 August 1991

Source: DeGraaf and Rudis 1986

Table 3-4

AMPHIBIANS AND REPTILES THAT ARE LIKELY TO OCCUR WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Blue-spotted salamander[a]	Ambystoma laterale
Spotted salamander	Ambystoma maculatum
Red-spotted newt	Notophthalmus viridescens
Northern dusky salamander	Desmognathus fuscus
Redback salamander	Plethodon cinereus
Northern two-lined salamander	Eurycea bislineata
American toad[b]	Bufo americanus
Spring peeper	Hyla crucifer
Gray treefrog	Hyla versicolor
Bullfrog[b]	Rana catesbiana
Green frog[b]	Rana clamitans
Wood frog	Rana sylvatica
Northern leopard frog	Rana pipiens
Pickerel frog[b]	Rana palustris
Common snapping turtle[b]	Chelydra serpentina
Stinkpot	Sternotherus odoratus
Spotted turtle[a]	Clemmys guttata
Wood turtle[a]	Clemmys insculpta
Eastern box turtle[a]	Terrapene carolina
Eastern painted turtle[b]	Chrysemys picta
Blanding's turtle[a]	Emydoidea bladingii
Northern water snake	Nerodia sipedon
Northern brown snake	Storeria dekayi
Northern redbelly snake	Storeria occipitomaculata
Eastern garter snake	Thamnophis sirtalis
Eastern ribbon snake	Thamnophis sauritus
Northern ringneck snake	Diadophis punctatus
Northern black racer	Coluber constrictor

RC424

Key at end of table

Table 3-4 (Cont.)

AMPHIBIANS AND REPTILES THAT ARE LIKELY TO OCCUR WITHIN FORT DEVENS ARMY INSTALLATION, MASSACHUSETTS

Common Name	Scientific Name
Eastern smooth green snake	Opheodrys vernalis
Eastern milk snake	Lampropeltis triangulum

RC424

Key:

[a]Endangered, threatened, and special-concern species known to occur within Fort Devens Army Installation (U.S. Army Corps of Engineers 1989)

[b]Observed during field surveys

Source: DeGraaf and Rudis 1986

Table 3-5

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE SHEPLEY'S HILL LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
1. Mature White Pine Forest	Tree	White pine	1797/2183	82
	Sapling	Red maple	10/20	50
	Shrub	Dwarf blueberry	20/20	100
	Herb	Bracken fern	30/35	86
2. Red Pine--Scarlet Oak Early Successional Forest	Tree	Red pine	307/327	94
	Sapling	Scarlet oak	70/90	77
	Shrub	Sweetfern	20/25	80
	Herb	Ground pine	10/20	50
3. Old Field	Sapling	Quaking aspen	10/10	100
	Shrub	Gray dogwood	10/30	33
		Tartarian honeysuckle	10/30	33
	Herb	Panic grass	30/70	43
		Early goldenrod	15/70	21
4. White Pine--Red Pine Plantation	Tree	White pine	506/832	61
		Red pine	224/832	27
	Sapling	White pine	10/15	67
5. Old Field	Tree	Quaking aspen	234/332	70
		Scarlet oak	98/332	30
	Sapling	Red pine	10/15	67
	Shrub	Tartarian honeysuckle	10/10	100
	Herb	Fescue	20/60	33
		Switchgrass	15/60	25
		Slender-leaved goldenrod	15/60	25

RC424

Key at end of table

Table 3-5 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE SHEPLEY'S HILL LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
6. Sand Barren	Sapling	Red pine	5/10	50
		Gray birch	5/10	50
	Shrub	Sweetfern	10/10	100
	Herb	Broomsedge	20/80	25
		Orange-grass	50/80	63
7. Aspen Early Successional Forest	Sapling	Quaking aspen	60/85	71
	Shrub	Sweetfern	10/10	100
8. Sand Barren	Shrub	Sweetfern	5/5	100
	Herb	Purple lovegrass	30/60	50
		Broomsedge	20/60	33
9. Dense Grassland	Herb	Bluegrass	40/100	40
		Orchard grass	20/100	20
		Path rush	20/100	20
10. Wet Meadow	Herb	Nodding smartweed	50/100	50
		Brome-like sedge	20/100	20
		Panic grass	20/100	20
11. Scarlet Oak--White Pine Forest	Tree	Scarlet Oak	509/883	58
		White pine	311/883	35
	Sapling	Scarlet oak	20/50	40
		Red maple	15/50	30
	Shrub	Dwarf blueberry	20/25	80
	Herb	Canada mayflower	5/20	20
		Running cedar	5/20	20
		Wintergreen	5/20	20
12. Scarlet Oak--White Pine Regeneration Area	Sapling	Scarlet oak	40/90	44
		White pine	30/90	33
		Red maple	20/90	22
	Shrub	Dwarf blueberry	60/60	100

RC424

Key at end of table

Table 3-5 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE SHEPLEY'S HILL LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
13. Scarlet Oak Forest	Tree	Scarlet oak	655/674	97
	Sapling	Scarlet oak	20/55	36
		Red maple	15/55	27
	Shrub	Dwarf blueberry	10/18	55
14. Burned Regeneration Area	Tree	Scarlet oak	501/584	86
	Sapling	Scarlet oak	40/90	44
		Red maple	30/90	33
		Black cherry	20/90	22
	Shrub	Sweet fern	10/25	40
		Dwarf blueberry	10/25	40
15. Red Maple Early Successional Forest	Tree	Red maple	327/405	81
	Sapling	Red maple	20/30	67
	Shrub	Choke cherry	10/20	50
	Herb	Canada Mayflower	40/55	73
16. Red Pine Plantation	Tree	Red pine	794/794	100
	Sapling	Red pine	60/60	100
17. White Oak--Scarlet Oak Forest	Tree	White oak	404/736	55
		Scarlet oak	273/736	37
	Sapling	Scarlet oak	20/45	44
		Red maple	15/45	33
	Shrub	Dwarf blueberry	25/25	100
	Herb	Wintergreen	50/50	100
18. Scarlet Oak Early Successional Forest	Tree	Scarlet oak	393/432	90
	Sapling	Scarlet oak	25/75	33
		Gray birch	25/75	33
		Red maple	20/75	27
	Shrub	Dwarf blueberry	80/90	88
	Herb	Wintergreen	2/4	50

RC424

Key at end of table

Table 3-5 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE SHEPLEY'S HILL LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
19. Red Maple Swamp	Tree	Red maple	394/394	100
	Shrub	Nannyberry	2/7	29
		Highbush blueberry	2/7	29
	Herb	Marsh fern	50/100	50
		Brome-like sedge	15/100	15
20. Shoreline Wetland	Tree	Red maple	30/30	100
	Sapling	Red maple	60/70	86
	Shrub	Silky dogwood	25/90	28
		Witch hazel	25/90	28
		Smooth alder	20/90	22
	Herb	Marsh fern	15/40	38
		Spotted jewelweed	15/40	38
21. Floating-leaved Deep Marsh (Plow Shop Pond)	Herb	Water marigold	50/80	62
		Sweet water lily	30/80	38

RC424

Key:

*Species listed only include dominant species

**Dominance ratio for trees is expressed as basal area per species/total basal area for all trees within 30-foot radius plot. Dominance ratio for sapling and shrubs is expressed as percent areal coverage per species/total percent areal coverage for all saplings or shrubs within a 15-foot radius plot. Dominance ratio for herbs is expressed as percent areal coverage per species/total percent areal coverage for all herbs within a 5-foot radius plot.

Source: E & E 1991 field survey

This forest provides food and cover for a variety of forest wildlife. Eastern white pine seeds are eaten by songbirds such as the black-capped chickadee (Parus atricapillus) and red-breasted nuthatch (Sitta canadensis), upland game birds such as the ruffed grouse (Bonasa umbellus) and wild turkey (Meleagris gallopavo), and rodents such as the red squirrel (Tamiasciurus hudsonicus), gray squirrel (Sciurus carolinensis), and white-footed mouse (Peromyscus leucopus) (Martin et al. 1961). Year-round cover provided by eastern white pine foliage occurring near the ground, shelters roosting upland game birds, raptors, and songbirds as well as squirrel nests. Dwarf blueberry provides late summer fruit for birds and mammals (Martin et al. 1961).

Cover Type 2: Red Pine--Scarlet Oak Early Successional Forest

Cover type 2 is an early successional forest located in five small patches on the south side of the landfill. The dominant tree is red pine (Pinus resinosa), which ranges in size between 5 and 8 inches in diameter. Other tree species include eastern white pine, gray birch (Betula populifolia), paper birch (Betula papyrifera), quaking aspen (Populus tremula), and big-tooth aspen (Populus grandidentata). Scarlet oak saplings and sweetfern (Comptonia peregrina) shrubs form a dense cover in the understory. The ground cover is relatively sparse with scattered mosses, ground pine (Lycopodiun obscurum), and pink ladyslipper (Cypripedium acaule).

The greatest value of this area to wildlife appears to be the cover provided by the red pine and dense understory growth. A coyote (Canis latrans) den is located within this cover type on the southeast side of the landfill. A wide variety of other animals, such as songbirds, raptors, and white-tailed deer (Odocoileus virginianus) are likely to obtain shelter within the dense growth of this cover type. Red pine seed may be produced here but only in relatively small amounts since the trees are still young. This seed is a valuable food source for a variety of birds and mammals, much like eastern white pine seed described for cover type 1. In addition, sweetfern provides browse for white-tailed deer.

Cover Type 3: Old Field

Cover type 3 is a small old field surrounded by pine forest on the south side of the landfill. The dominant herbs in this old field are panic grass (Panicum sp.) and early goldenrod (Solidago juncea). Other herbs, which occur in lesser abundance, include fescue (Festuca sp.), Queen Anne's lace (Daucus carota), common milkweed (Asclepias syriaca), mullein (Verbascum thapsus), and common Saint Johnswort (Hypericum perforatum). Saplings and shrubs form a moderately dense cover within the old field. The dominant sapling is quaking aspen. The dominant shrubs are gray dogwood (Cornus foemina) and Tartarian honeysuckle (Lonicera tatarica). Other shrubs growing in this area include silky dogwood (Cornus amomum), common elder (Sambucus canadensis), and black raspberry (Rubus occidentalis).

This old field area serves as a small wildlife opening, which provides edge and food. Panic grass produces seed, which is eaten by songbirds such as the song sparrow (Melospiza melodia), field sparrow (Spizella pusilla), and rufous-sided towhee (Pipilo erythrophthalmus). The shrubs produce fruit, which is important in the diets of a variety of songbirds such as the American robin (Turdus migratorius), gray catbird (Dumetella carolinensis), brown thrasher (Toxostoma rufum), and northern cardinal (Cardinalis cardinalis), as well as upland game birds such as the ring-necked pheasant (Phasianus colchicus). These shrubs also provide browse for white-tailed deer and the eastern cottontail (Sylvilagus floridanus) (Martin et al. 1961).

Cover Type 4: White Pine--Red Pine Plantation

This pine plantation consists of a mixture of pole-sized eastern white pine and red pine. Eastern white pine is approximately twice as abundant in the overstory as red pine and also occurs as scattered saplings in the understory. The ground beneath this plantation is nearly devoid of herbaceous plant growth.

Much like cover type 2, this pine plantation appears to provide excellent year-round protective cover for a variety of animals including songbirds, raptors, and white-tailed deer. The relatively young pine trees are beginning to produce seed, which is valuable to a variety of birds and mammals, as described for cover type 1.

Cover Type 5: Old Field

This old field community is very similar to cover type 3. The major difference is that the sapling and shrub growth in this area is relatively sparse and scattered, whereas it is moderately dense in cover type 3. Also, small trees are scattered throughout cover type 5, whereas none occur in cover type 3. The dominant herbs within this old field are fescue, switchgrass (Panicum virgatum), and slender-leaved goldenrod (Solidago tenuifolia). Butter-and-eggs (Linaria vulgaris) and bouncing bet (Saponaria officinalis) are also fairly common. Small quaking aspen and scarlet oak trees as well as red pine saplings and Tartarian honeysuckle shrubs are scattered throughout the old field.

This old field is fairly similar to cover type 3 in that it provides edge and produces grass seeds, which are eaten by various songbirds. However, the lack of quality fruit-producing shrubs makes this area markedly poorer for fruit-eating birds and mammals.

Cover Type 6: Sand Barren

The dry, sandy conditions and recently disturbed nature of this area result in a sparsely vegetated sand barren, which is in an early stage of succession. Broomsedge (Andropogon virginicus) and orange-grass (Hypericum gentianoides) are the dominant plants in this community. Red pine saplings, gray birch saplings, and small thickets of sweetfern are scattered throughout this area.

This sand barren, in general, appears to provide low-quality wildlife habitat because of the limited availability of food and cover. One potential use by wildlife, though, may be as a foraging habitat for winter-resident snow buntings (Plectrophenax nivalis) and horned larks (Eremophila alpestris), which search for wind-blown seed in sparsely vegetated areas.

Cover Type 7: Aspen Early Successional Forest

Cover type 7 is a relatively small, young forest dominated by quaking aspen saplings (up to 4 inches in diameter). Gray birch, bigtooth aspen, and scarlet oak saplings also grow in this area. Small thickets of sweetfern are scattered throughout the forest.

Quaking aspen is a valuable wildlife food plant. White-tailed deer, beaver (Castor canadensis), and the eastern cottontail eat foliage, twigs, and bark. Ruffed grouse feed heavily on buds and catkins during winter and early spring months. The value of this area for ruffed grouse and beaver appears to be limited, though, by the rather isolated location of this stand.

Cover Type 8: Sand Barren

This cover type is similar to cover type 6 in that it is sparsely vegetated due to the early stage of succession and the sand substrate. The primary difference from cover type 6 is that the vegetation structure and species composition in this area is very sparsely vegetated with purple lovegrass (Eragrostis spectabilis) and broomsedge. Scattered thickets of young sweetfern shrubs also occur in this cover type.

Like cover type 6, this area provides little food and cover and is therefore considered a fairly low-quality wildlife habitat. However, use by foraging snow buntings and horned larks during winter months is likely because of the proximity of this area to the large open grassland over the capped landfill.

Cover Type 9: Dense Grassland

The majority of the capped landfill at the Shepley's Hill Landfill site supports a dense cover of grasses. The southwest portion of the capped landfill supports an especially tall and dense cover of grasses. A diversity of herbs grow within this cover type. The dominant species are bluegrass (Poa sp.), orchard grass (Dactylis glomerata), and path rush (Juncus tenuis). Other common herbs include fescue, Timothy (Phleum pratense), white clover (Trifolium repens), early goldenrod, and common Saint Johnswort.

Although this cover type is a man-created and -maintained community, it is a very valuable wildlife resource. Its large size, dense grass cover, and assortment of grass heights make it attractive to a variety of grassland birds and mammals. At the time of the field survey, savanna sparrows (Passerculus sandwichensis) were abundant throughout much of this cover type. Three grasshopper sparrows (Ammodramus savannarum), a state special-concern species, were observed in the southwest portion of this cover type. The upland sandpiper (Bartramia longicauda), a state endangered species, has been reported to occur in this area as well (Poole 1991). Canada geese (Branta canadensis) forage in this grassland. Raptors use this area regularly, apparently due to an abundant meadow vole (Microtus pennsylvanicus) population. Red-tailed hawks (Buteo jamaicenisis) and American kestrels (Falco sparverius) were observed regularly during the field survey. An adult Cooper's hawk (Accipiler cooperii), a State special-concern species, was observed once along the southeast edge of the grassland. An unconfirmed sighting of a bald eagle (Haliaeetus leuocephalus), a federally endangered species, was reported over the west side of the landfill area in July 1991 by an E & E employee.

Mammals that use this grassland include the woodchuck (Marmota monax) and the coyote. Several woodchuck burrows were observed within or adjacent to this cover type during the field surveys. Coyote tracks were abundant in this area at the time of the field surveys. In addition, a coyote burrow was found in the open sand area east of this cover type and a den was found within cover type 2. Coyote use of this area is apparently linked to the abundance of meadow voles and woodchucks within this grassland as well as the availability of trash at the existing landfill.

Further information regarding current maintenance of the landfill is available from base personnel.

Cover Type 10: Wet Meadow

This cover type is described within Section 3.1.1.2, Wetland Plant Communities.

Cover Type 11: Scarlet Oak—White Pine Forest

Cover type 11 consists of a pole-sized forest dominated by scarlet oak and eastern white pine trees. Minor components of the canopy include hemlock (Tsuga canadensis), white oak, and northern red oak (Quercus rubra). The dominant understory saplings are scarlet oak and red maple. White pine, black cherry (Prunus serotina), and shagbark hickory (Carya ovata) are also common. Dwarf blueberry is the dominant shrub while running cedar (Lycopodium trystachyum), Canada mayflower (Pyrola americana), and wintergreen (Gaultheria procumbens) are the dominant herbs.

This cover type extends over a rather large area and appears to stretch well west of the area surveyed for this ecological characterization. The forest occurs on a hillside with a slope ranging between 30 and 50 percent. Numerous rock outcroppings are present.

The abundance of scarlet oak and, to a lesser extent, northern red oak and white oak results in a high-quality wildlife area. Oak acorns are valuable fall and winter wildlife foods. Upland game birds such as the ruffed grouse and wild turkey feed heavily upon acorns in season. A few songbirds, including the blue jay (Cyanocitta cristata) and northern flicker (Colaptes auratus), feed on acorns. Acorns are also important food items in the diets of several rodents including the southern flying squirrel (Glaucomys volens), eastern gray squirrel, and eastern chipmunk (Tamias striatus). White-tailed deer and black bear (Ursus americanus) also feed heavily upon acorns during fall and winter months (Martin et al. 1961).

The abundance of eastern white pine within this community adds to the wildlife value of this area. Refer to cover type 1 for a detailed discussion of white pine wildlife values. The availability of red maple saplings for deer browse and dwarf blueberry shrubs, which provide abundant late summer fruit, contribute to habitat quality.

Cover Type 12: Scarlet Oak-White Pine Regeneration Area

Cover type 12 is a relatively small area of early successional forest dominated by scarlet oak, eastern white pine, and red maple saplings. A dense shrub layer of dwarf blueberry (60 percent coverage) is also present.

This successional forest lacks mature oak trees and thus the acorn crop that makes cover type 11 a valuable wildlife habitat. However, red maple saplings provide browse for deer, and dwarf blueberry shrubs provide an abundance of late summer fruit for a variety of birds and mammals. The blueberry provides a seasonally important supply of high-quality fruits for upland game birds such as the ruffed grouse, songbirds such as the gray catbird and scarlet tanager (Piranga olivacea), and mammals such as the black bear and white-footed mouse (Martin et al. 1961).

Cover Type 13: Scarlet Oak Forest

Scarlet oak comprises 97 percent of the tree basal area of this forest. It is also the most abundant sapling in the understory. Red maple saplings and dwarf blueberry shrubs are the remaining dominant plants. Eastern white pine, shagbark hickory, black cherry, sassafras, (Sassafras albidum), and alternate-leafed dogwood (Cornus alternifolia) occur in lesser numbers. No herbs were present at the time of the field survey. This forest occurs on a steep slope (approximately 80 percent) with numerous rock outcrops.

This forest is similar in structure and species composition to cover type 11 except that it lacks the eastern white pine. Therefore, the value of this community to wildlife is expected to be similar to that of cover type 11 except for the lack of food and cover provided by eastern white pine.

A small area of dead trees is present in the northernmost portion of this cover type. These evidently stressed trees are discussed in more detail in Section 3.1.1.4.

Cover Type 14: Burned Regeneration Area

As evidenced by charred saplings and tree trunks a fire took place in this small area (approximately 0.5 acre) within the last two to three years. The community was apparently a recently cut-over forest at the time of the fire. Many of the saplings and trees that were burned in the fire are dead or dying, but the area now supports a dense cover of new growth. The dominant saplings and shrubs are scarlet oak, red maple, sassafras, sweetfern, and dwarf blueberry. This burned area is located on a steep slope (approximately 80 percent) with scattered rock outcrops.

Although this community is small, it likely serves as a locally important feeding area because of the abundance of browse and fruit-producing saplings and shrubs. One white-tailed deer was observed in this cover type during the field survey.

Cover Type 15: Red Maple Early Successional Forest

Red maple is the dominant tree and sapling within this forest. Choke cherry (Prunus virginiana) is the dominant shrub although it comprises only 10 percent of the areal coverage. Canada mayflower is abundant on the forest floor and is the dominant herb. This cover type is located adjacent to a red maple swamp (cover type 19), but lacks hydric soils and wetland hydrology.

Red maple is a valuable wildlife food plant that provides browse for white-tailed deer and spring fruits for a variety of birds and mammals. Choke cherry provides a seasonally important source of high-quality fruits. Songbirds such as the American robin and rose-breasted grosbeak (Pheucticus ludovicianus), game birds such as the ruffed grouse, and mammals such as the black bear and raccoon (Procyon lotor) feed heavily upon cherry fruits in season (Martin et al. 1961).

Cover Type 16: Red Pine Plantation

Cover type 16 consists of two narrow (40 feet wide) strips of red pine planted along the northeastern edge of the capped landfill. These pines appear to have been planted 10 to 20 years ago. The ground cover beneath the plantation is devoid of herbaceous plant growth.

This red pine plantation likely provides excellent year-round protective cover for a variety of animals including songbirds, raptors, and white-tailed deer. The relatively young trees are beginning to produce seed, which is valuable to a variety of birds and mammals, as described for cover type 1.

Cover Type 17: White Oak--Scarlet Oak Forest

The distinctive feature of this forest is the predominance of pole- to sawtimber-sized white oak trees. Scarlet oak is another dominant species, occurring both as pole-sized trees and saplings. Red maple saplings and dwarf blueberry shrubs are dominant in the understory. Wintergreen is very abundant on the forest floor.

The abundance of oaks within this forest results in high-quality wildlife habitat. Oaks are valuable because their acorns are an important staple in the diet of many birds and mammals. White oak acorns are especially important because they are produced annually and are more palatable than "red oak" acorns. Wildlife use of acorns is described in detail for cover type 11. The availability of red maple saplings for deer browse and dwarf blueberry shrubs, which provide late summer fruit, contribute to the habitat quality of this area.

Although the overall health of this stand is considered excellent, an area of dead trees occurs in the southern portion of this area. Section 3.1.1.4 discusses this stressed vegetation in more detail.

Cover Type 18: Scarlet Oak Early Successional Forest

This forest is dominated by scarlet oak trees and saplings, gray birch and red maple saplings, dwarf blueberry, and wintergreen. The trees in this area are relatively small (5 to 10 inches in diameter), and the understory vegetation is moderately dense.

Red maple saplings provide browse for deer. The abundance of dwarf blueberry (80 percent coverage) in this cover type provides a seasonally important supply of high-quality fruits. Wildlife use of blueberry fruits is described for cover type 12.

Cover Types 19 through 21

These cover types are described in the following Section 3.1.1.2, Wetland Plant Communities.

3.1.1.2 Wetland Plant Communities

Four wetland vegetation cover types were identified within the vicinity of the Shepley's Hill Landfill site. Two of these wetland cover types (cover types 20 and 21) are hydrologically connected and are located close to each other. These two cover types are collectively referred to as the "Plow Shop Pond Wetland Complex" in portions of this report.

The locations of the Shepley's Hill Landfill wetland cover types are shown in Figure 3-1. Table 3-5 summarizes the dominant plants present within each of these wetland cover types. Each wetland cover type is described below in terms of plant species composition, vegetation structure, edaphic conditions, and land use. The value of each for wildlife use is also reviewed.

New England Army Corps of Engineers Wetland Delineation Data forms were completed for each wetland cover type. These forms are provided in Appendix E. Each wetland cover type meets the three criteria (i.e., hydrophytic vegetation, hydric soils, and wetland hydrology) necessary to be classified as jurisdictional wetland.

Wetland Inventory Data form assessments were completed to evaluate wetland functions and values within the Plow Shop Pond Wetland Complex and cover type 19. Wetland functions and values are discussed in Section 3.1.1.4.

Cover Type 10: Wet Meadow

This meadow is located within a small (approximately 0.2 acre) depression on the north side of the capped landfill. The dominant plants in this palustrine emergent wetland are nodding smartweed (Polygonum lapathifolium), brome-like sedge (Carex bromides), and panic grass (Panicum sp.). Other herbs include woolgrass (Scirpus cyperinus), path rush (Juncus tenuis), straw-colored cyperus (Cyperus strigosus), and broad-leaf cattail (Typha latifolia).

This area meets the hydrophytic vegetation and wetland hydrology criteria of the federal wetland designation process. Soils were not sampled for the presence of hydric soil indicators because of the wetland's location over the capped landfill. The hydric soil criterion is assumed to be met based on the presence of hydrophytic vegetation and wetland hydrology. This meadow is therefore classified as jurisdictional wetland.

Due to the small size of this wetland area, its value for wildlife is limited. Amphibians such as the American toad (Bufo americanus) and northern leopard frog (Rana pipens) may use this wetland for breeding in the spring and early summer. Grassland birds and small mammals from the surrounding dense grassland area likely to forage and obtain water within the meadow at times.

Cover Type 19: Red Maple Swamp

This wetland is located in a lowland area near the confluence of Nonacoicus Brook and Plow Shop Pond. The dominant plants within this palustrine forested wetland are red maple, nannyberry (Viburnum lentago), highbush blueberry (Vaccinium corymbosum), marsh fern (Thelypteris palustris), and brome-like sedge. Other common herbs that occur in this area include spotted jewelweed (Impatiens capensis), spotted Joe-Pye weed (Eupatorium maculatum), and cinnamon fern (Osmunda cinnamomea).

Deerfield loamy sand soils are mapped for this area. This soil series is classified as nonhydric. However, soils were saturated at the time of the field survey, and soil sampling determined that the hydric soil criterion was met. Because the hydrophytic vegetation and wetland hydrology criteria are also met, this cover type is classified as jurisdictional wetland.

This red maple swamp likely serves as a water source for wildlife that populate the general area. The area supports a lush growth of herbaceous vegetation, which is valuable for supporting an abundance and diversity of animal life. In addition, the moist soil conditions likely make this area attractive to a variety of amphibians such as the spring peeper (Hyla crucifer) and northern two-lined salamander (Evrycea bislineata). Red maple fruits produced in this area likely serve as a seasonally important food source for the eastern chipmunk, gray squirrel, and southern flying squirrel (Martin et al. 1961). The USFWS NWI map shows that this wetland extends to the north of the Shepley's Hill Landfill site and covers approximately 6 acres. Therefore, this forested wetland appears to be relatively large and thus relatively important for wildlife. Wetland functions for this area are discussed in Section 3.1.1.4.

Cover Type 20: Shoreline Wetland

Cover type 20 is a narrow (1 to 10 feet wide) strip of palustrine forested/scrub-shrub wetland vegetation, which borders Plow Shop Pond. Red maple is the predominant overstory tree. The dense sapling and shrub layer consists primarily of red maple, silky dogwood (Cornus amomum), witch hazel (Hamamelis virginiana), and smooth alder (Alnus serrulata). Dense patches of marsh fern and spotted jewelweed occur sporadically within this area.

Carver loamy coarse sand soils are mapped for this area and are classified as nonhydric. However, soil sampling during the field survey determined that the hydric soil criterion was met within this narrow strip of hydrophytic vegetation. Because all three wetland criteria are met in this community, this area is classified as a jurisdictional wetland.

The relatively dense sapling and shrub growth adjacent to Plow Shop Pond is a valuable source of cover for the animals who frequent Plow Shop Pond. In addition, the abundance of red maple saplings is valuable to white-tailed deer, who feed heavily on the twigs and foliage. Wetland functions and values for this community were evaluated in conjunction with cover type 21 (together forming the Plow Shop Pond Wetland Complex). These general functions are described in detail in Section 3.1.1.4.

Cover Type 21: Floating-Leaved Deep Marsh

Plow Shop Pond is classified as a floating-leaved deep marsh. Although this pond is described in Section 3.1.1.3, Aquatic Ecosystems, it is also described here because, technically, it is a wetland; water bodies less than 6.6 feet deep are classified as wetlands by the Federal Manual (Federal Interagency Committee for Wetland Delineation 1989). This lacustrine wetland is shallow (approximately 3 feet deep), eutrophic, and dominated by water marigold (Megalodonta beckii) and sweet water lily (Nymphaea odorata). Water shield (Brasenia schreberi) also occurs within the pond. The vegetation growth in Plow Shop Pond is dense.

All three wetland criteria are met for Plow Shop Pond. This area is therefore classified as jurisdictional wetland. Plow Shop Pond appears to be a valuable wildlife resource. Although relatively few animals were observed during the August field survey, this area likely supports a relatively diverse fauna at other times of the year. Its large size and the abundance of floating-leaved and submergent vegetation make the pond attractive to wildlife. Sunfish (Lepomis spp.) were observed in abundance during the field survey. Several species of frogs and toads are expected to use the pond for breeding. Waterfowl, especially the wood duck (Aix sponsa), mallard (Anas platyrhynchos), American black duck (Anas strepera), and Canada goose likely use the pond for feeding and resting. These and other waterfowl may be abundant during the spring and fall migration periods. Herons and belted kingfishers (Ceryle alcyon) feed on fish and frogs in the pond. Barn swallows (Hirundo rustica) were observed foraging for insects over the pond. Tree swallows (Tachycineta bicolor), purple martins (Progne subis), chimney swifts (Chaetura pelagica), and bats likely forage for insects over the pond as well. Muskrat (Ondatra zibethica) and beaver (Castor canadensis) are expected to occur in the pond, although none were observed during the field survey.

The Plow Shop Pond Wetland Complex, which consists of cover types 20 and 21, was evaluated regarding wetland function. Wetland function and values are presented in Table 3-6. Biological, floodwater storage, and water quality maintenance were rated "moderate." All other functions were rated "high." These wetland functions are discussed in greater detail in Section 3.1.1.4.

3.1.1.3 Aquatic Ecosystems

The waters of Plow Shop Pond are designated as Class B (Environmental Reporter 1991). The pond appears to be eutrophic as evidenced by the dense stands of aquatic vegetation. Based on observations made during the field survey, it appears that greater than 80 percent of the surface area of the pond is colonized by sweet water lily (Nymphaea odorata) and water-shield (Brasenia schreberi). Submerged macrophytes consist primarily of water marigold (Megalodonta beckii), which covers approximately 75 percent of the submerged area of the pond. Such abundant growth is not unusual or unexpected for a pond with the basin morphometry of Plow Shop Pond. Many ponds which are very shallow (less than or equal to 3 feet deep) are eutrophic.

A pond of this type is likely to support a lentic macroinvertebrate community including taxa such as the Odonata (dragonflies) and/or Chironomids (midge larvae). Sunfish were observed in Plow Shop Pond, as well as green frogs, bullfrogs, and turtles. Largemouth bass (Micropterus salmoides), chain pickerel (Esor niger), and yellow

Table 3-6

WETLAND FUNCTIONS EVALUATION RATINGS FOR SHEPLEY'S HILL LANDFILL SITE AND COLD SPRING BROOK LANDFILL SITE WETLAND AREAS

Function	Wetland			
	Plow Shop Pond Complex	Shepley's Hill Red Maple Swamp	Cold Spring Brook Complex	Cold Spring Brook East
Biological	Moderate	Moderate	High	Moderate
Hydrologic Support	High	High	High	Moderate
Groundwater Discharge	High	Moderate	Moderate	High
Floodwater Storage	Moderate	Moderate	Moderate	Moderate
Water Quality Maintenance	Moderate	Moderate	High	Moderate
Cultural and Economic	High	Moderate	High	Moderate
Recreation	High	Moderate	High	Moderate
Aesthetic	High	Moderate	High	Moderate
Education	High	Moderate	High	Moderate

RC424

Source: Ecology and Environment, Inc. 1992 bullhead (Ameiurus natalis) likely occur in this water body, based on fish sampling efforts conducted by U.S. Army Corps of Engineers in nearby water bodies (U.S. Army Corps of Engineers 1989). It should be noted that individuals have been observed fishing in this pond.

3.1.1.4 Overview and Discussion

The Shepley's Hill Landfill site is considered a high-quality ecological area primarily because of the presence of the large (approximately 50 acres) grassland community, which is surrounded by a great diversity of cover types. The grassland community is considered fairly unique because it is a large, productive ecosystem which is maintained in an early serial stage by mowing. Few extensive grassland areas such as this are present within Fort Devens. The presence of Plow Shop Pond as one of the surrounding cover types contributes substantially to the quality of this site, because the pond is a large (approximately 25 acres) and a highly productive ecosystem. Overall, the presence of two large and highly productive ecosystems plus the great diversity of the remaining cover types at the Shepley's Hill Landfill site support an abundance and diversity of wildlife.

The large grassland community which covers the capped landfill, is a man-created ecosystem that supports an abundance of grassland birds and mammals. Canada geese regularly forage in this area. Three grasshopper sparrows (state special-concern species) were observed during the field survey. Poole (1991) reported that an upland sandpiper (state endangered species) has also been observed in the grassland cover type. Woodchucks use the perimeter of the grassland regularly, as evidenced by several woodchuck burrows present along the edge of this area.

The meadow vole population within this grassland is moderately high, as evidenced by numerous runways formed beneath the grass cover. There are also high populations of birds that eat garbage from the landfill, such as the ring-billed gull (Larus delawarensis) and European starling (Sterna vulgaris). The large numbers of meadow voles and scavenging birds attract many predators. Red-tailed hawks and American kestrels were observed regularly. A Cooper's hawk (state special-concern species) was observed once on the southeast edge of the grassland. An unconfirmed sighting of a bald eagle (federal endangered species) was reported in July 1991. Another predator that frequents the grassland cover type is the coyote. Coyotes are apparently attracted to the abundant meadow vole population as well as to the trash available at the currently active portion of the landfill.

As stated, Plow Shop Pond is a large, productive ecosystem. The Plow Shop Pond Wetland Complex consists of a narrow, forested, and scrub-shrub shoreline wetland (cover type 20) surrounding a large floating-leafed deep marsh (cover type 21). Both of these cover types meet the three criteria necessary to be classified as jurisdictional wetlands. Of the nine wetland functions evaluated during this study, three were rated "moderate" and six were rated "high" (see Table 3-6).

Based on the wetland functions' evaluation, this wetland complex is expected to support an average diversity and abundance of aquatic and terrestrial species; serve as an important groundwater discharge area and thereby support stream flow; effectively store and gradually release storm flood waters; retain sediments and remove nutrients and thereby improve water quality; and serve as an important area for cultural, economic, recreational, aesthetic, and educational uses.

A relatively small wetland area, a red maple swamp (cover type 19), is located near the northeastern edge of the site. This area meets the three criteria necessary to be classified as a jurisdictional wetland. Eight of the nine wetland functions evaluated during this study were rated "moderate" for this area (see Table 3-6). The functions of this wetland are therefore similar to those described above for the Plow Shop Pond Wetland Complex except in terms of cultural, economic, recreational, aesthetic, and educational uses. The value of the red maple swamp for these uses is expected to be "moderate," whereas the value of Plow Shop Pond for these uses was rated "high." The presence of this forested wetland within the Shepley's Hill Landfill site enhances the overall ecological quality of this site.

Mature forests surround much of the perimeter of the capped landfill, especially on the west side. Scarlet and white oak trees produce acorns, which are a seasonally important food source for numerous birds and mammals. Eastern white pine trees produce seed, which is eaten by many birds and mammals. Pine trees also provide year-round protective cover. Tree cavities and standing dead trees within mature forests provide roosting and nesting sites for a variety of animals.

Early successional forests and old fields are also scattered around the perimeter of the capped landfill. These cover types are valuable for the many species of wildlife attracted by the abundance of seed, fruit, and browse that are typically associated with these areas.

Conifer stands along the perimeter of the capped landfill contribute to the overall diversity of the site. These stands provide a year-round source of dense protective cover and, currently, a limited quantity of seed for consumption by various birds and mammals.

The Shepley's Hill Landfill site supports species-of-concern, which could potentially be impacted by site contaminants (see Table 3-7). Two state-listed species of special concern, the grasshopper sparrow and Cooper's hawk, were observed on-site during field surveys. A floristic survey of Fort Devens documented the presence of Houghton's flatsedge (state endangered) near the eastern boundary of the site (Hunt 1981). Two endangered species, the bald eagle (federal endangered species) and the upland sandpiper (state endangered species), have been reported to use the site at least occasionally (USFWS 1991, U.S. Army Corps of Engineers 1989). Agency contacts (USFWS 1991, 1992; Massachusetts Natural Heritage and Endangered Species Program (MNHESP) 1991, 1992) and the Fort Devens Draft Environmental Impact Statement (U.S. Army Corps of

Table 3-7

SPECIES OF CONCERN IDENTIFIED IN THE GENERAL VICINITY OF SHEPLEY'S HILL LANDFILL AND COLD SPRING BROOK LANDFILL SITES

Common Name	Scientific Name	Status		Shepley's Hill	Cold Spring Brook
		State	Federal		
Eastern box turtle	Terrapene carolina	Sc		Occurs within 1.5 miles	Occurs within 1.5 miles
Blanding's turtle	Emydoidea blandingii	T		Occurs within 1.5 miles	Occurs within 1.5 miles
Wood turtle	Clemmys insculpta	Sc		Occurs within 1.5 miles	Occurs within 1.5 miles
Climbing fern	Lygodium palmatum	Sc		Occurs within 1.5 miles	Occurs within 1.5 miles
Mystic valley amphipod	Crangonyx aberrans	Sc			Occurs within 1.5 miles
Bald eagle	Haliaeetus leucoephalus		E	Transient[a]	Transient
Peregrine falcon	Falco peregrinus anatum		E	Transient	Transient
Upland sandpiper	Bartramia longicauda	E		Transient	
Houghton's flatsedge	Cyperus houghtonii	E		Documented occurance within landfill site	
Grasshopper sparrow	Ammodramus savannarum	E		Observed during August field surveys	
Cooper's hawk	Accipiter cooperii	Sc		Observed during August field surveys	

RC424

Key:

E = Endangered
Sc = Species-of-concern
T = Threatened

[a]Unconfirmed sighting in spring of 1991

Sources: USFWS, Concord, New Hampshire (USFWS 1991, 1992)
Commonwealth of Massachusetts, Division of Fisheries and Wildlife/Natural Heritage and Endangered Species Program (MNHESP 1991, 1992)
EIS for Fort Devens Army Installation (U.S. Army Corps of Engineers 1989)
Floristic Survey of Fort Devens (Hunt 1991)

Engineers 1989) identified an additional six species-of-concern, which are known to occur within 1.5 miles of the Shepley's Hill Landfill site. The peregrine falcon (federal endangered species), like the bald eagle mentioned above, occurs as an occasional transient individual (USFWS 1991). The eastern box turtle (state special concern), Blanding's turtle (state threatened), wood turtle (Clemmys insculpta) and climbing fern (state special concern) have been documented within a 1.5-mile radius of the Shepley's Hill Landfill site (MNHESP 1991, 1992). Specific locational data for the latter four species were not provided by MNHESP. In addition, the small whorled pogonia (federal endangered) occurs within Middlesex and Worcester counties, although it has not been documented within 1.5 miles of the site (USFWS 1991).

No rare natural plant communities are documented within a 1.5-mile radius of the Shepley's Hill Landfill site (MNHESP 1991). However, USFWS NWI maps show numerous wetlands which are located within a 1.5-mile radius, which are considered significant ecological resources. Several large forested and scrub/shrub palustrine wetlands are associated with Cold Spring Brook, Nonacoicus Brook, and the Nashua River. Cold Spring Brook is located upstream of the site, but Nonacoicus Brook and Nashua River are located downstream of the site. Also, one of the wetlands within a 1.5-mile radius is classified as "estimated habitat of State-listed rare wetlands wildlife" (MNHESP 1992). This wetland area is located approximately 1.0 miles northwest of Shepley's Hill Landfill site and is associated with the Nashua River. No information regarding the rare species associated with this area is available (MNHESP 1992).

The Nashua River, several tributary streams, and four man-made ponds are located within 1.5 miles of the site. However, Bowers Brook and Mirror Lake are the only two water resources that have been surveyed by the Massachusetts Division of Fisheries. Assuming that the species composition of Plow Shop Pond is similar to that of these areas, fish species likely to occur in the pond may include yellow perch, bluegills, pumpkinseed, and black crappie. Plow Shop Pond is not stocked and is not considered a commercial or recreational fishery (Massachusetts Division of Fisheries and Wildlife 1991).

Oxbow National Wildlife Refuge and Ayer State Game Area are two nearby significant ecological resources; they are located approximately 2.5 miles south and north, respectively, of the Shepley's Hill Landfill site. These refuges are mentioned here because of the diverse waterfowl and other migratory bird populations that use these areas, and also because of the importance of these areas for consumptive and nonconsumptive use by the local population. Some of the birds from these refuges may occasionally use Plow Shop Pond or the grassland area that covers the capped landfill.

Evidence of physically stressed vegetation in the form of dead trees was observed within cover types 13 and 17. Interestingly, shrubs and herbs in these areas appeared relatively healthy at the time of the field survey, possibly due to the relatively shallow roots of these plants. Each of these areas of dead trees is located along drainage routes which apparently receive water from the landfill. One of these drainage routes flows toward Plow Shop Pond while the other flows toward Nonacoicus Brook.

No indications were observed that common terrestrial species known to be sensitive to site contaminants were absent from the Shepley's Hill Landfill site. A relatively high diversity and abundance of terrestrial wildlife was observed in the vicinity of the site, suggesting that site contaminants are not affecting terrestrial species' abundance significantly. Relatively little information regarding aquatic species' diversity and abundance was collected, because no aquatic sampling was conducted. Therefore, the potential effects of site contaminants on aquatic species' abundance could not be evaluated adequately.

3.1.2 Geology

3.1.2.1 Bedrock Geology

The bedrock at Shepley's Hill Landfill crops out on the west side of the landfill in three areas, Shepley's Hill, immediately east of the DRMO Yard, and south of Market Street immediately adjacent to the POL site.

The following thirteen borehole locations showed bedrock cores; SHL-1, SHL-2, SHL-3, SHL-4, SHL-5, SHL-8, SHL-10, SHL-11, SHL-14, SHL-16, SHL-20, SHL-22, and SHL-24 (see Section 1, Table 1-4). Of these locations, one showed "granite" (SHL-1), which was probably granodiorite, since the two rock types only differ in the percentage of potassic feldspar to plagioclase feldspar (two similar aluminum silicate minerals), and eight showed granodiorite (SHL-2, SHL-3, SHL-4, SHL-5, SHL-8, SHL-14, SHL-16, SHL-20). Two showed gneiss, which may be sheared or foliated granodiorite, (SHL-11 and SHL-22); and two showed phyllite or pellitic schist (SHL-10, SHL-24).

The predominance of granodiorite in both outcrop and boreholes does suggest that it underlies much of the landfill. However, there may be shear zones or granodioritic gneiss under part of the area and there are zones of metamorphic rock such as the phyllite/pellitic schist in SHL-10 and SHL-24, into which the granodiorite was possibly intruded.

The top of the bedrock forms a trough about 100 feet deep beneath the landfill, and appears to rise again close to the surface level of Plow Shop Pond in wells such as SHL-4, SHL-3, and SHL-10. This has an impact on groundwater flow (see Section 3.1.4).

3.1.2.2 Glacial Sediments/Overburden

The predominant materials in the glacial overburden are sand, gravel, and cobbles. In some instances, the layer immediately above bedrock is mixed with silt and even clay. This layer may be till, a dense, compressed material of very mixed grain size and of a hydraulic conductivity much lower than sand.

Boreholes identified as penetrating till include SHL-1, SHL-4, SHL-16, and SHL-25. The majority of boreholes penetrated coarse to fine sand with occasional layers of silt. SHL-24 appears to have been largely screened opposite silt, or till just above bedrock.

3.1.3 Soils

3.1.3.1 Site-Related Soils

Most soils on the landfill have been disturbed. SHL-2, SHL-5, SHL-8, SHL-9, SHL-13, SHL-21, and SHL-25 probably penetrated undisturbed soils. SHL-5 appears to have been in a wetland with 0.5 feet of peat on top of an organic-rich soil. All other boreholes began in sandy soil, or occasionally silty soil (SHL-16, SHL-17, SHL-20, and SHL-24), but rapidly change to sand. The wetlands covered by the fill probably had organic soils but no wells/boreholes penetrated them.

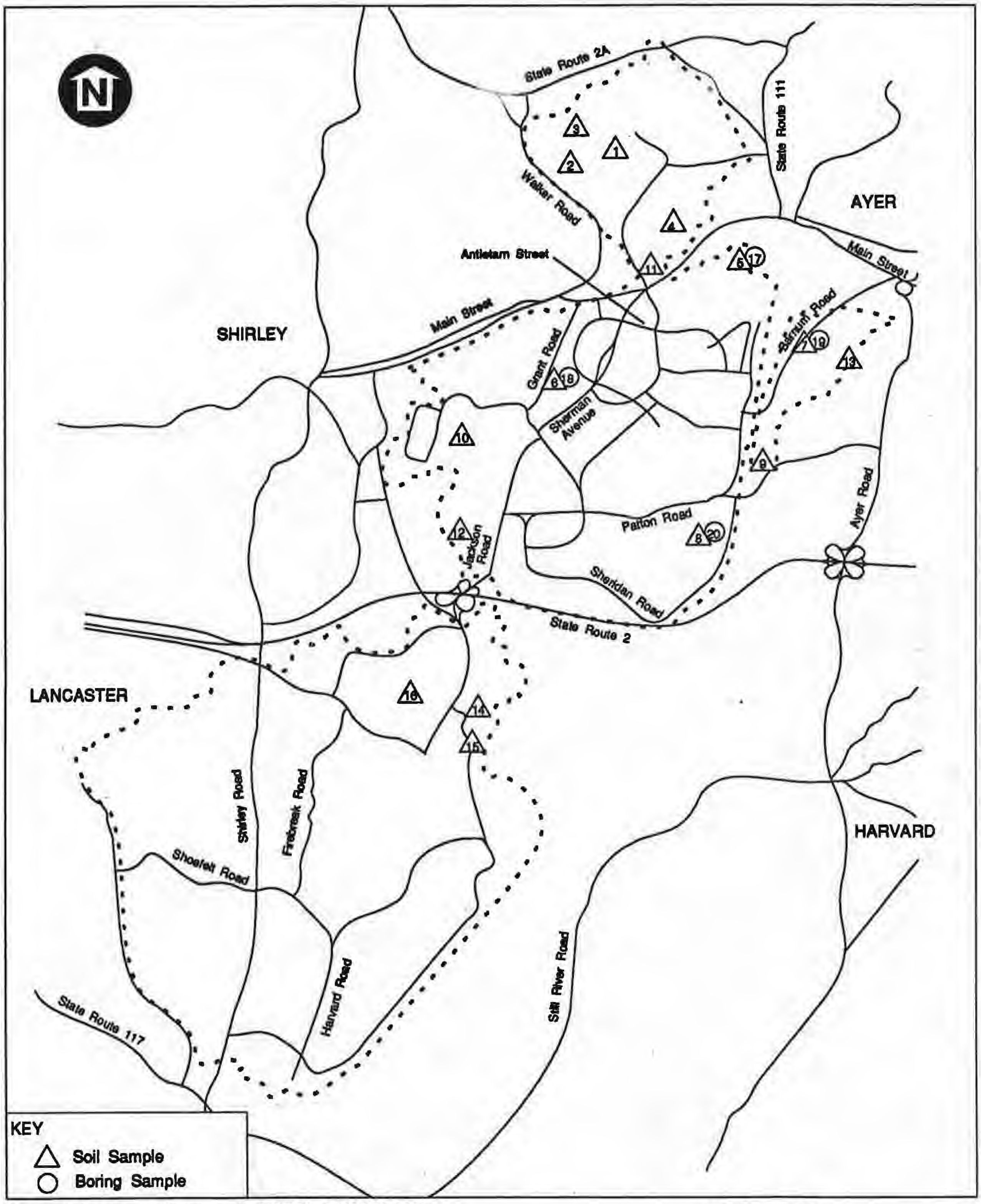
3.1.3.2 Background Soils

Twenty soil samples were taken from 16 locations (Figure 3-2). Most were taken from the Quonset-Hinkley-Windsor Soil Association, which covers the greatest area of Fort Devens and is representative of the former soils under much of Shepley's Hill Landfill and part of Cold Spring Brook Landfill. Some background soil samples (1, 4, and 11) were taken from areas of the Winooski-Limerick-Saco Soils Association, and one sample (13), from the Muck-Peat-Walpole Association found in wetlands. The samples were analyzed for metals to assist in defining what constitutes a "normal" range for metals in the soils at Fort Devens. Background soils were not classified or analyzed for their physical characteristics, but all were predominantly sandy with the exception of sample 13.

3.1.4 Groundwater Hydrology

The installation and measurement of additional wells at Shepley's Hill Landfill did not alter the initial understanding of the groundwater hydrology derived from previous investigations (see Section 1.6.2).

Groundwater elevations in the 29 wells at and around the landfill, as measured on 30 August 1991, show that flow in the southern part of the landfill is generally northeast to Plow Shop Pond (Figure 3-3). In the north end of the landfill, flow is northerly into the wetland north of the landfill. Flow also occurs from Plow Shop Pond north of SHL-20 and SHL-11 into the bank of the pond, under the terrace where SHL-21 is located and towards wells SHL-5, SHL-8, and SHL-13. Vertical gradients are slight at all pairs of wells such as SHL-11/SHL-20, SHL-8S/SHL-8D, or SHL-9/SHL-22.



Source: Interagency Agreement USEPA / USATHAMA

Legend

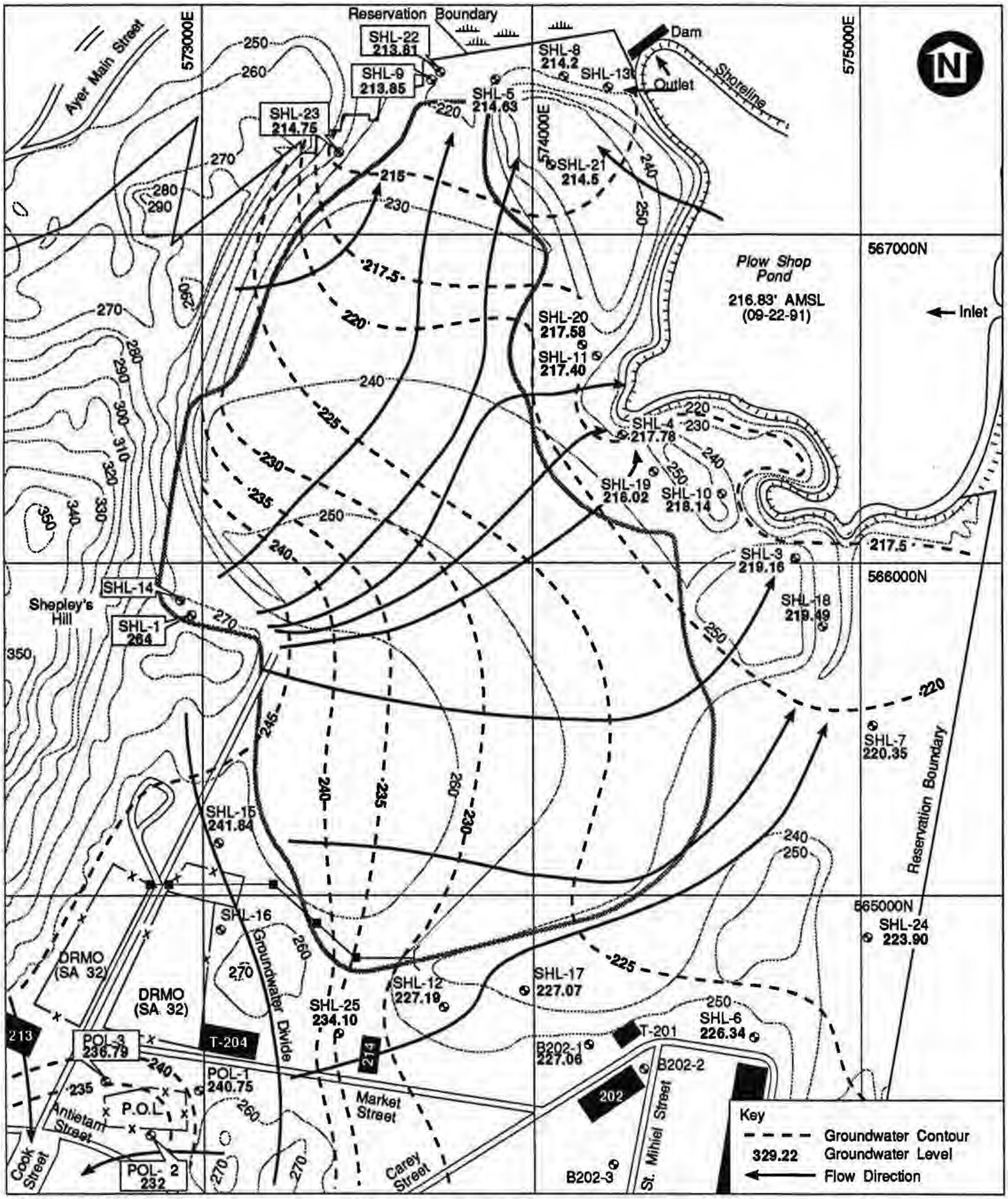
—— Road

- - - Installation Boundary

Scale in miles

1 3/4 1/2 1/4 0 1

Figure 3-2 LOCATIONS OF REGIONAL SOIL SAMPLES



Source: DEH Ft. Devens

Legend ··· 275 ··· Contour (10ft.) | Wetland | Approx. Extent of Fill | Building | Road | Fence | Monitoring Well | Storm Catch Basins | 565000N State Planar Coordinates

Figure 3-3 GROUNDWATER CONTOURS AT SHEPLEY'S HILL LANDFILL (8/30/91)

SHL7.CDR

The hydraulic gradients were calculated by measuring decline (or rise) in hydraulic head along flow paths as defined by lines drawn at right angles to the groundwater contours. Groundwater contours were drawn by interpolating lines of equal hydraulic head using the levels measured in the monitoring wells over one day. Most of the wells are screened across the water table, but the vertical hydraulic gradients have been found to be so slight when compared to the horizontal that levels from deeper wells (SHL-5, SHL-6, SHL-7, SHL-9, SHL-22, and SHL-24) have been interpolated without affecting the flow directions. Flow directions in the deeper overburden appear to be very similar to those in the shallow wells.

Horizontal hydraulic gradients start out steep near upgradient wells such as SHL-15, SHL-23, and SHL-25 (0.10 to 0.025 feet per foot), but dropping rapidly to as little as 0.006 across the middle of the landfill, and remaining generally low, except perhaps near SHL-3, where they steepen close to the pond (to 0.02 feet per foot). See Figure 3-3 and note the change in contour interval across the figure. Seasonal variations in groundwater elevations do not cause significant changes in flow direction.

As would be expected, the POL wells are on the other side of a groundwater divide that runs along the general line of the bedrock outcrops east of the DRMO Yard and the POL enclosure. Groundwater flow beneath the DRMO Yard and the POL enclosure is apparently southwest towards Willow Brook and does not impact Shepley's Hill Landfill. The Building 202 wells tie in precisely with the nearby Shepley's Hill Landfill wells and indicate that flow at Building 202 is northeast towards the south end of Plow Shop Pond.

Water level data are given in Tables 3-8, 3-9, and 3-10 for the three sets of data collected in August and December 1991, and in March 1992. All show essentially the same pattern, although during August SHL-1 was dry, and during March 1992 it was obstructed and could not be measured.

No bedrock wells were installed and no measurements of hydraulic gradients or hydraulic conductivity were made in the bedrock. Dry holes were drilled into the bedrock at SHL-14 and SHL-16 in attempts to install upgradient wells for the landfill. Hard, unweathered, and little fractured granodiorite or granodiorite gneiss was encountered in each instance. Rates of flow in the bedrock are not known.

Several wells around the landfill encountered finer grained materials or materials of lower hydraulic conductivity at the bottom of the overburden. These include SHL-15, SHL-22, SHL-24, and SHL-25. These materials included clay (SHL-15), till (SHL-22), silty clay (SHL-25), and possibly silt or till (SHL-24). If these types of material are widespread above the top of bedrock under the landfill they could impede flow between the bedrock and overburden.

Table 3-8

**WATER LEVEL DATA FOR SHEPLEY'S HILL LANDFILL
8/30/91 (FEET ABOVE MEAN SEA LEVEL)**

Well #	Top of Casing*	Depth to Water (Ft)	Water Level	Well #	Top of Casing	Depth to Water (Ft)	Water Level
SHL-1	--	--	DRY	SHL-21	259.94	45.44	214.5
SHL-3	249.20	30.04	219.16	SHL-22	221.25	7.44	213.81
SHL-4	228.76	10.98	217.78	SHL-23	242.35	27.60	214.75
SHL-5	218.77	4.16	214.63	SHL-24	239.76	15.86	223.90
SHL-6	254.17	27.84	226.34	SHL-25	259.10	25.00	234.10
SHL-7	238.14	17.79	220.35	POL-1	259.85	19.1	240.75
SHL-8D	222.04	7.84	214.20	POL-2	260.79	28.78	232.01
SHL-8S	222.04	7.82	214.32	POL-3	262.30	25.51	236.79
SHL-9	223.29	9.44	213.85	BLDG 202-1	254.75	27.69	227.06
SHL-10	249.48	31.34	218.14	BLDG 202-2	258.53	31.29	227.24
SHL-11	236.83	19.34	217.49	BLDG 202-3	258.56	30.48	228.08
SHL-12	249.91	22.72	227.19				
SHL-13	222.18	7.68	214.50				
SHL-15	261.04	19.20	241.84				
SHL-17	234.91	7.84	227.07				
SHL-18	238.64	19.15	219.49				
SHL-19	241.62	23.60	218.02				
SHL-20	236.90	19.32	217.58				

RC424

* From top of outer steel casing

Source: E & E 1991

Table 3-9

WATER LEVEL DATA FOR SHEPLEY'S HILL LANDFILL
12/12 - 12/13/91 (FEET ABOVE MEAN SEA LEVEL)

Well #	Top of Casing*	Depth to Water (Ft)	Water Level	Well #	Top of Casing	Depth to Water[1] (Ft)	Water Level
SHL-1	273.16	2.84	270.32	SHL-21	259.94	44.67	215.27
SHL-3	249.20	30.16	219.04	SHL-22	221.25	6.53	214.72
SHL-4	228.76	10.66	218.10	SHL-23	242.35	26.09	216.26
SHL-5	218.77	2.75	216.02	SHL-24	239.76	15.95	223.81
SHL-6	254.17	28.05	226.12	SHL-25	259.10	24.79	234.31
SHL-7	238.14	17.92	220.22	POL-1	259.85	19.07	240.78
SHL-8D	222.04	7.15	214.89	POL-2	260.79	28.70	232.09
SHL-8S	222.04	7.26	214.78	POL-3	262.30	25.88	236.42
SHL-9	223.29	8.46	214.83	BLDG 202-1	254.75	27.74	227.01
SHL-10	249.48	31.36	218.12	BLDG 202-2	258.53	31.44	227.09
SHL-11	236.83	19.02	217.81	BLDG 202-3	258.56	30.82	227.74
SHL-12	249.91	22.65	227.26				
SHL-13	222.18	7.06	215.12				
SHL-15	261.04	18.90	242.14				
SHL-17	234.91	7.80	227.11				
SHL-18	238.64	19.17	219.47				
SHL-19	241.62	22.84	218.78				
SHL-20	236.90	18.98	217.92				

RC424

* From top of outer steel casing

Source: E & E 1991

Table 3-10

WATER LEVEL DATA FOR SHEPLEY'S HILL LANDFILL
3/19/91 (FEET ABOVE MEAN SEA LEVEL)

	Top of Casing* (feet AMSL)	Depth to Water (feet)	Water Level (feet AMSL)
SHL-1	273.16 (steel)	NA (well obstructed)	
SHL-3	248.50 (steel)	30.27	218.23
SHL-4	228.71	10.95	217.76
SHL-5	218.53	3.73	214.80
SHL-6	253.82	28.33	225.49
SHL-7	238.14 (steel)	18.53	219.61
SHL-8S	221.85	7.68	214.17
SHL-8D	221.66	7.53	214.13
SHL-9	222.86	9.05	213.81
SHL-10	248.80	31.02	217.78
SHL-11	236.34	18.79	217.55
SHL-12	249.51	23.05	226.46
SHL-13	221.58	7.07	214.51
SHL-15	260.75	18.31	242.44
SHL-17	234.57	8.22	226.35
SHL-18	238.39	19.48	218.91
SHL-19	241.34	23.16	218.18
SHL-20	236.84	19.20	217.64
SHL-21	259.75	45.33	214.42
SHL-22	220.49	7.05	213.44
SHL-23	242.14	27.61	214.53
SHL-24	239.60	16.45	223.15
SHL-25	258.87	25.36	233.51
B202-1	254.43	28.14	226.29
B202-2	258.37	31.92	226.45
B202-3	Not accessible		
POL-1	259.77	19.01	240.76
POL-2	260.79	29.11	231.68
POL-3	261.94	26.00	235.94
POND	Top of Gauge = 218.60 feet AMSL, Depth to Water = 1.82 feet, Water Level in Pond = 216.78 feet.		

RC424

* From top of inner PVC casing except where noted

Source: E & E, 1992

3.1.5 Surface Water Hydrology

The surface elevation of Plow Shop Pond is controlled by dams, and varies very little over the course of a year. It was measured at 216.83 feet AMSL on 22 September 1991. This agrees well with the topographic map (Ayer Quadrangle), which indicates a surface elevation of 216 feet AMSL. Nonacoicus Brook below the dam and below the wetland north of the landfill was not surveyed, but must lie below 213.81 AMSL (the elevation of groundwater in SHL-22), since the groundwater discharges to the brook.

Almost all the flow of Nonacoicus Brook originates from flow over the dam at the northwest end of Plow Shop Pond. There is only a trickle of water over (or through) the dam at the north end of the Pond. Nonacoicus Brook flows through the North Post and discharges to the Nashua River only a mile west-northwest of Plow Shop Pond. Most of the flow into Plow Shop Pond comes from Grove Pond under the railroad through a culvert. This includes the combined flow of Bowers Brook, Cold Spring Brook, and another chain of ponds east of Ayer.

3.1.6 Sediments

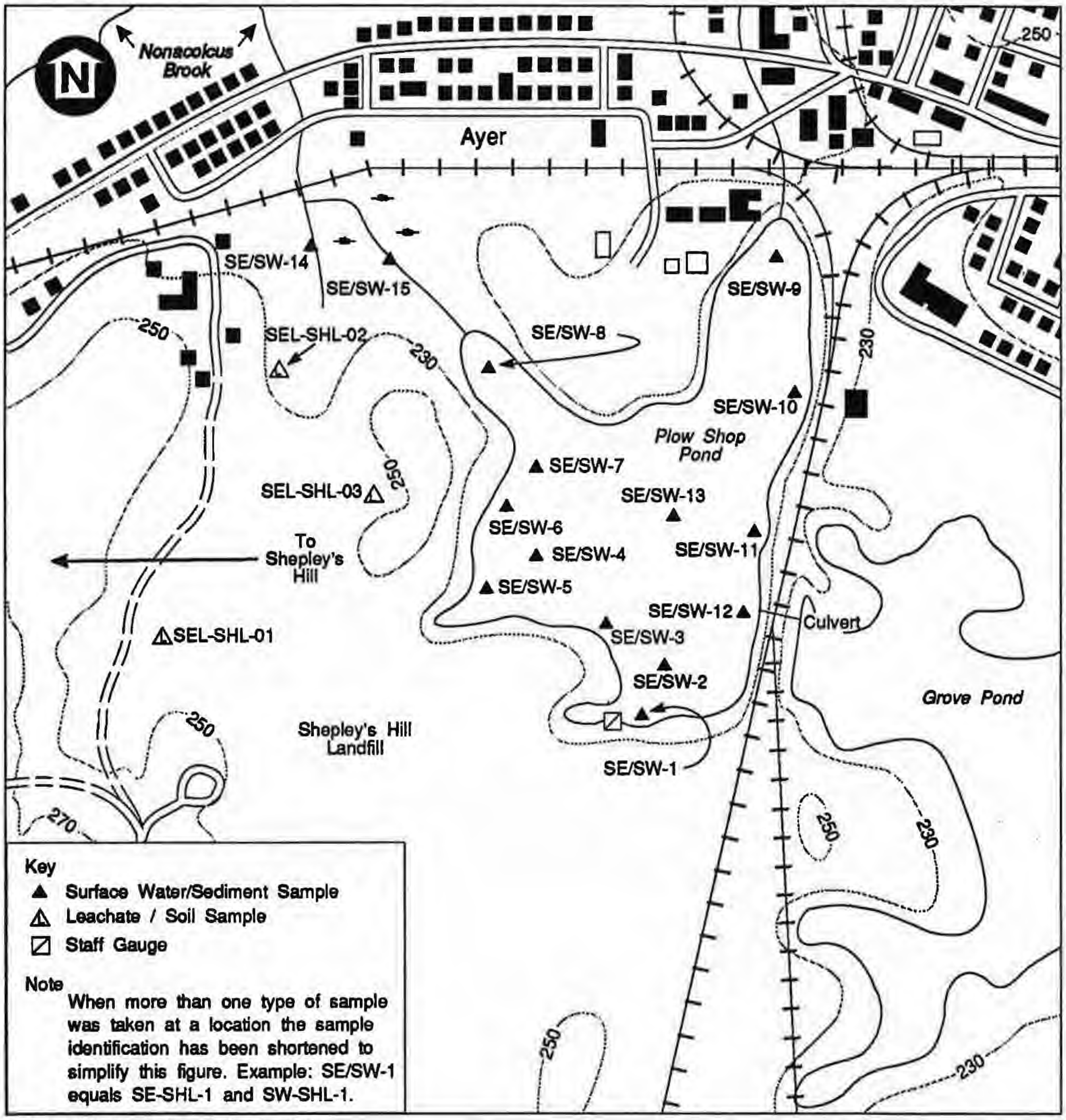
Fifteen sediment samples were collected in the vicinity of Shepley's Hill Landfill, thirteen from the Plow Shop Pond wetland and one each from the wetland just north of the north end of the landfill, and from Nonacoicus Brook just below its origin as overflow from Plow Shop Pond (see Figure 3-4).

Sediments from the pond were predominantly sandy and ranged from clean gravelly sand (SE-SHL-12), through sand, silt, and clayey silt, to one example of clay (SE-SHL-03). Particle size distribution is tabulated in Appendix F. Total organic carbon content was generally high, ranging from 2.19 percent to 24.2 percent, with an arithmetic mean of 12.16 percent.

The sample from the wetland north of the landfill was sand with 2.2 percent organic carbon. The sample from Nonacoicus Brook was coarse sandy gravel, as would be expected from this high energy environment, and contained only 0.24 percent organic carbon.

3.1.7 Meteorology

Meteorological measurements were made as part of the air quality survey at Shepley's Hill Landfill and at Cold Spring Brook Landfill. The data were collected during the period 13 August 1991 to 25 August 1991, and is reported in Appendix G.



Source: USGS, 1966, Revised 1979

Legend

- 275 Contour
- Building, Permanent
- Building, Temporary
- Wetland
- Road, Paved
- Road, Unimproved
- Railroad

Scale In Feet
600 300 0 600

Figure 3-4 SHEPLEY'S HILL LANDFILL / PLOW SHOP POND SAMPLING LOCATIONS

3.2 COLD SPRING BROOK LANDFILL

3.2.1 Ecological Characterization of the Cold Spring Brook Landfill Site

The purpose of this ecological characterization is to identify, map, and describe the upland, wetland, and aquatic ecosystems that occur within the vicinity of the Cold Spring Brook Landfill site. A major objective of this ecological characterization is to determine whether or not significant ecological resources that could be impacted by site contaminants are present within the vicinity of the site. These significant resources include jurisdictional wetlands and other sensitive environments; Federal or State endangered, threatened, or rare species; and economically or recreationally important fisheries or wildlife. Observations of physically-stressed plants and animals or the absence of common species known to be sensitive to site contaminants, which may indicate the effects of Cold Spring Brook Landfill site contaminants, are also discussed in this section. The methodology used during the site ecological field survey is described in Section 2.2.9.

3.2.1.1 Upland Plant Communities

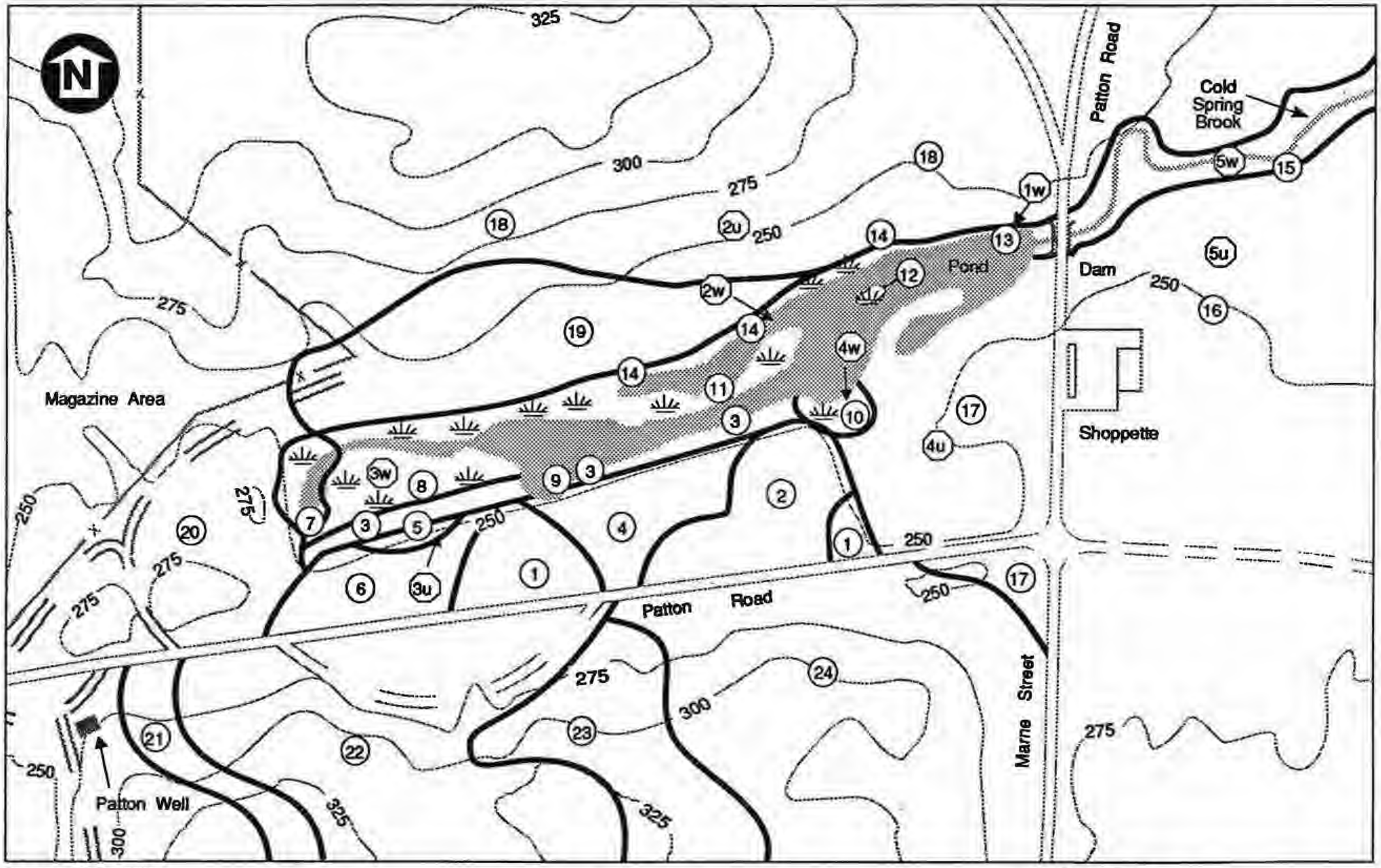
Of the 24 cover types, a total of 15 were distinct upland vegetation types identified within the vicinity of Cold Spring Brook Landfill site. No areas of dead trees or other evidence of physical stress were noted. The boundaries between the cover types are depicted in Figure 3-5. Plant species identified within the Cold Spring Brook Landfill site as well as within the Shepley's Hill Landfill site are listed in Table 3-1. Mammals, birds, reptiles, and amphibians that were observed during the field surveys or that are likely to occur in the area, based on range maps (DeGraaf and Rudis 1986), are listed in Tables 3-2, 3-3, and 3-4, respectively. Table 3-11 summarizes the dominant plants present within each cover type for the site.

Each cover type present within the Cold Spring Brook Landfill site is described below in terms of plant species composition, vegetation structure, edaphic conditions, and land use. The value of each area for wildlife is also evaluated.

Cover Type 1: Scotch Pine Plantation

Located along Patton Road on the landfill is an area of planted Scotch pine (Pinus sylvestris). Originally introduced to this country from Europe, this tree is widely used in reforestation programs and more recently in Christmas tree plantations. This Scotch pine plantation can be described as a moderately dense stand with little understory or herbaceous growth. The trees are 20 to 30 feet tall and range in diameter at breast height (dbh) from 8 to 10 inches.

Pines provide a variety of benefits to birds and mammals. For many wildlife species, the seeds, bark, and needles are part of their diet. In addition, pine trees provide excellent roosting and nesting areas for



Source: E&E, 1991

Legend

- Wetland
- Contour (—275—)
- Plant Community Boundary
- (21) Plant Community Numbers
- (1w) Wetland Plot Location
- Road
- Fence
- (1u) Upland Plot Location

Scale in Feet

300 0 300

Figure 3-5 COVER TYPE BOUNDARIES FOR ECOLOGICAL ASSESSMENT OF COLD SPRING BROOK LANDFI' '

1ARI/Fig.3-5.CDR

Table 3-11

SPECIES COMPOSITION* OF PLANT COMMUNITIES
IDENTIFIED IN THE GENERAL VICINITY OF THE
COLD SPRING BROOK LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
1. Scotch Pine Plantation	Tree	Scotch pine	155/155	100
	Sapling	Scotch pine	60/60	100
2. Old Field	Sapling	White pine	5/5	100
	Shrub	Sweetfern	5/7	71
		Spotted knapweed	50/95	53
	Herb	Panic grass	40/95	42
3. Aspen--Birch Early Successional Forest	Sapling	Quaking aspen	20/50	40
		Paper birch	20/50	40
		Smooth sumac	10/20	50
	Shrub	Smooth alder	5/20	25
	Herb	Panic grass	10/15	67
4. Aspen Early Early Successional Forest	Tree	Eastern cottonwood	455/632	72
		Quaking aspen	137/632	2
	Sapling	Quaking aspen	30/70	43
		Big-tooth aspen	30/70	43
	Shrub	Sweetfern	10/10	100
	Liana	Poison ivy	60/60	100
	Herb	Rough goldenrod	10/15	67
5. Sumac Thicket	Sapling	Red pine	15/17	75
	Shrub	Staghorn sumac	30/60	50
		Black raspberry	20/60	33
	Herb	Panic grass	80/90	88
6. Red Pine Plantation	Sapling	Red pine	60/60	100
	Shrub	Autumn olive	35/40	88
	Herb	Spotted knapweed	5/5	100

RC424

Key at end of table

Table 3-11 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE COLD SPRING BROOK LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
7. Alder--Buttonbush Wetland	Shrub	Smooth alder	10/17	50
		Buttonbush	10/17	50
	Herb	Sedge	15/30	50
		Enchanter's nightshade	10/30	33
8. Peat Wetland	Tree	Red maple	10/10	100
	Sapling	Red maple	15/30	50
		Paper birch	10/30	33
	Shrub	Meadowsweet	25/45/	55
		Bristly dewberry	15/45	33
	Herb	Marsh fern	60/70	86
9. Swamp Loosestrife Peninsula	Herb	Swamp loosestrife	60/100	60
		Marsh fern	20/100	20
10. White Pine--Cinnamon Fern Forested Wetland	Tree	White pine	1,961/2,559	77
		Red maple	597/2,559	23
	Shrub	American hazelnut	6/10	60
	Herb	Cinnamon fern	75/90	83
11. Red Maple Peninsula	Sapling	Red maple	60/80	75
		Paper birch	20/80	25
	Shrub	Silky dogwood	20/30	67
	Herb	Marsh fern	10/25	40
		Swamp loosestrife	10/25	40
12. Red Maple Island	Sapling	Red maple	25/30	83
	Shrub	Smooth alder	25/60	42
		Bristly dewberry	20/60	33
	Herb	Marsh fern	10/30	33
		Swamp loosestrife	10/30	33

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Key at end of table

Table 3-11 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE COLD SPRING BROOK LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
13. Emergent Marsh	Shrub	Silky dogwood	15/25	60
	Herb	Broad-leaf cattail	25/75	33
		Soft rush	25/75	33
14. Red Maple--Highbush Blueberry Wetland	Tree	Red maple	39.2/39.2	100
	Sapling	Red maple	40/40	100
	Shrub	Highbush blueberry	70/90	77
		Smooth alder	20/90	22
	Herb	Cinnamon fern	20/60	33
		Marsh fern	15/60	25
15. Red Maple--White Pine Forested Wetland	Tree	Red maple	190/323	59
		White pine	132/323	41
	Sapling	American elm	40/80	50
		Red maple	35/80	44
	Shrub	Witch hazel	10/30	33
		Silky dogwood	10/30	33
	Herb	Rice cutgrass	30/90	33
		Spotted jewelweed	20/90	22
		Cinnamon fern	20/90	22
16. White Pine Forest	Tree	White pine	983/1,494	66
		Red maple	331/1,494	22
	Sapling	White pine	10/35	29
		Red maple	10/35	29
	Shrub	American hazelnut	20/35	57
	Herb	Canada mayflower	10/34	29
		Ground cedar	10/34	29

RC424

Key at end of table

Table 3-11 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE COLD SPRING BROOK LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
17. Scarlet Oak Forest	Tree	Scarlet oak	438/750	58
		White pine	176/750	24
	Shrub	American hazelnut	20/25	80
	Herb	Ground cedar	5/10	50
		Canada mayflower	5/10	50
18. Mixed Oak Forest	Tree	Scarlet oak	153/366	41
		White oak	116/366	32
		White pine	76/366	21
	Sapling	Scarlet oak	30/30	100
	Shrub	Sheep laurel	50/70	71
	Herb	Ground pine	10/15	67
19. White Pine--Red Maple Forest	Tree	White pine	641/1,240	52
		Red maple	472/1,240	38
	Sapling	White pine	60/100	60
		Red maple	20/100	20
	Herb	Cinnamon fern	10/15	67
20. Mixed Oak--White Pine Forest	Tree	Scarlet oak	413/1,136	36
		White oak	401/1,136	35
		White pine	243/1,136	21
	Sapling	American chestnut	10/17	60
	Shrub	Witch hazel	15/35	43
		Dwarf blueberry	10/35	29
	Herb	Wintergreen	2/3	67

RC424

Key at end of table

Table 3-11 (Cont.)

SPECIES COMPOSITION* OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE COLD SPRING BROOK LANDFILL SITE

Cover Type	Stratum	Species	Dominance Ratio**	Percent Dominance
21. Aspen Early Successional Forest	Tree	Quaking aspen	212/406	52
		Big-tooth aspen	97/406	24
	Sapling	Quaking aspen	20/50	40
		Big-tooth aspen	10/50	20
	Shrub	Sweet fern	50/60	83
	Herb	Early goldenrod	5/7	71
22. Paper Birch--White Pine Shrubland	Sapling	Paper birch	50/97	52
		White pine	30/97	31
	Shrub	Dwarf blueberry	10/12	83
	Herb	Moss	10/14	71
23. Scarlet Oak--Birch Early Successional Forest	Tree	Scarlet oak	407/887	46
		Paper birch	243/887	27
		Gray birch	217/887	25
	Sapling	Red maple	10/30	33
		White pine	10/30	33
	Shrub	Dwarf blueberry	90/100	90
	Herb	Wintergreen	5/9	55
24. Scarlet Oak Forest	Tree	Scarlet oak	743/899	83
	Sapling	White pine	25/60	42
		Scarlet oak	25/60	42
	Shrub	Black huckleberry	5/8	63
	Herb	Indian pipe	1/2	50
		Pink ladyslipper	1/2	50

RC424

Key:

*Species listed only include dominant species

**Dominance ratio for trees is expressed as basal area per species/total basal area for all trees within 30-foot radius plot. Dominance ratio for sapling and shrubs is expressed as percent areal coverage per species/total percent areal coverage for all saplings or shrubs within a 15-foot radius plot. Dominance ratio for herbs is expressed as percent areal coverage per species/total percent areal coverage for all herbs within a 5-foot radius plot.

Source: E & E Field Survey 1991

songbirds and game birds, as well as valuable cover for deer, squirrels, and chipmunks (Martin et al. 1961).

Cover Type 2: Old Field

This cover type is an early successional community that has developed on the eastern end of the Cold Spring Brook Landfill site. This area is primarily herbaceous and is dominated by spotted knapweed (Entaurea maculosa), sweetfern (Comptonia peregrina), and panic grass (Panicum sp.). Scattered throughout this cover type are eastern white pine (Pinus strobus), autumn olive (Elaeagnus umbellata), and staghorn sumac (Rhus typhina) seedlings and saplings.

In this relatively open area, the scattered shrubs and saplings provide protective cover for wildlife. The food value of autumn olive and staghorn sumac during winter months is excellent for a number of songbirds and game birds. Although the herbaceous dominants of this cover type do not provide a preferred food source, they will be utilized during severe conditions.

Cover Type 3: Aspen--Birch Early Successional Forest

Located on the northern edge of the landfill, on the sloped area between the pond and the actual fill, is a narrow strip of aspen-birch forest. Both quaking aspen (Populus tremuloides) and paper birch (Betula papyrifera) are fast-growing, short-lived species that develop in disturbed areas (i.e., burns, clearcuts), and are considered pioneer species that will eventually be replaced by more tolerant species (Harlow et al. 1979). This particular stand consists of trees that are approximately 10 to 20 feet tall and range in dbh from 3 to 5 inches. Because this stand is located on the edge of the landfill, exposed debris (primarily concrete blocks) is present throughout this cover type.

The understory or shrub layer in this young pioneer stand primarily includes smooth alder (Alnus serrulata) and seedlings of the overstory species. The dominant herbaceous plant is panic grass, with occurrences of sensitive fern (Onoclea sensibilis), marsh fern (Thelypteris palustris) and rough-stemmed goldenrod (Solidago rugosa).

Aspen and birch are considered valuable winter and spring food sources for various kinds of wildlife. The resinous buds and catkins are eaten by grouse; the bark, twigs, and leaves are eaten by deer and rabbit; while the bark is a preferred food item for beaver (Martin et al. 1961). Evidence of beaver activity was observed throughout this area during the field survey.

Cover Type 4: Aspen Early Successional Forest

Located towards the eastern end of the landfill area, between the Scotch pine plantation and the old field, is a forested area dominated by eastern cottonwood (Populus deltoides) and quaking aspen. Unlike cover type 3, this stand does not include paper birch as a dominant species. Trees in this forest range in height from 30 to 40 feet, and in dbh from 6 to 12 inches. This much more mature stand has an understory of aspen saplings, as well as red maple, white pine, paper birch, and green ash (Fraxinus pennsylvanica). There is a dense ground cover of poison ivy (Toxicodendron radicans) with sweetfern and rough goldenrod scattered throughout. This area provides essentially the same wildlife benefits as discussed for cover type 3. In addition, due to the larger size of this stand, a variety of wildlife species will benefit from the cover/shelter this forested area can provide.

Cover Type 5: Sumac Thicket

This small stand of staghorn sumac and smooth sumac (Rhus glabra) is located on the northern side of the landfill just west of the middle point. Although there are a few red maple saplings scattered throughout this area, the dominant cover type is sumac. Black raspberry (Rubus occidentalis), autumn olive, and sweetfern constitute the shrub layer but are not very abundant. The thick groundcover consists primarily of spotted knapweed and panic grass.

This area does not provide choice food for wildlife, except for the few autumn olive bushes, but does provide an excellent area for cover and shelter. Sumac fruits provide a good source of food but they are not actually utilized until the winter, when other more desirable foods are scarce (Martin et al. 1961).

Cover Type 6: Red Pine Plantation

On the extreme western end of the landfill area, a stand of red pines (Pinus resinosa) has been planted. Used primarily in reforestation programs, this fast-growing tree is capable of growing in fairly poorly developed soils. The plantation on the Cold Spring Brook Landfill site is a young stand, which is only 10 to 20 feet tall with a dbh ranging from 3 to 6 inches. A dense shrub layer of autumn olive, staghorn sumac, and sweetfern grows between the straight rows of pines. In the areas where this shrub layer is sparse, the herbaceous cover consists of spotted knapweed and rough goldenrod; otherwise, there is very little ground cover.

Wildlife benefits in this cover type are approximately the same as those previously discussed for cover type 1 (Scotch pine plantation). However, the abundant autumn olive shrubs in this area provide an excellent fruit source for a variety of songbirds. At the time of the field survey, numerous songbirds were observed in this cover type, presumably because of the abundance of ripening autumn olive fruits. In addition, the dense shrub layer in this red pine plantation provides greater cover and shelter than the relatively open Scotch pine plantation.

Cover Types 7 through 15

These cover types are described in Section 3.2.1.2, Wetland Plant Communities.

Cover Type 16: White Pine Forest

Located on the east side of Marne Road to the south of Cold Spring Brook is a mature stand of healthy eastern white pines. The overstory is dominated by 70- to 80-foot tall and 20- to 25-inch dbh eastern white pines, with some red maple trees scattered throughout the stand. The understory consists of seedlings and saplings of eastern white pine and red maple, as well as American hazelnut (Corylus americana) shrubs. Canada mayflower (Haianthemum canadense) and ground cedar (Lycopodium tristachium) are the dominant herbaceous plants that constitute the sparse ground cover in this area.

Similar to the wildlife benefits discussed for cover types 1 and 6, this area provides an excellent source of food for songbirds, game birds, small mammals, and deer. Pine seeds as well as the hazelnuts are food for grouse, nuthatches, chipmunks, squirrels, and deer (Martin et al. 1961). In addition, the mature pine trees provide nesting and roosting areas for a number of bird species including raptors.

Cover Type 17: Scarlet Oak Forest

Located on the eastern edge of the landfill on the northern side of Patton Road and to the west of Marne Road, the forest is dominated by scarlet oak (Quercus coccinea). Considered an important component of the climax forests of the east (Harlow 1979), scarlet oak is a shade-intolerant species that grows rapidly on dry soils.

In this particular stand, the scarlet oaks are 70 to 80 feet tall with dbh ranging from 15 to 22 inches. White pine and northern red oak (Quercus rubra) are also present in the overstory. Some portions of the understory have a dense layer of American hazelnut, while others have a dense cover of white pine, northern red oak, black cherry, dogwood, and blueberry. Still other areas are fairly open with no understory growth. Similar to the understory, the herbaceous layer occurs in clumps scattered throughout the area. Herbaceous plant species observed include Canada mayflower, royal fern (Osmunda regalis), poison ivy, pink ladyslipper (Cypripedium acaule), sarsaparilla (Aralia nudicaulis), and ground cedar.

Acorns are considered an important wildlife food because they are abundant and provide a reliable source. Acorns are eaten year-round, but are of greatest value during the winter. Many wildlife species, including ducks, turkeys, squirrels, and deer, eat acorns (Martin et al. 1961). In addition to providing an excellent food source, oaks also provide useful cover and nesting material for a variety of wildlife species. Therefore, this cover type is considered an area with significant wildlife value.

Cover Type 18: Mixed Oak Forest

This area, located north of the pond, is very similar to cover type 17. The overstory consists of mature sawtimber-sized (20- to 27-inch dbh) scarlet oak, eastern white pine, and white oak (Quercus alba), which are approximately 70 to 80 feet tall. Unlike cover type 17 there is a uniformly dense understory of white oak, eastern white pine, scarlet oak, sheep laurel (Kalmia angustifolia), mountain holly (Ilex montana), sassafras (Sassafras albidum), and highbush blueberry (Vaccinium corymbosum). The ground cover includes a thick leaf litter with patches of ground pine (Lycopodium obscurum).

The wildlife values of this cover type are approximately the same as those discussed for cover type 17.

Cover Type 19: White Pine--Red Maple Forest

This area is located on the northwest side of the pond. This stand consists of predominantly eastern white pine (20- to 27-inch dbh) and red maple (8- to 12-inch dbh), with a few scattered northern red oak and white oak trees. The overstory consists of 70- to 80-foot tall sawtimber-sized trees, with the understory consisting of saplings and seedlings of the overstory species. Pockets of cinnamon fern (Osmunda cinnamomea) are scattered throughout the area and constitute the majority of the ground cover.

Both the red maple and eastern white pine provide a variety of benefits to wildlife. As previously discussed for the two pine plantations, pine seeds provide food for a number of birds and small mammals, as do maple fruits (and acorns from the scattered oak). In addition, both white pine and red maple provide roosting and nesting habitat as well as nesting materials. Deer browse on the twigs and foliage of red maple and white pine seedlings and saplings, and also eat available acorns.

Cover Type 20: Mixed Oak--White Pine Forest

This upland forest is located on the western edge of the pond and on the northern side of Patton Road. Scarlet and white oak are the dominant species in the 60- to 70-foot-tall overstory. The average dbh in this area is approximately 15 inches. The understory is fairly sparse and open with a few American chestnut (Castanea dentata), witch hazel (Hamamelis virginiana), and dwarf blueberry (Vaccinium angustifolium) shrubs scattered throughout. The ground is predominantly covered with a thick leaf litter with little herbaceous growth except for a few wintergreen (Gaultheria procumbens) plants.

Wildlife species derive approximately the same benefits from this cover type as from those cover types previously discussed for other oak and pine stands. Evidence of heavy wildlife use in this area was observed during the field survey. The blueberry shrubs had been picked clean of their berries, and some berry-laden black bear (Ursus americana) scat was observed. In addition, a great horned owl roost tree was found. Raccoon tracks were observed, and a number of large eastern white pine snags were noted as potential den trees or cavity-nesting trees.

Cover Type 21: Aspen Early Successional Forest

Located across Patton Road from the Cold Spring Brook Landfill Site, toward the western end, is a young pole-sized stand of aspen. Both quaking aspen and big-tooth aspen (Populus grandidentata) dominate the 30- to 40-foot-tall overstory with dbhs ranging from 4 to 8 inches. In addition, these two species occur in the dense understory along with northern red oak, white pine, paper birch, and sweetfern. The sparse herbaceous layer consists of early goldenrod (Solidago juncea).

Aspen, oak, and pine have considerable value to wildlife, as previously discussed. In particular, the young aspen saplings provide an excellent food source for browsing deer. The added advantage of cover is much greater in this stand because of the young age and dense nature of the trees of this area.

Cover Type 22: Paper Birch—White Pine Shrubland

On the eastern side of the cover type 21 area is a heavily disturbed area with exposed piles of soil, gravel paths, and clumps of vegetation scattered throughout. The vegetated areas are dominated by sapling paper birch and eastern white pine with an average dbh of 3 inches. Other vegetation in the area includes dwarf blueberry, early goldenrod, evening primrose (Oenothera biennis), butter-and-eggs (Linaria vulgaris), and broom-sedge (Andropogon virginicus).

This shrubland area provides an excellent area for songbirds, small mammals, and snakes. As previously discussed, birch, pine, and bilberry provide food and cover.

Cover Type 23: Scarlet Oak—Birch Early Successional Forest

Located on the southern side of Patton Road (across from the Cold Spring Brook Landfill site) and to the east of the cover type 22 area, is a steeply sloped forested area. The 30- to 40-foot-tall overstory is comprised chiefly of scarlet oak, paper birch, and gray birch (Betula populifolia). The dbh of trees in this area ranges from 1 to 6 inches. The dense understory consists of seedlings and saplings of red maple, white pine, and species that occur in the overstory. Sweetfern and blueberry also occur in the shrub layer. The sparse herbaceous layer is primarily comprised of wintergreen and scattered mosses.

The dense undergrowth and low branches in this cover type provide excellent cover for a number of wildlife species as well as excellent nesting habitat for a variety of songbirds. Food plants in this area include the oaks and birches.

Cover Type 24: Scarlet Oak Forest

This cover type is located on the southern side of Patton Road and to the east of the cover type 23 area. The dominant overstory species is scarlet oak although gray birch and northern red oak also occur. The dbh of the scarlet oaks ranges from 8 to 16 inches, and the trees are approximately 50 to 60 feet tall. The understory is moderately dense and consists of blueberry and huckleberry (Gaylussacia dumosa), while the ground cover is very sparse and scattered. Indian pipe (Monotropa uniflora) and pink ladyslipper are the most common herbaceous plants found in this area.

Wildlife values for this cover type are basically the same as those previously described for oak stands.

3.2.1.2 Wetland Plant Communities

Nine wetland vegetation cover types were identified within the vicinity of the Cold Spring Brook Landfill site. Eight of these wetland areas (cover types 7 through 14) are hydrologically connected and are located close to each other. These eight wetland cover types are collectively described as the "Cold Spring Brook Wetland Complex" in portions of this report.

The locations of the Cold Spring Brook Landfill site wetland cover types are shown in Figure 3-5. Table 3-11 summarizes the dominant plant species present within each of these wetland cover types. Each wetland cover type is described below in terms of plant species composition, vegetation structure, edaphic conditions, and land use. The value of each for wildlife use is also reviewed.

New England Army Corps of Engineers Wetland Delineation Data forms were completed for each wetland cover type and are provided in Appendix E. Each wetland cover type meets the three criteria (i.e., hydrophytic vegetation, hydric soils, and wetland hydrology) necessary to be considered jurisdictional wetland. Similar to the Shepley's Hill Landfill site wetlands, data forms were completed to evaluate wetland functions within the Cold Spring Brook Wetland Complex and cover type 15. Wetland functions are discussed in more detail in Section 3.2.1.4.

Cover Type 7: Adler--Buttonbush Wetland

At the western edge of the Cold Spring Brook pond is an inundated, palustrine scrub-shrub/emergent wetland, which supports hydrophytic vegetation around its perimeter. Smooth alder (Alnus serrulata) and buttonbush (Cephalanthus occidentalis) are the dominant woody plants. Sedge (Carex sp.) and enchanter's nightshade (Circaea alpina) are the dominant herbs, although spotted jewelweed (Impatiens capensis) and sensitive fern (Onoclea sensibilis) are also common. This wetland is characterized by deep muck soils and a hummocky surface. Soils surrounding the flooded center of the wetland are saturated.

Eastern painted turtles (Chrysemys picta) and green frogs (Rana clamitans) were abundant in the flooded center of this wetland at the time of the field survey. This area likely serves as a breeding pool for a variety of frogs and the American toad (Bufo americanus). Spotted salamanders (Ambystoma maculatum) may also breed in this pool. The relatively small size (approximately 0.5 acre) of this wetland and the relatively poor food value of smooth alder and buttonbush limit the value of this wetland to other animals. This shrub area may serve as nesting habitat for birds.

Cover Type 8: Peat Wetland

Cover type 8 is a palustrine scrub/shrub wetland dominated by red maple and paper birch saplings, meadowsweet (Spiraea latifolia), and bristly dewberry (Rubus hispidus). Small (5- to 7-inch dbh) red maple trees are scattered around the edge. Marsh fern (Thelypteris palustris) is the dominant herb, although reed canary grass (Phalaris arundinacca) is abundant along the edge of the pond.

This wetland area is underlain by a deep (greater than 3 feet) layer of peat. At the time of the field survey, the upper 4 inches of peat were dry, the zone from 4 to 12 inches deep was saturated, and the peat deeper than 12 inches was inundated. All three wetland designation criteria were met within this area. This community is therefore classified as a jurisdictional wetland.

This wetland provides a low, dense protective cover and a moderate food supply for wildlife. Red maple is a high-quality browse plant for white-tailed deer but is limited in availability in this area. Meadowsweet is abundant but is of lower quality. Little seed or fruit is produced in this area other than the seasonally important fruits of the scattered red maple trees.

Cover Type 9: Swamp Loosestrife Peninsula

This approximately 90-foot-long peninsula extends westward into Cold Spring Brook Pond from the north side of the landfill. Approximately 60 percent of the plant growth in this palustrine emergent wetland is swamp loosestrife (Deacodon verticillatus). Marsh fern is a second dominant plant. Purple loosestrife (Lythrum salicaria) is scattered amongst the swamp loosestrife. The soils throughout the peninsula were saturated at the time of the field survey.

This cover type is very small (less than 0.1 acre) and therefore of limited importance to wildlife when considered independently of the other wetlands that constitute the Cold Spring Brook Wetland Complex. Evidence of foraging by muskrats (Ondatra zibethicus) on swamp loosestrife was observed during the field survey.

Cover Type 10: White Pine--Cinnamon Fern Forested Wetland

A small lowland area located along the edge of Cold Spring Brook Pond immediately east of the landfill site supports a palustrine forested wetland with an unusual plant species composition. The most abundant tree is eastern white pine, although red maple is also dominant in the overstory. No saplings are present in the understory. The dominant shrub is American hazelnut, although it comprises only six percent areal coverage. A dense growth of cinnamon fern covers the ground. Fifty percent of the dominant plant species are wetland plants; therefore, the hydrophytic vegetation criterion is met, although marginally.

Although soils within this wetland area were not saturated at the time of the field survey, wetland hydrology indicators such as water-stained leaves and buttressed tree trunks were observed. In addition, the hydric soil criterion was met. This cover type is therefore classified as a jurisdictional wetland.

Because this forested wetland is small (approximately 0.1 acre), it provides little value for wildlife. Its chief benefits are the production of eastern white pine seed and red maple fruits, which are valuable for a number of birds and mammals.

Cover Types 11 and 12: Red Maple Peninsula and Red Maple Island

Cover types 11 and 12 are combined for this discussion because the vegetation for each is very similar and because cover type 12 is very small (approximately 0.04 acre). Red maple is the dominant tree within these palustrine forested/scrub-shrub wetland cover types. Paper birch is an additional dominant tree on the peninsula. Dominant shrubs include silky dogwood (Cornus amomum), smooth alder, and bristly dewberry. Marsh fern and swamp loosestrife form a dense cover along the shores of both the island and peninsula. Additional herbs include spotted jewelweed and bur-reed (Sparganium sp.).

At the time of the field survey, soils within a narrow strip (2 to 3 feet wide) along the edge of the peninsula were saturated and apparently met the hydric soil criterion. However, the remainder of the peninsula was dry, and these soils did not appear to meet the hydric soil criterion. A formal wetlands delineation was not conducted for this narrow strip of wetland, due to its small size and inaccessibility, but it appears that all three criteria are met within this shoreline edge area. It is likely that the red maple island cover type has a similar pattern of shoreline wetland and inland upland separation.

Evidence of foraging by muskrats on swamp loosestrife and bur-reed was observed during the field survey and a muskrat den was identified near the eastern end of the peninsula. One great blue heron (Ardea herodias), one green-backed heron (Butorides striatus), and three American black ducks (Anas rubripes) were also observed foraging along the edge of the peninsula. A variety of other animals such as fish, frogs, turtles, and the northern water snake (Nerodia sipedon) likely use the shoreline wetland associated with the peninsula and island.

Cover Type 13: Emergent Marsh

Cover type 13 is a very small (0.05-acre) palustrine emergent marsh, which borders the north shoreline of Cold Spring Brook Pond near Patton Road. The marsh consists chiefly of broad-leaf cattail (Typha latifolia) and soft rush (Juncus effusus), with scattered silky dogwood shrubs. All three wetland designation criteria are met within this cover type, so it is classified as a jurisdictional wetland.

The value of this wetland community for wildlife is likely to be similar to that described for cover types 11 and 12.

Cover Type 14: Red Maple--Highbush Blueberry Wetland

Most of the north shore of Cold Spring Brook Pond supports a red maple--highbush blueberry wetland. This shoreline is rather irregular with several small inlets and peninsulas. The width of this scrub-shrub/emergent wetland strip varies from approximately 2 to 40 feet. The dominant plants are red maple saplings, highbush blueberry (Vaccinium corymbosum), smooth alder, cinnamon fern, and marsh fern. A few red maple trees are scattered throughout this community. Swamp loosestrife and sedges (Carex spp.) are also common.

Sudbury fine sandy loam soils, which are nonhydric, are mapped up to the edge of the pond (USDA 1985). However, soils within this wetland strip were saturated to the surface and met the hydric soil criterion. All three wetland criteria are met for this community, so the cover type is classified as a jurisdictional wetland.

The shoreline portion of this wetland likely provides wetland wildlife values that are very similar to those described for cover types 11 and 12. In addition, the abundance of highbush blueberry away from the shoreline provides a secondarily important source of deer browse and a seasonally important source of high-quality fruits. These fruits are consumed heavily by upland game birds such as the ruffed grouse (Bonasa umbellus), songbirds such as the gray catbird (Dumetella carolinensis) and scarlet tanager (Piranga divacea), and mammals such as the black bear and white-footed mouse (Martin et al. 1961).

Cover Type 15: Red Maple--White Pine Forested Wetland

Cover type 15 is a palustrine forested wetland associated with Cold Spring Brook on the east side of Patton Road. Red maple and eastern white pine are the dominant tree species. Red maple and American elm (Ulmus americanus) saplings form a moderately dense understory with witch hazel (Hamamelis virginiana) and silky dogwood. The dominant herbs include rice cutgrass (Leersia oryzoides), spotted jewelweed, and cinnamon fern. Horsetail (Equisetum) also commonly occurs within this cover type.

This forested wetland is underlain by Swansea muck soils. These soils were saturated at the time of the field survey. All three wetland designation criteria were met within this area; therefore, this cover type is classified as a jurisdictional wetland.

Forested wetlands provide high-quality wildlife habitat due to the structural diversity, lush ground cover, availability of water, and abundance of insects. The prevalence of red maple in both the overstory and understory provides a year-round source of high-quality deer browse as well as a seasonally important crop of fruit, which is especially important to squirrels and the eastern chipmunk. Eastern white pine produces seed that is important to a variety of songbirds such as the black-capped chickadee (Parus atricapillus) and red-breasted nuthatch (Sitta canadensis), upland game birds such as the ruffed grouse and wild turkey (Meleagris gallopavo), and rodents such as the red squirrel (Tamiasciurus hudsonicus), gray squirrel (Sciurus carolinensis), and white-footed mouse (Peromyscus leucopus). Eastern white pine is also important because of the year-round cover it provides. Additional wetland values of this community are discussed in Section 3.2.1.4.

3.2.1.3 Aquatic Ecosystems

The waters of Cold Spring Brook are designated as Class B. Cold Spring Brook flows approximately 1.2 miles northeast from its headwaters in Cold Spring Brook Pond to is confluence with Bowers Brook, where it continues through a number of wetland areas to Grove Pond. Grove Pond empties into Plow Shop Pond, which in turn flows into Nonacoicus Brook.

Cold Spring Brook has a varied flow regime consisting of a large slow-flowing pools separated by riffle areas. Benthic substrate available for benthic macroinvertebrate colonization includes rocks of various sizes, woody debris, leaf litter, and macrophyte beds. With the habitat available, one would expect to find all of the general functional groups of benthic invertebrates: shredders (cranefly larvae), collectors (Baetid mayflies), scrapers (Heptageniid mayflies), and predators (Rhyacophilid [free living] caddisflies).

Finfish have been collected in this geographic region (U.S. Army Corps of Engineers 1989). Based on these collections, which described the Nashua River system as an impoverished finfish community, one might expect to find white suckers (Atostomus colmmersoni), golden shiners (Notemigonus crysolencas), yellow bullhead (Ameiuaus natalis), and small-mouth bass (Micopterus dolomieu). Pumpkinseed (Lepomis gibbosus) and redbreast sunfish (Lapomis aaritus) likely occur in Cold Spring Brook. Cover for a healthy piscivore population is abundant, while riffle areas provide cover and spawning habitat for forage fish. This stream should support a healthy invertebrate community (based on available habitat) and thus provide ample food for an omnivorous fish population (e.g., pumpkinseed, and redbreast sunfish).

The waters of Cold Spring Brook Pond are also designated Class B (Environmental Reporter 1991). Although this area is shown on the Ayer topographic quadrangle map (USGS 1988) as a wetland area rather than a perennial pond, the culvert beneath Patton Road has recently been plugged with natural debris (i.e., mud, leaves, and twigs) and the wetland is now a perennial open water body. Large areas of wetland and shallow water habitat tend to make this pond prime habitat for lentic macroinvertebrates such as dragonflies and midges.

During the August field survey a number of wildlife species were observed using the pond area. These included great blue heron, mallard ducks, green heron, belted kingfisher, painted turtles, snapping turtles, muskrat, beaver (based on the presence of old stumps in the pond area), wood ducks, and green frogs. It does not appear that this pond is used by local residents for recreational purposes.

Overall, the pond can be described as a small body of water with a number of peninsulas and islands. Vegetation includes scrub/shrub, emergent, and forested wetlands along the shore and on the islands (see Section 3.2.1.2). Aquatic vegetation includes cattails and water lilies. The pond appears to be deeper than Plow Shop Pond and not as eutrophic, although no boats were used to survey the center of the pond.

3.2.1.4 Overview and Discussion

The Cold Spring Brook Landfill site is a moderately high-value ecological area mostly because of the presence of a diverse and productive wetland complex surrounded by a diversity of upland plant communities. The wetland complex consists of eight relatively small wetland plant communities (cover types 7 through 14). The quality of these plant communities considered separately is relatively poor, but the quality of the entire complex is rather high due to the combined size and diversity. The presence of upland cover types around the perimeter of the wetland complex augments the ecological quality of the site by supporting a diverse array of upland plants and animals.

Seven of the nine wetland functions evaluated for the Cold Spring Brook Wetland Complex during the field survey were rated "high," and the remaining two were rated "moderate" (see Table 3-6). Based on the wetland functions evaluation, this wetland complex is expected to support a high diversity and abundance of aquatic and terrestrial species; effectively support stream flow; serve as a groundwater discharge area; store and gradually release storm flood waters; retain sediments and remove nutrients, and thereby improve water quality; and serve as an important area for cultural, economic, recreational, aesthetic, and educational uses.

One of the nine wetland functions evaluated for the forested wetland located east of Patton Road was rated "high," and the remaining eight were rated "moderate" (see Table 3-6). Overall, this wetland is considered average in terms of the functions it supports. Compared to

Cold Spring Brook Wetland Complex, this wetland is considered lower quality in regard to these nine wetland functions.

Many wetland-associated animals were observed within the Cold Spring Brook Wetland Complex during the field survey. Numerous green frogs as well as an occasional leopard frog and American toad were observed. The wetland complex likely supports breeding populations of these frogs as well as other frogs listed in Table 3-4. The smooth alder-buttonbush wetland on the west side of the complex may be a suitable spotted-salamander breeding pond. Eastern painted turtles were abundant in portions of the wetland complex and one common snapping turtle was observed. Three American black ducks and several wood ducks were observed foraging along the edges of the pond. The wood ducks may nest within the wetland complex because at least two wood duck nest boxes are present there. Predatory birds observed within the wetland complex include the great blue heron, green-backed heron, and belted kingfisher. A muskrat den and evidence of muskrat foraging were observed. Relatively old (at least several months) beaver-cut trees were noted along the southern edge of the wetland complex.

No Federal or State endangered, threatened, or special-concern plants or animals were observed within the Cold Spring Brook Landfill site during the field surveys. Agency contacts (USFWS 1991, 1992; MNHESP 1991, 1992) and the Fort Devens Draft Environmental Impact Statement (U.S. Army Corps of Engineers 1989) identified seven species-of-concern that are known to occur within 1.5 miles of the Cold Spring Brook Landfill site (see Table 3-7). The bald eagle (federally endangered) and peregrine falcon (federally endangered) occur as occasional transients (USFWS 1991). The eastern box turtle (state special-concern), wood turtle (state special-concern), Blanding's turtle (state threatened), Mystic Valley amphipod (State special-concern) and climbing fern (State special-concern) have been documented within 1.5 miles of the Cold Spring Brook Landfill site (Massachusetts Natural Heritage and Endangered Species Program 1991). Specific locations for these latter four species were not provided by MNHESP. In addition, the small whorled pogonia (federal endangered) occurs within Middlesex and Worcester counties, although it has not been documented within 1.5 miles of the site (USFWS 1991).

The peat wetland located on the western side of the wetland complex is not a significant ecological resource. The presence of a thick mat of peat is noteworthy, but the absence of bog conditions and typical flora makes it a more common plant community.

No rare natural plant communities are documented within a 1.5-mile radius of the Cold Spring Brook Landfill site (MNHESP 1991). However, several relatively large wetland areas, which are considered significant ecological resources in the context of this ecological characterization, are depicted on the USFWS NWI map of the Ayer quadrangle. Forested and scrub/shrub palustrine wetlands are associated with the entire length of Cold Spring Brook and Bowers Brook downstream of the site to Grove Pond, including an especially large wetland area located approximately 1 mile downstream. A large forested, scrub/shrub, emergent wetland system is associated with the Oxbow National Wildlife Refuge, which is located approximately 1 mile southwest of the site, and a large forested, scrub/shrub wetland complex is associated with Bowers Brook approximately 1.5 miles southeast of the site. Neither of these wetland systems is hydrolically connected to the Cold Spring Brook Landfill site. A portion of the wetland complex associated with Bowers Brook is classified as "estimated habitat of state-listed rare wetlands wildlife" (MNHESP 1992). No information regarding the rare species associated with this area is available (MNHESP 1992).

Several streams, two natural lakes, and three man-made ponds are located within 1.5 miles of the site. However, no information is available from the Massachusetts Division of Fisheries for the fish which populate Cold Spring Brook Pond or Cold Spring Brook. In addition, of all the water resources located within 1.5 miles of the site, only two areas have been surveyed for fish: Bowers Brook and Mirror Lake (Massachusetts Division of Fisheries and Wildlife 1991). If the species composition of these two areas is similar to Cold Spring Brook and Cold Spring Brook Pond, fish species likely to occur include pumpkinseed, bluegill, black crappie, and yellow perch. Neither Cold Spring Brook Pond nor Cold Spring Brook is stocked, and neither is considered a commercial or recreational fishery (Massachusetts Division of Fisheries and Wildlife, 1991).

Oxbow National Wildlife Refuge is a significant ecological resource located approximately 1 mile southwest of the landfill site. Although the refuge is upstream of the site, birds from the refuge may occasionally use Cold Spring Brook Pond. The refuge supports a diversity of waterfowl and other birds and is important for consumptive and nonconsumptive use by local residents.

No evidence of physically stressed vegetation or animal life was observed during the field survey. A few dead staghorn sumac shrubs were noted along Patton Road, but these appeared to have died as a result of competition for light and other resources as the vegetation on the landfill progresses from the shrub/sapling successional stage to forest. Numerous green frogs and eastern painted turtles were observed in the Cold Spring Brook Pond relatively close to the edge of the landfill. No evidence of physical stress to these animals was observed.

There was no indication that common aquatic and terrestrial species known to be sensitive to site contaminants were absent from Cold Spring Brook Landfill site. A realtively high diversity and abundance of terrestrial and aquatic species was observed in the vicinity of the site, suggesting that site contaminants are not affecting species' abundance significantly.

3.2.2 Geology

Because no further drilling was performed at Cold Spring Brook Landfill, nothing new was learned of the underlying geology.

3.2.3 Soils

The only soil samples collected from Cold Spring Brook Landfill were from the disturbed materials used as cover for the fill, and do not represent the impact of the site on natural soils.

3.2.4 Groundwater Hydrology

Of the eight wells originally installed by the USAEHA, two (CSB-4 and CSB-5) were installed in low hydraulic conductivity sediments (silts and clays). These two wells were located close together and showed similar chemical characteristics in the samples collected from them, notably elevated arsenic.

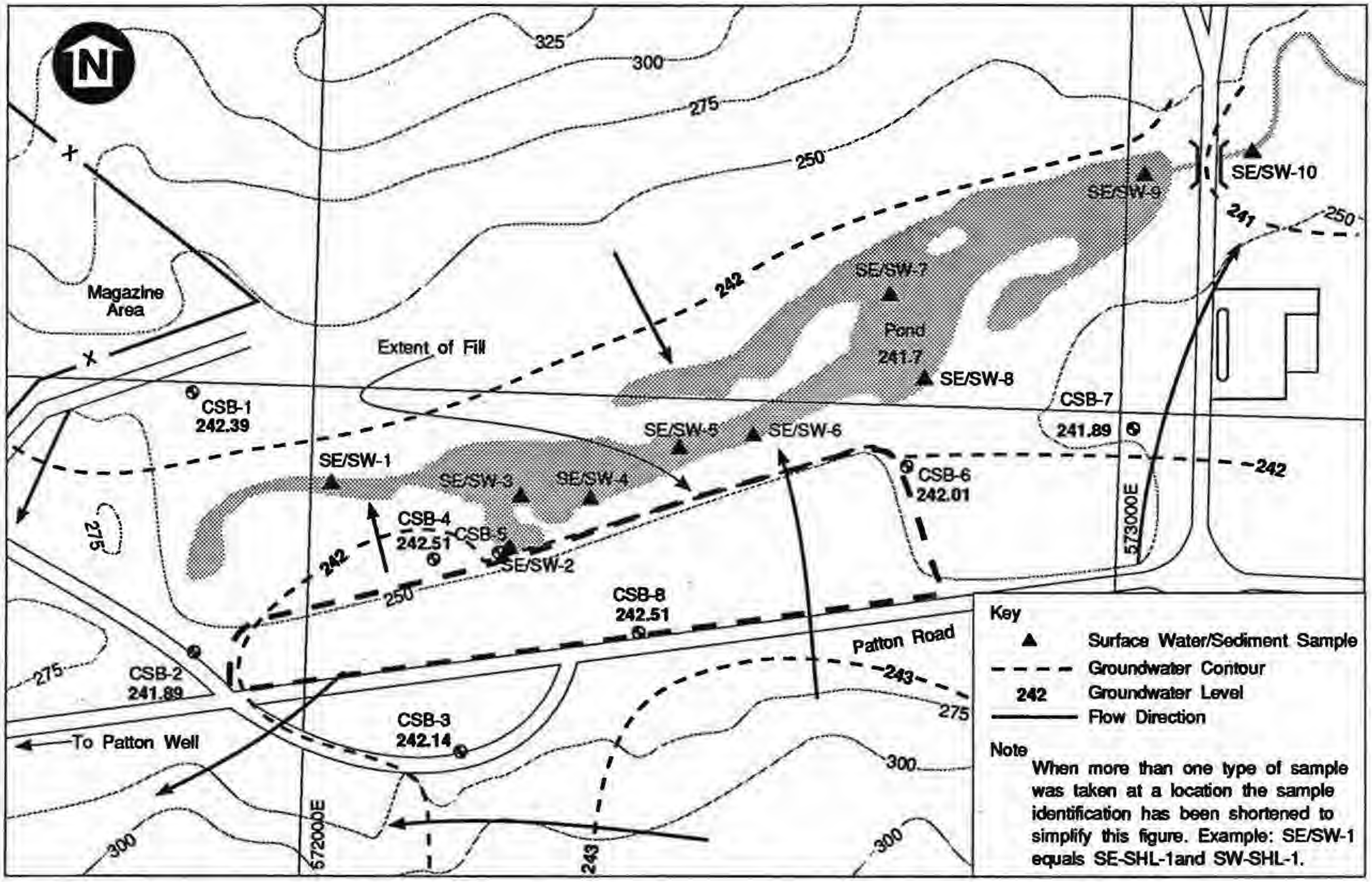
E & E arrived at the following interpretation of groundwater flow using data gathered from surveying the elevations of the wells, the elevation of the soil surface next to the wells, and the elevation of the pond adjacent to the landfill.

The pond elevation is below the water table elevations in the wells, which implies that flow is from the groundwater into the pond in most cases. It is possible that, during the periods when the Patton Well is pumping, it causes flow in the aquifer at CSB-2 to be westward towards the well. This may also be true of flow in the vicinity of CSB-3. Groundwater contours and flow direction for August 1991 are represented on Figure 3-6. Seasonal variations in water table elevation do cause significant changes in flow direction. This can be seen by comparing Figures 1-18 and 1-19. In Figure 1-18 it appears that CSB-3 may not be affected by flow from the landfill, but in the second figure it is clearly implied that CSB-3 will monitor flow from the landfill.

In general, CSB-4 is the well with the highest hydraulic head, indicating that there is a groundwater mound in its vicinity, sustained by the low hydraulic conductivity sediments underlying the mound. The mound causes flow to radiate outwards from it both towards the pond and towards other wells such as CSB-2, CSB-3, and CSB-8. CSB-5 has been damaged and is no longer a usable monitoring well.

CSB-1 receives flow from the east end of the magazine area, and is unaffected by the landfill. CSB-6 is probably receiving flow from under the east end of the landfill, but CSB-7 is not, and as a consequence water quality in CSB-7 is not affected by the landfill. CSB-7 may be regarded as a "background" well with respect to the landfill.

The term "background" implies that the sample site (whether a well or a soil sample) is located in an area unaffected by the study area or AOC, whereas "upgradient" implies that the sample site is up the hydraulic gradient from the study area or AOC, and presumably should therefore be "background." In the case of Cold Spring Brook Landfill, there are no upgradient wells, because there is a groundwater mound under the fill area and flow is outward in all directions. CSB-7 is



Source: E&E, 1991

Legend

- Monitoring Well
- Channel and Culvert
- 275 Contour (25ft.)
- Road, Surfaced
- Road, Unimproved
- Fence

Scale in Feet
200 0 200

Figure 3-6 GROUNDWATER CONTOURS AND FLOW DIRECTION AT COLD SPRING BROOK 8/30/91

1ARI/Fig.3-6.CI

sufficiently far from the landfill that it receives flow from an area unaffected by the flow from the fill area and is hence regarded as "background."

Flow under much of the landfill discharges to Cold Spring Brook Pond, although some of the flow under the west end is captured by the Patton Well, when it is pumping.

Water level data are shown in Table 3-12 for the three rounds of water level measurements in August and December 1991 and for March 1992.

The monitoring wells were only installed into the first zone of saturation encountered under the site. The quality of water in deeper zones was tested by sampling the Patton Well (see Section 5.2.2). This showed no apparent impact from the landfill. The bedrock under the landfill was not investigated.

3.2.5 Surface Water Hydrology

Installation of a surface water level gauge, and surveying of the elevation of the Cold Spring Brook Pond, demonstrated that the pond was at a lower elevation than previously thought, and is a receiving body of water, not perched above the aquifer beneath it. This misconception arose because the Fort Devens base map omitted two contours, the 245 foot and the 240 foot contours from the wetland area now flooded by the pond. The ecological assessment of Cold Spring Brook Landfill noted beaver activity around the pond, and it now appears that the pond was created by beavers blocking the culvert under Patton Road. This has resulted in periods during which Cold Spring Brook east of Patton Road is dry. It has also resulted in enhanced trapping of sediment, both from the Magazine Area and from the landfill.

The pond generally receives flow from the surrounding aquifer, but when the Patton Well is pumping it appears to dewater part of the aquifer under the west end of the pond, as shown by the decline in head in CSB-2 to below the surface of the pond. This would theoretically cause flow from the pond into the aquifer. Since the pond appears unaffected, it may be that low permeability sediments under the pond prevent much flow into the aquifer.

3.2.6 Sediments

To assess the possible impact of the landfill on surface water and the ecology of the surrounding area, nine sediment samples were collected from the pond, and one from Cold Spring Brook below (east of) Patton Road (see Figure 3-6).

Analyses of the particle size distribution in these sediments showed that the sediments ranged from dominantly gravel (SE-CSB-01) to dominantly silt and clay (SE-CSB-09). Sand was a major component of all samples, except SE-CSB-09, ranging from 54 percent in SE-CSB-01 to greater than 90 percent in SE-CSB-02, SE-CSB-05, and SE-CSB-10 (see

Table 3-12

**WATER LEVEL DATA 1991 and 1992 FOR
COLD SPRING BROOK LANDFILL
(FEET ABOVE MEAN SEA LEVEL)**

	Top of Casing* (feet AMSL)	Depth to Water (feet)	Water Level (feet AMSL)
		3/19/92	
CSB-1	250.11	7.20	242.91
CSB-2	260.07	17.56	242.51
CSB-3	267.48	24.76	242.72
CSB-4	247.54	4.10	243.44
CSB-6	246.39	3.57	242.82**
CSB-7	257.83	14.11	243.72
CSB-8	260.77	17.54	243.23

POND Surface Staff Gauge = 244.97 feet, Depth to Water = 2.21 feet,
Top of ice/snow = 242.76.

		12/12 to 12/13/91	
CSB-1	250.11	7.14	242.97
CSB-2	260.07	17.67	242.40
CSB-3	267.48	24.81	242.67
CSB-4	247.54	3.65	243.89
CSB-6	246.39	3.39	243.00**
CSB-7	257.83	13.70	244.13
CSB-8	260.77	17.52	243.25

		8/30/91	
CSB-1	250.11	7.72	242.39
CSB-2	260.07	18.18	241.89
CSB-3	267.48	25.34	242.14
CSB-4	247.54	5.03	242.51
CSB-6	246.39	4.38	242.01
CSB-7	257.83	15.94	241.89
CSB-8	260.77	18.26	242.51

POND Surface Staff Gauge = 244.97 feet, Depth to Water = 3.27 feet,
Surface = 241.7 feet AMSL.

RC424

* From top of inner PVC casing
** Water level is above ground surface

Source: E & E, 1992

Appendix F). Organic carbon content in the pond sediments ranged from 1.03 percent in SE-CSB-05, to 17.0 percent in SE-CSB-02 and averaging 5.92 percent with a median value of 5.19 percent. The single sample from Cold Spring Brook below Patton Road was 96 percent sand, with an rganic carbon content of only 0.751 percent.

3.2.7 Meteorology

No meteorological measurements were made at Cold Spring Brook Landfill, because of the lack of open areas. Meteorological data from Shepley's Hill Landfill was used in assessing the results of the air quality samples collected at Cold Spring Brook Landfill.

4. 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 the RI report and associated computer files. The discussion below outlines the steps that E & E and its subcontractor, ADL, followed to ensure the flow and quality of data from input in the field to delivery to USATHAMA's Installation Restoration Data Management Information System (IRDMIS). The discussion also outlines Quality Assurance/Quality Control (QA/QC) procedures for assessing data usability implemented as part of the analytical data review process. The ultimate uses of IRDMIS data files includes: routine summary reporting, statistical analyses, hydrogeological assessments and groundwater modeling, human exposure and health risk assessments, and ecological risk assessments.

4.1 DATABASE MANAGEMENT

The overall data management program covers three categories of data, which originated from different sources:

- o map data,
- o geotechnical data, and
- o chemical data.

Figure 4-1 illustrates the data flow by which these data were captured from their respective sources, and entered into the central USATHAMA IRDMIS computer system. These categories and sources of data are described further below.

For each of these data categories, three levels of data quality are distinguished, as follows:

- o Level I: raw data collected in the field or laboratory;
- o Level II: data as transmitted to the USATHAMA IRDMIS computer system; and
- o Level III: data in IRDMIS that have been validated and for which QA/QC has been performed.

In general, data quality begins at Level I in the field or laboratory, and increases to Level II and Level III as successive validation and QA/QC checks are performed on the data during the investigation phases of the project. The three levels are used to track the degree of validation that has been completed on the data.

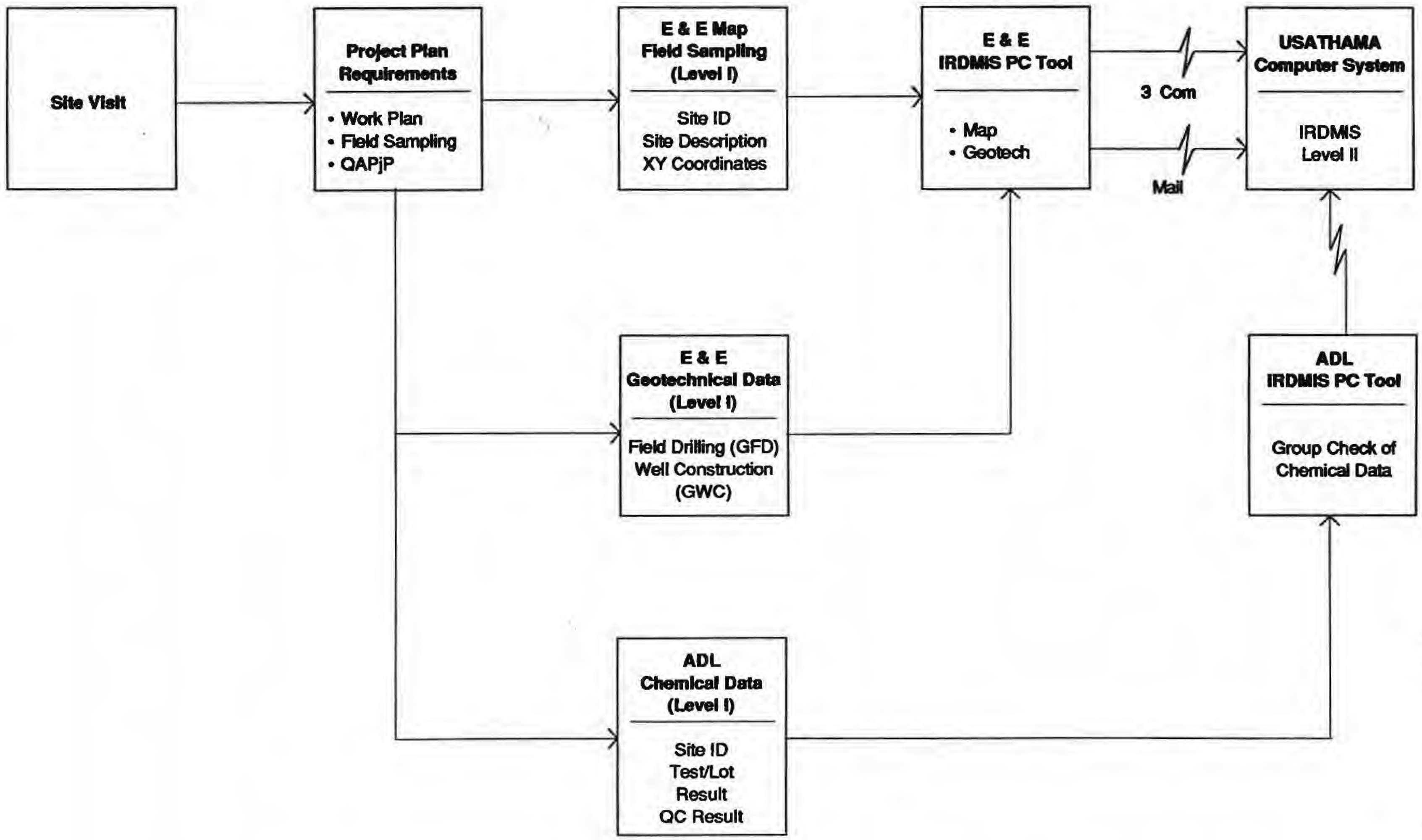


Figure 4-1 DATA MANAGEMENT PROGRAM BLOCK DIAGRAM

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As shown in Figure 4-1, 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 validation and reporting requirements which were incorporated into an RI Work Plan, an RI Field Sampling Plan, and a Quality Assurance Project Plan (QAPjP). The plans provided initial requirements for sampling locations, site and field identifications, chemical tests, and quality control (QC) sample requirements. These initial requirements incorporated definitions from the Fort Devens Master Environmental Plan (MEP) (Biang et al. 1991) and were subject to review and approval by USATHAMA and outside regulatory agencies. Any changes made to plans during the field investigation were later incorporated into a Fort Devens Site Master Database maintained in E & E's USATHAMA Project Management Office in Arlington, Virginia. The Site Master Database includes information on the identification of specific site study areas, the required analytical tests, and QC data requirements. A list of site identifiers (IDs) and site types by area of concern (AOC) is also assembled in the site Master Database.

During the field investigation, E & E field personnel filled out two standardized forms: one for Map Data, and one for Geotechnical Data. The Level 1 map data defined the specific site by providing a site ID, description, and X-Y coordinates of a reference point in the State Planar (STP) coordinate system. STP coordinates are commonly used for surveyed locations. Map data were entered from the standardized form by E & E personnel into a microcomputer using the PC Data Entry and Validation Subsystem Software (IRDMIS PC Tool) (PRI 1991).

The Level I geotechnical data included information on field drilling, well construction, soil identification, water level measurements, and other items. In cases where standardized forms were not completed, field data from log books had to be reduced to the standardized information required by IRDMIS PC Tool. E & E then entered these data into a microcomputer using the IRDMIS PC Tool software.

Once entered into the microcomputer, both map data and geotechnical data were transmitted to the USATHAMA IRDMIS system by uploading these files over the 3COM network to the central computer or by sending diskettes to USATHAMA. USATHAMA then validated these files and either accepted or rejected the data. Data was rejected when there was a discrepancy between the file name established by USATHAMA for a specific sample and the sample identification used by ADL or E & E. If rejected, E & E was informed and the particular file or site data were reviewed and re-submitted by E & E.

As the map and geotechnical data were collected in the field, the third category of data, chemical data, were also being gathered by the laboratory, ADL. E & E field personnel completed chain-of-custody (COC) records for all samples sent to ADL for chemical analysis. The COC record includes site ID, field sample ID, sample date, and chemical tests. This information was transferred by ADL into IRDMIS PC Tool and the samples were assigned to individual lots (i.e., analytical batches) for each chemical test. After analysis was performed and the lot was determined to be acceptable (see Section 4.3), ADL entered raw laboratory analytical results (Level I) using the IRDMIS PC Tool software. These data were subsequently group checked to Level II and uploaded to the central USATHAMA computer over the 3COM network.

The site map data had to be uploaded to the USATHAMA computer before IRDMIS would accept the corresponding analytical (chemical) data from ADL, because the map data provided the necessary site identification for the computer system.

At this point in the data management process, all three categories of site data (map, geotechnical, and chemical) were collected in the central USATHAMA IRDMIS data base, at Level II quality. IRDMIS performed validation checks on the quality of these data and exceptions (errors) were noted. Level II 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.

The process for validating and reporting the chemical data is shown on Figure 4-2 and the format for the chemical data file is shown on Table 4-1. The validation step of Level II data for processing to Level III data is shown in the top half of Figure 4-2. The Level II data exceptions or errors were resolved by comparing the Level II map and chemical data files to the information in the site Master Database and the original COC documentation. Most of the errors concerned inconsistent data entry of site and field IDs or assignment of the samples to the wrong site type or AOC.

Site type refers to a classification of contamination sources, (e.g., bore, well, pond, or area). As described in the MEP, AOCs are identified in the RI Work Plan by specific numbers, with AOC numbered "0" referring to background data for the site. The RI Work Plan also specifies which locations are RI sites.

For each location, the first validation performed was a check that the same site IDs and site type combinations occurred in both the input chemical data file and the site Master Database. Within the database, each site ID plus site type is a unique value. E & E performed QC functions on many smaller data files for completeness and accuracy as to site types, file types, and RI classification. This check ensures that data for the right sites are included for each location.

The second major validation involved checking that the right chemical tests were performed for each site, according to the specifications of the RI Work Plan. This step involved ensuring that each sample was assigned to appropriate lots unique to each type of chemical test required. Each lot is assigned a unique three letter identification. For example, a sample requiring Target Compound List (TCL) organics analysis should be assigned to a "V__" lot for volatiles, a "S__" for semi-volatile base neutral/acid extractables (BNA), and a "C__" for pesticide/polychlorinated biphenyls (Pest/PCBs).

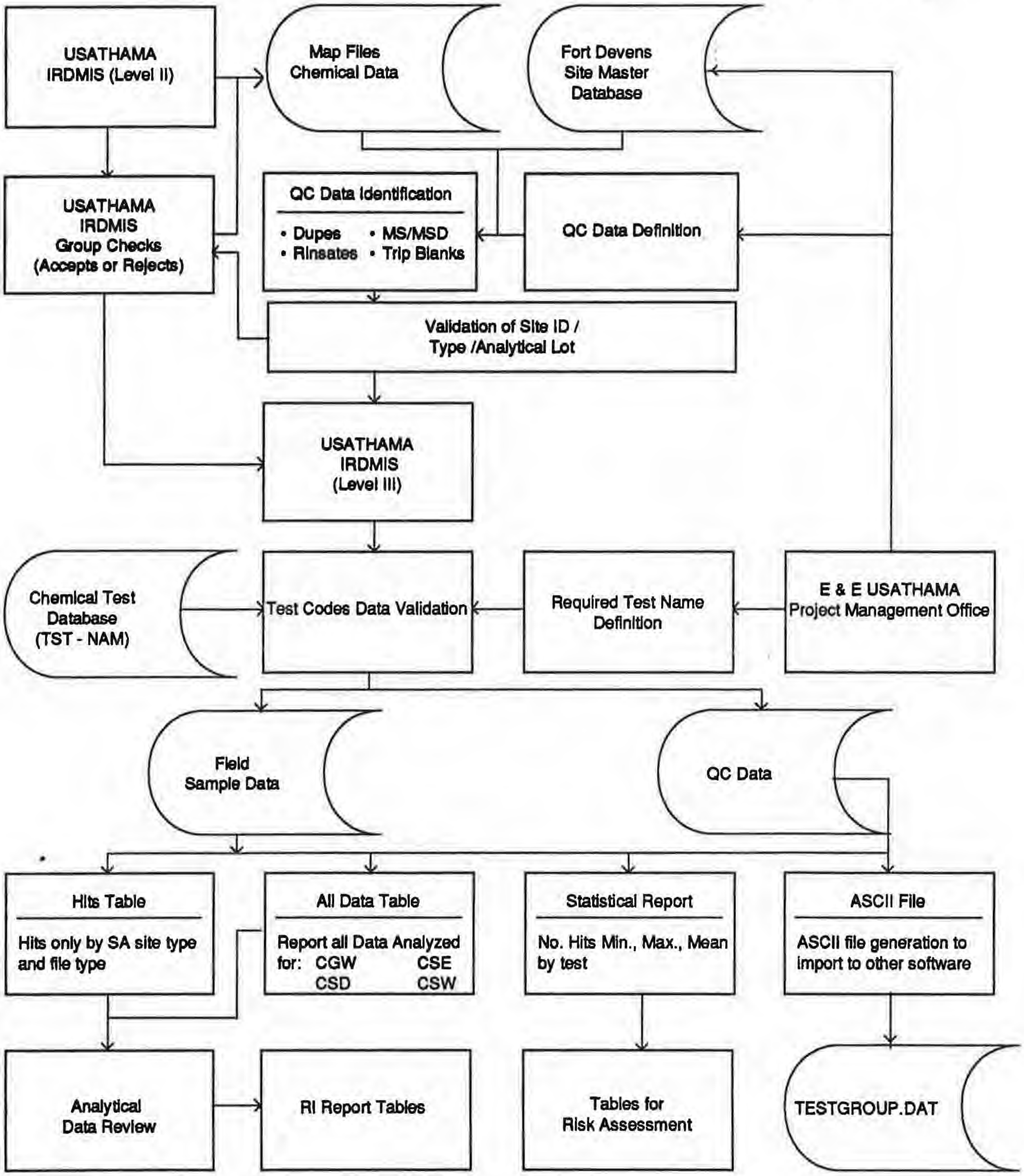


Figure 4-2 SI/RI VALIDATION AND REPORTING FOR CHEMICAL DATA

Table 4-1

RECORD FORMAT FOR CHEMICAL DATA FILE *
USED FOR RETRIEVALS FROM IRDMIS

Field No.	Field name	Type	Width	Description
1	FILETYPE	Character	7	File type (sample medium, e.g., SO for soil)
2	SITETYPE	Character	4	Site type (BORE, WELL, POND, AREA)
3	SITEID	Character	10	Site identifier
4	SAMPPROG	Character	3	Sample program
5	SAMPDATE	Character	8	Sample date
6	LABOR	Character	2	Laboratory
7	TESTNAME	Character	6	Test name: specific chemical parameter
8	METHNO	Character	4	Test method number
9	SAMPDEPTH	Character	8	Sample depth
10	MEASBOOL	Character	2	Measurement boolean (used to indicate "less thans")
11	VAL	Character	10	Measurement value (right-justified, not in scientific notation)
12	UNITMEAS	Character	4	Measurement units
13	FLAGCODE	Character	1	Flag
14	FSANNO	Character	8	Field sample number (used to distinguish field data from QC data)
			—	
	Total record length:		77	

RC424

* Note: this file can be either ASCII or dBase.

Source: Ecology and Environment, Inc.

The last data validation step shown in Figure 4-2 is the identification and separation of QC data from the field data. This identification was made using the field sample number (see field FSANNO in Table 4-1). E & E QA chemists reviewed the chemical QC data to check for the presence of prescribed QC samples against the RI Work Plan or QAPjP to verify that the QC data values were within limits established in the QAPjP. Four types of QC data were used: field duplicates, matrix spike/matrix spike duplicate (MS/MSD), rinsates, and trip blanks. In addition, chemical data files must receive acceptance from the USATHAMA Chemistry Branch (see Section 4.3 for description).

Once the data validation and error correction process was complete, the data could be processed to Level III and the data reduction and reporting phase begun. The final data reduction and reporting phase resulted in the production of specific types of reports and computer data files for end use. The QC data were separated from the field data, and were put in a separate report. The data reduction and reporting phase is described in the next section.

4.2 DATA REDUCTION AND REPORTING

Figure 4-2 presents the data management program block diagram that covers the SI/RI validation and reporting activities for chemical (analytical) data. The starting point for the data reduction and reporting is Level III, i.e., QA/QC-validated chemical data in the USATHAMA central IRDMIS database. The end results are various reports, tables, and computer data files of these chemical data, produced by E & E, in formats suitable for end use, either report tables or data for input to further data analyses. In addition, the entire database and associated geotechnical and chemical data files are available to specialists in USATHAMA through the IRDMIS network.

In general, before usable chemical data reports and data files could be produced for the RI project, these data had to be checked against the requirements in the project RI Work Plan, Field Sampling Plan, and QAPjP (see Figure 4-1). Any discrepancies found were corrected in IRDMIS. This error correction process ultimately resulted in elevating the quality of the chemical data in IRDMIS to Level III (see Section 4.1). However, the process may continue throughout the analytical data review and further modifications made to the Level III data. Discrepancies primarily arose from the assignment of the correct sample identification to the appropriate data file based on matrix and type of sample collected. Data manipulation involved transferring sample and analytical results to the correct data file.

E & E developed specialized software programs in dBase III®, a relational database management system, and Clipper® (a compiler for dBase) to implement these data reduction operations on E & E's in-house microcomputers. The data validation and reporting operations performed by E & E are shown in the bottom half of Figure 4-2 and described below.

Initially, the analytical data lots had to be defined in terms of the chemical tests required by RI Work Plan and QAPjP. These tests include TCL volatiles, BNAs, Pest/PCBs, target analyte list (TAL) metals, explosives, and other general analytical parameters. Because the lots contain multiple test names, each test name had to be assigned to chemical test. This required the comparison of the specific chemical parameter names in the input chemical data file (see field TESTNAME in Table 4-1) with the expected generic test names as specified in the RI Work Plan or the RI Field Sampling Plan. This check was made separately by site type and file type (sample medium). A list of valid generic chemical test names is available by using the PC Tool software to access the Chemical Test Names Database (TST_NAM). Each specific parameter name in the input file was matched with an appropriate generic test name from this list.

For example, for an AREA or BORE site type at the Fort Devens site, the Work Plan specifications for the required generic tests in soils (file type "SO") included: TAL metals, BNAs, pesticides, volatiles (VOCs), total petroleum hydrocarbons (TPHC), and explosives. Additional chemical test codes were specified for other site types and file types (media).

Once the specific chemical tests were assigned, the data 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 specified in the RI Work Plan. 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).

For the field data, two types of reports were generated, by AOC and by site type: a "hits only" table, and an "all data" table. Because the table containing all data is voluminous, it is placed in an appendix in the RI report in the form of a diskette (see Appendix C). Such reports are also generated separately for each file type, such as sample media (which includes groundwater (GW), sediment (SE), soil (SO), and surface water (SW)). The "hits only" table provides summarized results that are used in the RI report.

A systematic output report file naming convention was used to keep track of report contents by AOC, site type, and file type. For example, the hits-only report for AOC 05 at a borehole site (site type BORE) for groundwater (file type "GW") would be named "05BOREGW.RPT".

In addition to the hits-only table, a statistical summary report was also produced for the field data, which includes, for each chemical test, the number of hits, and minimum, maximum, and mean values. This statistical report was used for the risk assessment.

Finally, output data files in electronic format (American Standard Code for Information Interchange (ASCII)) by chemical test group can also be produced for the field data. For example, an ASCII file was produced that contains all the results for the TAL metals analyses at a specific site. These files were then used as input files to other software for additional analyses, such as statistical analysis, chemical fate and transport modeling, hydrogeological assessment, and risk assessment. Examples of the PC software data analysis tools that E & E uses are: SYSTAT® and Abstat® (statistical packages), Geo-EAS® (geostatistical or spatial analysis package), and SURFER® (graphics and contouring package).

4.3 ANALYTICAL DATA REVIEW

Analysis of Fort Devens samples was performed by ADL. Analyses included TCL volatile organic compounds (VOCs), BNAs, Pest/PCBs, TAL Metals, explosives, total organic carbon (TOC), total petroleum hydrocarbons (TPHC), anions, hardness, and percent solids. VOCs, BNAs, Pest/PCBs, TAL Metals, and explosives were analyzed using USATHAMA certified methods. TOC, TPHC, anions, hardness, and percent solids were analyzed using uncertified methods. These parameters do not require USATHAMA certification as explained in Section 5 of the USATHAMA Quality Assurance Program (January 1990). Selenium, lead, and silver in soil were also analyzed using uncertified methods. Approval for these parameters was based on certification for the water methods and pending certification for the soil methods.

Analyses for pesticides/PCBs and some explosive components were also conducted during the BNA gas chromatography/mass spectrometry (GC/MS) analysis. In all cases, the detection levels for the GC/MS analysis were significantly greater than the dedicated methods for these compounds and no values were reported.

Analytical data generated using certified and uncertified methods are presented as method-specific lots, except for percent solids. For each lot, ADL submitted weekly control charts to the USATHAMA Chemistry Branch. The USATHAMA Chemistry Branch reviews all certified method control charts and determines acceptability for submission to IRDMIS.

Table 4-2 summarizes the number of lots provided by ADL for each analytical parameter for each matrix, and the number of acceptable and unacceptable lots for certified methods as determined by USATHAMA at the time of this draft. Some lots of data for certified methods are accepted by USATHAMA with the qualification that results are generated as an uncertified method (i.e., not all QC criteria were met for the certified method for that lot); these lots are indicated with an asterisk in a separate column on Table 4-2. For uncertified methods, USATHAMA acknowledges receipt of the lots but does not require official acceptance. These lots are indicated with two asterisks on the Table.

The USATHAMA Chemistry Branch must submit a flag to IRDMIS indicating that acceptable control charts have been received before the data can be elevated to Level III.

Table 4-2

SUMMARY OF LOT STATUS FOR FORT DEVENS SI/RI

Matrix	Parameter	Number of Lots	Number of Acceptable Lots	Number of Lots Not Acceptable*	Number of Lots Acceptable as Uncertified**
Water	Volatiles	27	23	2	2
	Semi-volatiles	22	22	0	0
	Pest/PCBs	22	22	0	0
	ICP Metals	7	7	0	0
	Mercury	11	11	0	0
	GF Metals***	8	8	0	0
	Explosives	10	10	0	0
	TKN	2	2	0	0
	TPHC***	5	0	0	5
	Anions	21	20	1	0
Soil	Volatiles	17	15	1	1
	Semi-volatiles	24	23	1	0
	Pest/PCBs	18	18	0	0
	ICP Metals	10	9	1	0
	Mercury	9	9	0	0
	GF Metals***	10	0	0	10
	Explosives	11	10	0	1
	TOC***	11	0	0	11
	TPHC***	6	0	0	6

RC424

NOTES:

ICP = Inductively coupled plasma metals
GF = Graphite furnace metals
* Lot not accepted pending review of additional information
** Lot accepted as generated from an uncertified method; non-detects are reported as "ND"
***Checked and filed by USATHAMA; no "acceptance", as analytes are not determined by a certified method

Source: E & E, 1992

As shown on Figure 4-2, all data tables and "hits only" tables are subject to an analytical data review step. During this process, the "hits only" results were compared to the all data table to ensure that the appropriate values were reported in the correct units, that all chemical tests have been included even if no "hits" are present, and that the appropriate field sample IDs have been matched to the site IDs. The less than symbol (<) is equivalent to the USATHAMA flagging codes ND and LT, indicating that the compound was not detected at the specified level. The greater than symbol (>) is equivalent to the USATHAMA flagging code GT, indicating that the compound was detected above the specified level. The GT code is used for samples exceeding the calibration range when additional analysis could not be performed. The data review step provided a final check on the validation of Level II data to Level III data, and the overall completeness of the database. Any errors or exceptions noted were resolved by comparing to the ADL raw data and the COC documentation. The errors in the Level III data were then adjusted and the data reduction process repeated.

In addition to the chemical data file, ADL provided a hard copy data package with all calibration information, raw data, and a case narrative describing any problems. This original data file along with the weekly control charts and acceptance letters were compared to the all data table to ensure that appropriate flagging codes indicating other that usual analytical conditions or results were added to the database. Any data flags or other QC problems, as described below, potentially impacting data usability are described in Section 5 of this report.

As discussed in Section 2.3, several types of field and laboratory QC samples were taken throughout the RI. The QC sample results were reviewed and used to make qualitative statements about the quality of the analytical data presented for each AOC. All QC sample results are presented in Appendix D and discussed briefly below.

Field duplicates were taken at each of the RI areas to assess overall sampling and analytical precision for various matrices. Field duplicate results for six wells, two surface soil, two surface waters, and two sediment samples are presented in Appendix D. Only those target compounds detected in sample are included in the summary tables.

Eighteen field blank rinsates were collected throughout both the SI and RI. The results for all detected compounds are summarized on Table D-1. The rinsates for groundwater are directly comparable to groundwater sample results. In general, levels in the samples less than five times the levels in the rinsates may be attributable to background field contamination and should be suspect. The rinsates for the boring samples are not directly comparable to the soil boring sample results and need to be converted.

Trip blanks were sent with sample shipments throughout the SI and RI and analyzed for VOCs to assess potential contamination during transport. The results for detected compounds only are summarized on Table D-2. Twenty-two trip blanks were shipped during the first round of sampling and nine trip blanks were shipped during the second round of sampling. Methylene chloride was detected in most blanks, acetone was detected in five blanks, chloromethane was detected in eleven blanks, and chloroform was detected in two blanks. 1,2-Dichloroethane was found in only one blank. The trip blank contaminants were relatively uniform and most likely attributable to background laboratory contamination. Therefore, the results were averaged and a value equal to three times the standard deviation plus the mean was used to assess whether the levels in the samples were attributable to background contamination.

Laboratory method blanks were analyzed for standard water and soil matrices for each lot. All detected results for both the SI and RI are summarized in Table D-3. These results are directly comparable to results for samples analyzed in that lot. Blank contamination was assessed by comparing sample results to laboratory method blanks. Any concentration less than 10 times the blank level for common laboratory contaminants and less than five times the blank level for other compounds was attributed to laboratory background.

Samples were also collected for MS/MSD for organics analysis and MS and duplicate for inorganics analysis. These samples were designated by field personnel as representative matrices for each RI area throughout Fort Devens. The MS/MSD results for Shepley's Hill Landfill and Cold Spring Brook Landfill are presented in Tables D-16 through D-40. All results are acceptable with the exception of a few values outside EPA CLP limits indicated on the table. No affect on data usability was determined.

The laboratory also analyzed standard matrix spikes for each analytical lot. In general, the standard matrix spike results must be within control criteria for the analysis to be accepted. Therefore, these results are not presented. In a few cases, lots were considered acceptable even though standard spike results were out of control. Any effects on analytical data quality for these lots are discussed in the QA/QC section for each RI.

5. NATURE AND EXTENT OF CONTAMINATION

In this section, E & E describes its evaluation of analytical data to better define the nature and extent of contamination at Shepley's Hill Landfill and Cold Spring Brook Landfill. For each of these sites, E & E discusses the analytical results of samples taken in various media: soil, groundwater, surface water, sediment, and air. To determine the actual presence of contaminants in the analyses of samples, E & E attempted to compare results for samples in each sample medium against background samples of the same medium that were unaffected by the landfill sites.

Representative samples from the major soil association were analyzed for Target Analyte List (TAL) metals to establish a background concentration level for metals in soils within Fort Devens. As discussed in Section 1.3.3, there are three major soil series found on Fort Devens. These are:

- o the Hinkley-Merrimac-Windsor association;
- o the Paxton-Woodbridge-Canton association; and
- o the Winooski-Limerick-Saco association.

In addition, there are poorly-drained soils associated with bogs and swamps such as the Scarboro mucky fine sandy loam and Freetown muck. As noted in Section 1.3.3, the Hinkley-Merrimac-Windsor association is the most important for the RIs since this association underlies most of the RI sites. Background soil analyses results are presented in Table 5-1. Nineteen out of 23 TAL metals were detected in 16 background surface soil and 4 background subsurface soil samples. Surface samples were taken from 0 to 6 inches from surface after removing surface vegetation, leaf litter, etc. Subsurface samples were taken from 5 to 6 feet below surface. Background soil locations are shown in Figure 5-1 and described in Table 5-2. Ideally, the soils on site should have been compared by soil type and horizon. At the time the work plan was prepared and submitted for review, it was thought necessary to collect a number of soil samples from similar soils to those found on the AOCs to be investigated, so as to have some basis for comparison. One soil sample was taken from a flood plain/wetland environment (Soil-13) but did not prove to be markedly different from the the others. Obviously contaminated soils were avoided by sampling only from areas outside or away from known SAs or AOCs.

As will be shown below, background levels for sediments and surface water could not be established for either RI site because all sampling locations in nearby surface water bodies at each RI site are exposed or potentially exposed to leachate from the landfill or to other upstream contaminant sources.

Table 5-1

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR REGIONAL SOIL SAMPLES (AUGUST 1991) - FILE TYPE: CSO
AOC: 0 SITE TYPE: AREA UNITS: UGG

		SITES								
Test	Parameter	SOIL-01	SOIL-02	SOIL-03	SOIL-04	SOIL-05	SOIL-06	SOIL-07	SOIL-08	SOIL-09
TAL_METAL	ALUMINUM	6400.000	14000.000	12000.000	8800.000	9900.000	13000.000	12000.000	< 5000.000	24000.000
	ARSENIC	9.600	13.000	9.300	9.400	12.000	32.000	15.000	15.000	25.000
	BARIUM	14.200	35.000	14.500	14.200	15.500	< 23.000	36.000	15.600	54.000
	BERYLLIUM	0.119	0.126	< 0.078	0.141	0.124	0.108	0.133	0.142	0.335
	CADMIUM	< 0.424	< 0.424	< 0.424	< 0.424	< 0.424	1.280	1.060	< 0.424	1.060
	CALCIUM	610.000	610.000	330.000	630.000	430.000	710.000	1400.000	310.000	< 1300.000
	CHROMIUM	7.110	11.100	7.570	10.200	8.200	30.300	29.000	9.590	56.500
	COPPER	5.250	2.450	< 1.950	4.810	4.100	6.550	9.380	2.530	7.620
	IRON	6000.000	12000.000	9400.000	7100.000	6800.000	17000.000	>50000.000	8200.000	27000.000
	LEAD	9.720	16.300	18.600	25.300	8.700	42.800	46.600	11.000	14.800
	MAGNESIUM	1500.000	2300.000	700.000	910.000	1300.000	4500.000	5500.000	1800.000	11000.000
	MANGANESE	130.000	380.000	73.000	100.000	87.000	230.000	240.000	85.000	460.000
	MERCURY	0.042	0.081	0.060	0.334	< 0.026	0.055	< 0.026	< 0.026	0.085
	NICKEL	< 2.460	< 2.460	< 2.460	< 2.460	< 2.460	6.810	11.200	< 2.460	27.000
	POTASSIUM	620.000	660.000	530.000	314.000	470.000	1100.000	1700.000	630.000	2400.000
	SILVER	< 0.086	< 0.086	< 0.086	< 0.086	< 0.086	0.208	< 0.086	< 0.086	< 0.086
	SODIUM	< 52.000	58.600	< 52.000	< 52.000	71.200	79.800	117.000	< 52.000	85.800
	VANADIUM	7.570	16.600	17.900	11.700	7.910	32.300	23.400	8.030	44.300
	ZINC	16.500	27.700	14.600	13.600	14.700	< 80.000	< 80.000	13.200	130.000

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-1 (cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR REGIONAL SOIL SAMPLES (AUGUST 1991) - FILE TYPE: CSO
AOC: 0 SITE TYPE: AREA UNITS: UGG

Test	Parameter	SITES						
		SOIL-10	SOIL-11	SOIL-12	SOIL-13	SOIL-14	SOIL-15	SOIL-16
TAL_METAL	ALUMINUM	8500.000	11000.000	7400.000	18000.000	6900.000	8000.000	13000.000
	ARSENIC	14.000	13.000	7.100	28.000	11.000	4.600	11.000
	BARIUM	< 23.000	52.000	12.900	67.200	16.600	16.200	46.000
	BERYLLIUM	< 0.780	0.350	0.172	0.672	0.146	0.145	0.533
	CADMIUM	< 4.200	4.480	< 0.424	3.520	< 0.424	< 0.424	< 0.424
	CALCIUM	2100.000	2800.000	810.000	< 3000.000	740.000	144.000	720.000
	CHROMIUM	< 39.000	27.100	6.020	33.000	13.800	< 3.900	12.500
	COPPER	< 20.000	30.200	< 1.950	27.800	6.860	2.520	< 1.950
	IRON	> 5000.000	11000.000	6900.000	15000.000	> 5000.000	6100.000	8500.000
	LEAD	17.300	106.000	42.900	326.000	47.100	10.300	21.200
	MAGNESIUM	2500.000	2300.000	1000.000	4900.000	2600.000	490.000	2700.000
	MANGANESE	170.000	220.000	170.000	350.000	130.000	110.000	190.000
	MERCURY	0.288	0.412	0.108	0.263	0.056	0.068	0.053
	NICKEL	< 25.000	< 2.460	< 2.460	14.600	4.060	< 2.460	< 2.460
	POTASSIUM	990.000	1100.000	600.000	2200.000	700.000	248.000	2400.000
	SILVER	< 0.086	0.582	< 0.086	< 0.086	< 0.086	< 0.086	< 0.086
	SODIUM	680.000	123.000	< 52.000	231.000	100.000	< 52.000	130.000
	VANADIUM	< 13.000	18.100	16.300	46.600	13.800	6.190	17.500
	ZINC	< 80.000	< 80.000	17.700	< 80.000	22.200	11.700	23.400

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992

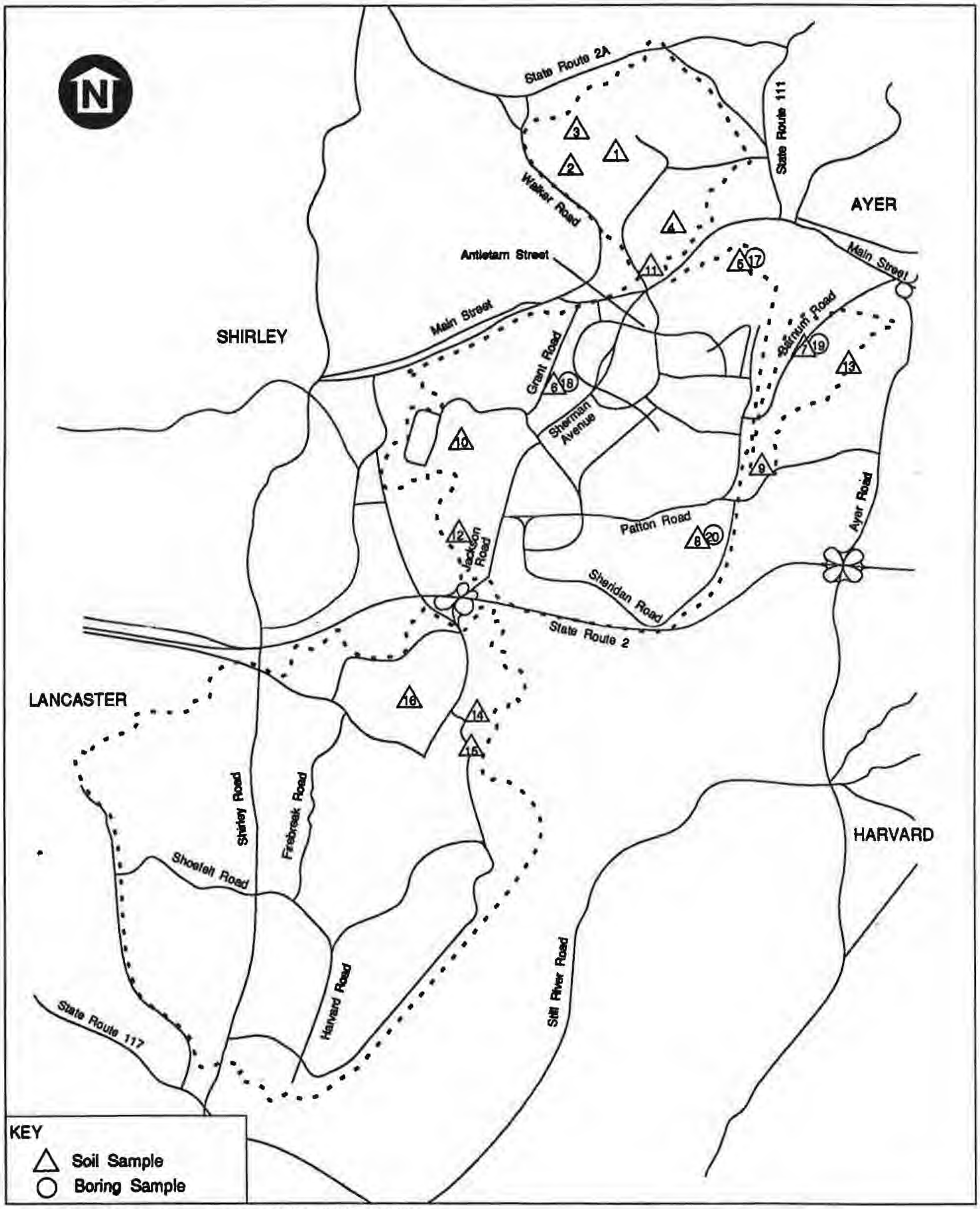
Table 5-1 (cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR REGIONAL SOIL SAMPLES (AUGUST 1991) - FILE TYPE: CSO
AOC: 0 SITE TYPE: AREA UNITS: UGG

		SITES				SUMMARIES			
Test	Parameter	SOIL-17	SOIL-18	SOIL-19	SOIL-20	MINIMUM	MAXIMUM	MEDIAN	95TH PERCENTILE
TAL_METAL	ALUMINUM	4300.000	11000.000	7100.000	7100.000	4300.0	24000.0	9350.0	18000.0
	ARSENIC	9.500	99.000	11.000	19.000	4.6	99.0	12.5	32.0
	BARIUM	9.670	29.000	14.200	31.000	9.67	67.2	<19.8	54.0
	BERYLLIUM	< 0.078	< 0.078	0.104	0.188	<0.078	0.672	0.137	0.533
	CADMIUM	< 0.424	< 0.424	< 0.424	< 0.424	<0.424	4.48	<0.424	3.52
	CALCIUM	350.000	< 1300.000	710.000	810.000	144.0	2800.0	730.0	2100.0
	CHROMIUM	7.710	39.500	14.100	9.250	<3.9	56.5	11.8	39.5
	COPPER	4.780	12.000	7.120	5.480	<1.95	30.2	5.36	27.8
	IRON	6000.000	18000.000	7300.000	7400.000	6000.0	>50000.000	8950.00	27000.0
	LEAD	3.430	11.300	12.700	< 5.360	3.43	326.0	17.45	106.0
	MAGNESIUM	2000.000	7900.000	3200.000	2200.000	490.0	11000.0	24000.0	7900.0
	MANGANESE	110.000	300.000	130.000	150.000	73.0	460.0	160.0	350.0
	MERCURY	< 0.026	0.035	< 0.026	< 0.026	<0.026	0.412	0.125	0.334
	NICKEL	4.800	24.400	5.910	5.510	<2.46	27.0	<3.63	24.4
	POTASSIUM	590.000	1700.000	880.000	1000.000	248.0	2400.0	790.0	2400.0
	SILVER	< 0.086	< 0.086	< 0.086	< 0.086	<0.086	0.582	<0.086	0.208
	SODIUM	57.500	124.000	86.700	93.900	<52.0	680.0	82.4	231.0
	VANADIUM	6.120	22.800	9.890	7.200	6.10	46.6	15.05	44.3
	ZINC	11.200	< 80.000	14.200	13.500	11.2	130.0	27.8	<80.0

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992



Source: Interagency Agreement USEPA / USATHAMA

Legend

—— Road

- - - Installation Boundary

Scale in miles
1 3/4 1/2 1/4 0 1

Figure 5-1 LOCATIONS OF REGIONAL SOIL SAMPLES

Table 5-2

SPECIFIC LOCATIONS OF REGIONAL SOIL SAMPLES

Site Type	Site ID	Soil Association	Post	General Location
AREA	Soil-1	H-M-W	North	Terrace surface south of west end E/W runway
AREA	Soil-2	H-M-W	North	Terrace surface west of filtration beds
AREA	Soil-3	P-W-C	North	Northwest of sand filtration beds
AREA	Soil-4	W-L-S	North	South of sand filtration beds along Nonacoicus Brook
AREA	Soil-5	H-M-S	Main	From hilltop 100' south of well SHL-21
AREA	Soil-6	H-M-W	Main	Inside traffic island at intersections of Grant and Pine
AREA	Soil-7	H-M-W	Main	East side of Barnum Road north of Army Reserve Center
AREA	Soil-8	H-M-W	Main	Level area northwest of intersection of Marne and Shilo
AREA	Soil-9	P-W-C	Main	Southeast of intersection of Barnum and Saratoga east of railroad tracks
AREA	Soil-10	W-L-S	Main	Nashua River flood plains north of intersection with Hospital Road
AREA	Soil-11	W-L-S	Main	North of Verbeck Gate along Willow Branch
AREA	Soil-12	W-L-S	Main	Nashua River floodplain west of Jackson Road
AREA	Soil-13	M-P-W	Main	Cold Spring Brook East of Army Reserve Center
AREA	Soil-14	H-M-W	South	East of Jackson Road across from Cutulo Memorial
AREA	Soil-15	W-L-S	South	East of area "G" where Dixie Road is closest to the Nashua River
AREA	Soil-16	M-P-W	South	Area south of Medical Litter Obstacle course along Slate Rock Pond
BORE	Soil-17	H-M-W	Main	From hilltop 100' south of well SHL-21
BORE	Soil-18	H-M-W	Main	Inside traffic island at intersection of Grant and Pine
BORE	Soil-19	H-M-W	Main	East of Barnum Road north of Army Reserve Center
BORE	Soil-20	H-M-W	Main	Level area north of intersection of Marne and Shilo

RC424

H-M-W: Hinkley-Merrimac-Windsor
M-P-W: Paxton-Woodbridge-Canton
W-L-S: Winooski-Limerick-Saco

Source: E & E, 1991

Background levels for air and for groundwater were established during the RI sampling and are discussed under the appropriate heading for each site. A review of which wells may be considered background wells at either Shepley's Hill Landfill or at Cold Spring Brook Landfill is included in the discussion of the nature and extent of contamination sections of this report (Sections 5.1.2 and 5.2.2).

5.1 SHEPLEY'S HILL LANDFILL

5.1.1 Soils

Three soil samples were taken for chemical analyses at Shepley's Hill Landfill. Results are summarized on Table 5-3. Each was taken from the site of a seep, either observed on a previous occasion or inferred from signs of flow and staining of surface soils.

Of the TCL organics and explosives tested for, the only ones detected were low levels of acetone in SE-SHL-01 and SEL-SHL-02, and low levels of methylene chloride in all three samples (see Table 5-3). All these results are attributable to laboratory contamination. The samples were sandy surface soils, with highly variable organic carbon (0.062 percent, 0.12 percent, and 1.74 percent respectively). It should be noted that SEL-SHL-03, with much the highest level of organic carbon, had no more detectable organics than the other samples.

All the metals levels were within the limits of those found for background soils with the following single exception: calcium was elevated in SEL-SHL-03 (3,200 µg/g) compared to a maximum of 2,800 µg/g in background soils (see Table 5-1). This is not considered significant.

5.1.2 Groundwater

Two rounds of groundwater samples were collected at 25 monitoring wells at Shepley's Hill Landfill and at the POL. The first round was collected in August 1991 and results are summarized on Table 5-4. The second round was collected in December 1991 and results are summarized on Table 5-5. All the wells sampled were completed in glacial sediments above the igneous and metamorphic bedrock. All but eight wells (SHL-5, SHL-6, SHL-7, SHL-8 (deep), SHL-9, SHL-20, SHL-22, and SHL-24) are screened across the water table, and are wholly or partly screened in sandy material. SHL-22 and SHL-24 are both screened in lower hydraulic conductivity materials, till or possibly silt, just above bedrock. All the other deeper wells (SHL-5, SHL-6, SHL-7, SHL-8 (deep), SHL-9, and SHL-20) are screened opposite sandy glacial outwash. SHL-5, SHL-9, and SHL-22 monitor the deep overburden at the north end of the landfill, while SHL-6, SHL-7, and SHL-24 perform the same function at the south end of the landfill. Of these wells, the following are not located in a downgradient location from any part of the landfill, and any contaminants in them cannot be from the landfill: SHL-6, SHL-8 (shallow and deep), SHL-12, SHL-13, SHL-17, SHL-23, SHL-24, SHL-25, and POL wells

Table 5-3

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL
LEACHATE SOIL (AUGUST 1991) - FILE TYPE: CSE
AOC: 5 SITE TYPE: SPRG UNITS: UGG

Test	Parameter	SITES		
		SEL-SHL-01	SEL-SHL-02	SEL-SHL-03
TAL_METAL	ALUMINUM	4600.000	8600.000	16000.000
	ARSENIC	11.000	5.100	9.300
	BARIUM	9.410	9.090	31.600
	BERYLLIUM	< 0.078	0.135	< 0.078
	CALCIUM	640.000	400.000	3200.000
	CHROMIUM	6.940	7.290	16.200
	COPPER	4.570	2.790	14.300
	IRON	5800.000	6700.000	13000.000
	LEAD	< 5.360	< 5.360	47.800
	MAGNESIUM	1900.000	1900.000	4300.000
	MANGANESE	140.000	110.000	240.000
	MERCURY	< 0.026	< 0.026	0.086
	NICKEL	3.660	< 2.460	< 2.460
	POTASSIUM	650.000	590.000	1100.000
	SODIUM	53.200	< 52.000	160.000
	VANADIUM	5.250	7.800	30.700
	ZINC	11.700	14.300	< 80.000
TCL_VOA	ACETONE	0.020	0.018	< 0.010
	METHYLENE CHLORIDE	0.007	0.008	0.011
TOC	TOTAL ORGANIC CARBON	620.000	1200.000	17400.000

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-4
INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL GROUNDWATER (AUGUST 1991)
FIRST ROUND - FILE TYPE: CGW

AOC: 5 **SITE TYPE: WELL** **UNITS: UGL**

Test	Parameter	SITES								
		POL-1	POL-2	POL-3	SHL-10	SHL-11	SHL-12	SHL-13	SHL-15	SHL-17
ANIONS	CHLORIDE	11000.000	35000.000	12000.000	1660.000	79000.000	4400.000	35000.000	21000.000	3500.000
	FLUORIDE	86.400	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000
	NITRATE	600.000	860.000	1700.000	660.000	< 24.300	520.000	30.500	184.000	700.000
	NITRITE	< 28.300	500.000	< 28.300	< 28.300	< 28.300	< 28.300	< 28.300	83.500	< 28.300
	SULFATE	16000.000	28000.000	32000.000	11000.000	225.000	13000.000	12000.000	39000.000	13000.000
	BROMIDE	92.700	112.000	< 50.000	< 50.000	186.000	< 50.000	< 50.000	199.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388
	1,3-DINITROBENZENE	< 0.270	2.220	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270
	2,4-DINITROTOLUENE	< 1.160	1.630	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160
	TETRYL	< 0.191	0.310	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191
TCL_BNA	2-METHYLNAPHTHALENE	< 10.000	16.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	DIETHYL PHTHALATE	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
TAL_METAL	ALUMINUM	29000.000	7400.000	41000.000	15000.000	4200.000	14000.000	13000.000	29000.000	4200.000
	ARSENIC	340.000	57.000	170.000	67.000	320.000	69.000	58.000	580.000	> 20.000
	BARIUM	190.000	42.800	350.000	120.000	150.000	88.000	110.000	240.000	22.500
	BERYLLIUM	1.690	0.430	2.680	0.580	< 0.341	0.546	0.555	3.160	< 0.341
	CADMIUM	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670
	CALCIUM	17000.000	14000.000	22000.000	8000.000	48000.000	16000.000	14000.000	34000.000	10000.000
	CHROMIUM	28.700	10.800	50.000	20.200	21.200	40.400	22.000	28.800	5.590
	COBALT	< 250.000	< 25.000	< 250.000	< 250.000	< 25.000	< 25.000	< 250.000	< 250.000	< 25.000
	COPPER	45.700	16.500	51.500	20.400	19.300	31.500	25.600	41.600	7.950
	IRON	32000.000	7800.000	>50000.000	15000.000	>50000.000	27000.000	16000.000	48000.000	4500.000
	LEAD	< 24.000	20.800	170.000	29.000	12.700	35.700	27.800	240.000	7.690
	MAGNESIUM	8700.000	3500.000	16000.000	4200.000	15000.000	9000.000	5700.000	7600.000	1600.000
	MANGANESE	1500.000	710.000	2200.000	520.000	4700.000	790.000	760.000	9100.000	90.200
	NICKEL	< 8.760	11.900	< 8.760	17.900	< 8.760	35.600	12.100	10.300	< 8.760
	POTASSIUM	8300.000	2370.000	15000.000	4000.000	11000.000	5300.000	2670.000	9100.000	1350.000
	SODIUM	<15000.000	20000.000	<15000.000	1670.000	<150000.00	<15000.000	20000.000	<15000.000	<15000.000
	VANADIUM	22.600	7.460	56.900	8.590	11.800	24.100	15.700	17.500	< 4.000
	ZINC	500.000	84.300	560.000	57.900	57.400	89.900	52.400	380.000	93.200
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	0.073	< 0.006
	DIELDRIN	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	0.032	< 0.022
	ENDOSULFAN SULFATE	0.107*	< 0.100	0.269*	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.118*
	ENDRIN	< 0.008	0.051*	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	0.018*	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	0.035*	0.016	< 0.008
	LINDANE	< 0.033	0.099*	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
	ALPHA CHLORDANE	< 0.002	0.057*	< 0.002	< 0.002	0.009	< 0.002	< 0.002	< 0.002	< 0.002
TCL_VOA	1,1-DICHLOROETHANE	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100
	1,2-DICHLOROETHANE	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600
	ACETONE	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	BENZENE	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400
	CHLOROBENZENE	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400
	CHLOROETHANE	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000
	VINYL CHLORIDE	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900
	CHLOROFORM	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	8.000	6.800	7.500	8.000	8.000	7.200	7.900	6.200	118.000
	TRICHLOROETHYLENE	< 7.000	< 7.000	19.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000

RC424

* Result not confirmed on a second column

Source: USATHAMA IRDMIS Level 3/E & E, 1992

RC424

Table 5-4 (cont.)
INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL GROUNDWATER (AUGUST 1991)
FIRST ROUND - FILE TYPE: CGW
AOC: 5 SITE TYPE: WELL UNITS: UGL

		SITES								
Test	Parameter	SHL-18	SHL-19	SHL-20	SHL-21	SHL-22	SHL-23	SHL-24	SHL-25	SHL-3
ANIONS	CHLORIDE	1110.000	18000.000	76000.000	2360.000	100000.000	1690.000	19000.000	20000.000	2070.000
	FLUORIDE	< 71.000	< 71.000	116.000	< 71.000	< 710.000	< 71.000	< 71.000	< 71.000	< 71.000
	NITRATE	2300.000	< 24.300	254.000	188.000	40.700	8400.000	3400.000	1100.000	850.000
	NITRITE	< 28.300	< 28.300	< 28.300	< 28.300	< 280.000	< 28.300	< 28.300	< 28.300	< 28.300
	SULFATE	12000.000	27000.000	15000.000	14000.000	14000.000	2610.000	29000.000	17000.000	12000.000
	BROMIDE	< 50.000	84.800	200.000	< 50.000	517.000	< 50.000	< 50.000	< 50.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	< 0.388	< 0.388	1.350	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388
	1,3-DINITROBENZENE	< 0.270	< 0.270	< 0.270	< 0.270	1.300	< 0.270	< 0.270	< 0.270	< 0.270
	2,4-DINITROTOLUENE	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160
	TETRYL	< 0.191	< 0.191	0.864	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191
TCL_BNA	2-METHYLNAPHTHALENE	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	DIETHYL PHTHALATE	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
TAL_METAL	ALUMINUM	895.000	7100.000	< 81.500	304.000	< 820.000	47000.000	< 81.500	1550.000	4600.000
	ARSENIC	12.000	340.000	98.000	3.410	27.000	140.000	8.240	17.000	35.000
	BARIUM	12.700	93.000	43.200	12.000	88.000	210.000	11.600	16.800	30.200
	BERYLLIUM	< 0.341	0.439	< 0.341	< 0.341	< 0.341	1.260	< 0.341	< 0.341	0.351
	CADMIUM	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670
	CALCIUM	6800.000	45000.000	71000.000	11000.000	>100000.000	14000.000	22000.000	12000.000	7500.000
	CHROMIUM	< 4.470	23.000	8.710	< 4.470	16.300	67.600	7.580	< 4.470	16.400
	COBALT	< 25.000	< 25.000	< 25.000	< 25.000	27.700	< 250.000	< 25.000	< 25.000	< 25.000
	COPPER	7.730	53.700	< 4.290	19.900	5.180	90.800	7.380	< 4.290	18.900
	IRON	2300.000	51000.000	16000.000	458.000	17000.000	55000.000	366.000	2100.000	7800.000
	LEAD	< 4.740	24.800	< 4.740	8.900	< 4.740	78.000	< 4.740	< 4.740	15.100
	MAGNESIUM	1200.000	8800.000	11000.000	1600.000	24000.000	18000.000	3900.000	1500.000	2300.000
	MANGANESE	83.900	3300.000	4700.000	390.000	5200.000	1700.000	22.000	82.300	340.000
	NICKEL	< 8.760	20.900	9.810	< 8.760	17.100	37.200	< 8.760	< 8.760	20.200
	POTASSIUM	1040.000	7800.000	7700.000	1430.000	35000.000	8800.000	9900.000	1900.000	1660.000
	SODIUM	1880.000	<15000.000	<150000.00	2420.000	<150000.00	2230.000	18000.000	18000.000	1840.000
	VANADIUM	< 4.000	10.900	< 4.000	< 4.000	< 4.000	44.800	< 4.000	< 4.000	7.210
	ZINC	< 19.400	124.000	209.000	39.200	26.000	155.000	47.100	30.500	177.000
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	< 0.006	0.013*	< 0.006	< 0.006	0.046	< 0.006	< 0.006	< 0.006	< 0.006
	DIELDRIN	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022
	ENDOSULFAN SULFATE	0.111*	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
	ENDRIN	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	< 0.008	< 0.008	0.065*	< 0.008	0.017	0.013*	< 0.008	< 0.008	0.020*
	LINDANE	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
	ALPHA CHLORDANE	< 0.002	< 0.002	0.014*	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
TCL_VOA	1,1-DICHLOROETHANE	< 1.100	1.900	< 1.100	< 1.100	4.600	< 1.100	< 1.100	< 1.100	< 1.100
	1,2-DICHLOROETHANE	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600
	ACETONE	< 10.000	< 10.000	5.800	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	BENZENE	< 2.400	< 2.400	< 2.400	< 2.400	2.060	< 2.400	< 2.400	< 2.400	< 2.400
	CHLOROBENZENE	< 1.400	< 1.400	< 1.400	< 1.400	1.940	< 1.400	< 1.400	< 1.400	< 1.400
	CHLOROETHANE	< 5.000	< 5.000	< 5.000	< 5.000	7.780	< 5.000	< 5.000	< 5.000	< 5.000
	VINYL CHLORIDE	< 2.900	3.400	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900
	CHLOROFORM	< 0.830	< 0.830	5.300	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	7.200	9.000	5.700	9.610	7.350	6.800	7.060	6.700	7.500
	TRICHLOROETHYLENE	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000

RC424

* Result not confirmed on a second column

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RC424
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5-11

Table 5-4 (cont.)
INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL GROUNDWATER (AUGUST 1991)
FIRST ROUND - FILE TYPE: CGW
AOC: 5 SITE TYPE: WELL UNITS: UGL

		SITES						
Test	Parameter	SHL-4	SHL-5	SHL-6	SHL-7	SHL-8D	SHL-8S	SHL-9
ANIONS	CHLORIDE	55000.000	2380.000	49000.000	8100.000	7200.000	7300.000	2380.000
	FLUORIDE	< 71.000	< 71.000	< 71.000	172.000	< 71.000	< 71.000	< 71.000
	NITRATE	430.000	< 24.300	2300.000	450.000	860.000	36.000	530.000
	NITRITE	< 28.300	< 28.300	< 28.300	67.900	< 28.300	< 28.300	< 28.300
	SULFATE	14000.000	15000.000	29000.000	9600.000	12000.000	2530.000	2070.000
	BROMIDE	209.000	71.900	< 50.000	< 50.000	< 50.000	< 50.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	0.649
	1,3-DINITROBENZENE	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270
	2,4-DINITROTOLUENE	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160	< 1.160
	TETRYL	0.612	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191	< 0.191
TCL_BNA	2-METHYLNAPHTHALENE	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	DIETHYL PHTHALATE	12.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
TAL_METAL	ALUMINUM	8600.000	5600.000	786.000	3900.000	136.000	< 81.500	1310.000
	ARSENIC	260.000	23.000	4.380	20.000	< 3.090	4.150	37.000
	BARIUM	170.000	20.300	18.400	26.200	15.600	11.900	35.500
	BERYLLIUM	0.521	< 0.341	< 0.341	< 0.341	< 0.341	< 0.341	< 0.341
	CADMIUM	< 2.670	10.800	< 2.670	< 2.670	< 2.670	< 2.670	3.150
	CALCIUM	27000.000	23000.000	18000.000	15000.000	17000.000	7800.000	36000.000
	CHROMIUM	24.700	10.800	5.660	10.300	< 4.470	< 4.470	10.600
	COBALT	< 25.000	< 25.000	< 25.000	< 25.000	< 25.000	< 25.000	< 25.000
	COPPER	42.800	33.400	9.460	19.000	13.700	14.300	41.100
	IRON	>50000.000	4900.000	1500.000	5600.000	256.000	102.000	8100.000
	LEAD	37.400	14.700	< 4.740	9.200	7.990	6.020	11.800
	MAGNESIUM	14000.000	5000.000	2700.000	3000.000	3100.000	1200.000	3400.000
	MANGANESE	3200.000	590.000	194.000	2000.000	2100.000	2000.000	390.000
	NICKEL	15.100	< 8.760	< 8.760	19.900	< 8.760	< 8.760	18.400
	POTASSIUM	11000.000	6800.000	2280.000	4400.000	1780.000	1170.000	5500.000
	SODIUM	30000.000	1940.000	26000.000	< 5000.000	<15000.000	<15000.000	2710.000
	VANADIUM	13.400	< 4.000	< 4.000	4.860	< 4.000	< 4.000	8.770
	ZINC	42.200	42.400	127.000	59.100	189.000	158.000	177.000
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	0.018*	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
	DIELDRIN	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022	< 0.022
	ENDOSULFAN SULFATE	< 0.100	< 0.100	0.188*	< 0.100	< 0.100	< 0.100	< 0.100
	ENDRIN	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	0.018*	0.010*	0.034*	0.012*	0.057*	0.038*	0.069*
	LINDANE	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
	ALPHA CHLORDANE	< 0.002	< 0.002	0.008*	0.004*	0.009*	0.024*	0.004
TCL_VOA	1,1-DICHLOROETHANE	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100
	1,2-DICHLOROETHANE	14.000	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600	< 7.600
	ACETONE	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	BENZENE	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400
	CHLOROBENZENE	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400	< 1.400
	CHLOROETHANE	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000	< 5.000
	VINYL CHLORIDE	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900	< 2.900
	CHLOROFORM	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	7.400	7.500	5.330	7.500	6.500	8.530	8.300
	TRICHLOROETHYLENE	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.000

RC424

* Result not confirmed on a second column

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-5

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL GROUNDWATER (DECEMBER 1991)
SECOND ROUND - FILE TYPE: CGW

AOC: 5 SITE TYPE: WELL UNITS: UGL

		SITES								
Test	Parameter	POL-1	POL-2	POL-3	SHL-10	SHL-11	SHL-12	SHL-13	SHL-15	SHL-17
	ALKALINITY**	18.000	16.000	20.000	10.000	236.000	56.000	10.000	4.000	26.000
	TOTAL KJELDAHL NITROGEN	89.100	333.000	159.000	< 70.000	8700.000	109.000	87.000	223.000	95.600
ANIONS	CHLORIDE	6400.000	25000.000	15000.000	907.000	86000.000	2540.000	25000.000	5700.000	1970.000
	FLUORIDE	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000
	NITRATE	330.000	440.000	1900.000	520.000	30.700	67.200	< 24.300	2600.000	240.000
	NITRITE	< 28.300	277.000	< 28.300	< 28.300	< 280.000	< 28.300	< 28.300	< 28.300	< 28.300
	SULFATE	12000.000	36000.000	35000.000	6100.000	1870.000	13000.000	8400.000	13000.000	15000.000
	BROMIDE	51.700	93.800	< 50.000	< 50.000	285.000	< 50.000	< 50.000	125.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	< 0.388	0.401	< 0.388	< 0.388	< 0.780	< 0.388	< 0.388	< 0.388	< 0.388
	1,3-DINITROBENZENE	< 0.270	< 0.270	< 0.270	< 0.270	0.642	< 0.270	< 0.270	< 0.270	< 0.270
	CYCLONITE (RDX)	< 0.617	1.910	< 0.617	< 0.617	< 1.200	< 0.617	< 0.617	< 0.617	< 0.617
TCL_BNA	2-METHYLNAPHTHALENE	< 12.000	45.000	< 11.000	< 10.000	< 11.000	< 10.000	< 10.000	< 11.000	< 10.000
	DIETHYL PHTHALATE	< 12.000	< 10.000	< 11.000	< 10.000	< 11.000	< 10.000	< 10.000	< 11.000	< 10.000
TAL_METAL	ALUMINUM	100000.000	46000.000	32000.000	26000.000	8600.000	94000.000	19000.000	7600.000	3500.000
	ARSENIC	1600.000	200.000	67.000	120.000	320.000	360.000	71.000	130.000	21.000
	BARIUM	570.000	170.000	530.000	150.000	240.000	710.000	130.000	71.000	20.400
	BERYLLIUM	4.380	1.200	2.580	0.540	0.733	3.900	0.608	1.240	< 0.341
	CADMIUM	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	44.700	< 2.670
	CALCIUM	42000.000	27000.000	41000.000	8600.000	55000.000	99000.000	12000.000	9300.000	8700.000
	CHROMIUM	120.000	62.100	28.800	37.500	29.800	240.000	33.100	< 4.470	5.670
	COPPER	113.000	62.500	39.900	32.900	48.700	250.000	27.200	71.500	9.590
	IRON	>50000.000	50000.000	40000.000	35000.000	51000.000	51000.000	29000.000	14000.000	4800.000
	LEAD	300.000	69.000	62.000	35.900	31.400	190.000	23.700	26.200	8.380
	MAGNESIUM	28000.000	15000.000	12000.000	9100.000	12000.000	48000.000	7800.000	2600.000	1500.000
	MANGANESE	4600.000	1700.000	1800.000	790.000	7600.000	7200.000	710.000	770.000	128.000
	NICKEL	24.300	32.300	13.700	29.700	18.600	290.000	17.100	< 88.000	< 8.760
	POTASSIUM	18000.000	10000.000	8700.000	6000.000	11000.000	25000.000	4100.000	2850.000	1280.000
	SILVER	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	0.667	< 0.316	< 0.316	< 0.316
	SODIUM	<15000.000	28000.000	<15000.000	1840.000	<150000.00	< 1530.000	18000.000	2870.000	<15000.000
	VANADIUM	77.000	38.800	19.100	18.200	22.100	160.000	24.000	75.000	< 4.000
	ZINC	620.000	103.000	204.000	71.500	51.000	570.000	52.200	64.500	47.800
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	< 0.006	0.013*	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
	ENDRIN	< 0.008	0.015	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	PCB 1260	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	2.070	< 0.075	< 0.075	< 0.075
	ALPHA CHLORDANE	< 0.002	0.056*	< 0.002	< 0.002	< 0.002	0.020*	< 0.002	< 0.002	< 0.002
TCL_VOA	1,1,2,2-TETRACHLOROETHANE	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	9.000
	1,1-DICHLOROETHANE	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100
	BENZENE	< 2.400	< 2.400	< 2.400	< 2.400	2.060	< 2.400	< 2.400	< 2.400	< 2.400
	CHLOROETHANE	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100
	CHLOROFORM	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	4.510	5.000	5.590	4.610	5.880	4.220	4.310	4.510	3.820
	TETRACHLOROETHYLENE	< 0.500	0.614	0.396	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500
	TRICHLOROETHYLENE	< 0.500	0.754	18.000	< 0.500	0.340	< 0.500	< 0.500	< 0.500	< 0.500

RC424

*Result not confirmed on a second column
**Result reported in mg/l

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Tab- -5 (Cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL GROUNDWATER DECEMBER 1991)
SECOND ROUND - FILE TYPE: CGW
AOC: 5 SITE TYPE: WELL UNITS: UGL

Test	Parameter	SITES								
		SHL-18	SHL-19	SHL-20	SHL-21	SHL-22	SHL-23	SHL-24	SHL-25	SHL-3
	ALKALINITY**	16.000	92.000	256.000	42.000	492.000	6.000	40.000	30.000	9.000
	TOTAL KJELDAHL NITROGEN	132.000	1030.000	5600.000	141.000	8500.000	186.000	130.000	184.000	130.000
ANIONS	CHLORIDE	1180.000	7400.000	77000.000	2680.000	86000.000	1330.000	14000.000	18000.000	843.000
	FLUORIDE	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000	< 71.000
	NITRATE	640.000	29.100	< 24.300	400.000	< 24.300	5600.000	2800.000	1200.000	770.000
	NITRITE	< 28.300	< 28.300	< 280.000	< 28.300	< 28.300	< 28.300	< 28.300	< 28.300	< 28.300
	SULFATE	12000.000	15000.000	5900.000	11000.000	6900.000	3040.000	21000.000	17000.000	6100.000
	BROMIDE	< 50.000	< 50.000	406.000	< 50.000	386.000	< 50.000	< 50.000	< 50.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	< 0.388	< 0.388	< 3.900	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388
	1,3-DINITROBENZENE	< 0.270	0.169	< 2.700	< 0.270	1.490	< 0.270	< 0.270	< 0.270	< 0.270
	CYCLONITE (RDX)	< 0.617	< 0.617	< 6.700	< 0.617	< 0.617	< 0.617	< 0.617	< 0.617	< 0.617
TCL_BNA	2-METHYLNAPHTHALENE	< 10.000	< 11.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 11.000	< 11.000
	DIETHYL PHTHALATE	< 10.000	< 11.000	< 10.000	< 10.000	32.000	< 10.000	< 10.000	< 11.000	< 11.000
TAL_METAL	ALUMINUM	4100.000	7800.000	< 820.000	4100.000	< 820.000	6400.000	90.500	433.000	29000.000
	ARSENIC	45.000	710.000	89.000	25.000	25.000	16.900	11.300	4.290	120.000
	BARIUM	39.200	73.000	68.000	26.500	75.000	37.200	12.500	5.510	200.000
	BERYLLIUM	< 0.341	0.578	< 0.341	< 0.341	< 0.341	< 0.341	< 0.341	< 0.341	0.988
	CADMIUM	< 2.670	< 2.670	3.140	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670
	CALCIUM	10000.000	9600.000	85000.000	18000.000	>100000.00	8000.000	21000.000	15000.000	38000.000
	CHROMIUM	7.570	8.790	11.000	9.860	12.000	20.600	17.400	< 4.470	74.300
	COPPER	11.200	11.600	8.380	9.110	4.740	13.500	5.980	< 4.290	111.000
	IRON	8400.000	7900.000	35000.000	7200.000	18000.000	7700.000	377.000	710.000	>50000.000
	LEAD	8.940	62.000	< 4.740	12.300	< 4.740	9.070	< 4.740	< 4.740	41.400
	MAGNESIUM	2300.000	2600.000	11000.000	3100.000	23000.000	2400.000	3200.000	1300.000	15000.000
	MANGANESE	300.000	800.000	6100.000	450.000	6100.000	260.000	19.800	8.610	3400.000
	NICKEL	< 8.760	< 8.760	< 8.760	< 8.760	12.000	10.900	12.600	< 8.760	87.900
	POTASSIUM	2340.000	3900.000	8800.000	2280.000	14000.000	2770.000	4300.000	2340.000	10000.000
	SILVER	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316
	SODIUM	2460.000	<15000.000	<150000.00	3330.000	<15000.000	1980.000	<15000.000	<15000.000	<15000.000
	VANADIUM	5.990	6.320	< 4.000	< 4.000	< 4.000	7.700	< 4.000	< 4.000	41.100
	ZINC	54.000	60.900	162.000	91.200	< 19.400	33.600	23.000	< 19.400	242.000
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	< 0.006	< 0.006	0.018	< 0.006	0.058*	< 0.006	< 0.006	< 0.006	< 0.006
	ENDRIN	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	< 0.008	< 0.008	0.014	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	0.041*
	PCB 1260	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
	ALPHA CHLORDANE	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
TCL_VOA	1,1,2,2-TETRACHLOROETHANE	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700
	1,1-DICHLOROETHANE	< 1.100	1.400	< 1.100	< 1.100	1.200	< 1.100	< 1.100	< 1.100	< 1.100
	BENZENE	< 2.400	< 2.400	1.180	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400
	CHLOROETHANE	< 2.100	< 2.100	2.180	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100
	CHLOROFORM	< 0.830	< 0.830	0.734	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	4.220	4.510	5.880	4.510	4.900	4.220	5.390	4.020	4.310
	TETRACHLOROETHYLENE	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500
	TRICHLOROETHYLENE	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500

RC424

*Result not confirmed on a second column
**Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E 1992

RC424

Table 5-5 (Cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL GROUNDWATER (DECEMBER 1991)
SECOND ROUND - FILE TYPE: CGW
AOC: 5 SITE TYPE: WELL UNITS: UGL

Test	Parameter	SITES						
		SHL-4	SHL-5	SHL-6	SHL-7	SHL-8D	SHL-8S	SHL-9
	ALKALINITY**	16.000	34.000	6.000	50.000	44.000	22.000	94.000
	TOTAL KJELDAHL NITROGEN	373.000	986.000	87.000	577.000	171.000	< 70.000	3700.000
ANIONS	CHLORIDE	3600.000	1070.000	45000.000	4900.000	4900.000	5700.000	2210.000
	FLUORIDE	< 71.000	< 71.000	< 71.000	86.200	< 71.000	< 71.000	< 71.000
	NITRATE	1800.000	< 24.300	2400.000	280.000	730.000	34.000	< 24.300
	NITRITE	< 28.300	< 28.300	< 28.300	< 28.300	< 28.300	< 28.300	< 28.300
	SULFATE	13000.000	4670.000	29000.000	6000.000	7800.000	2510.000	2270.000
	BROMIDE	< 50.000	< 50.000	< 50.000	< 50.000	< 50.000	< 50.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388	< 0.388
	1,3-DINITROBENZENE	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270	< 0.270
	CYCLONITE (RDX)	< 0.617	< 0.617	< 0.617	< 0.617	< 0.617	< 0.617	< 0.617
TCL_BNA	2-METHYLNAPHTHALENE	< 11.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
	DIETHYL PHTHALATE	< 11.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000	< 10.000
TAL_METAL	ALUMINUM	9400.000	23000.000	1650.000	4100.000	< 81.500	< 81.500	15000.000
	ARSENIC	140.000	38.000	9.550	17.600	< 3.090	< 3.090	67.000
	BARIUM	73.000	45.000	19.400	29.900	15.000	5.010	57.000
	BERYLLIUM	0.426	< 0.341	< 0.341	< 0.341	< 0.341	< 0.341	< 0.341
	CADMIUM	< 2.670	150.000	< 2.670	< 2.670	< 2.670	< 2.670	< 2.670
	CALCIUM	11000.000	15000.000	18000.000	19000.000	17000.000	7600.000	37000.000
	CHROMIUM	21.000	37.900	20.200	11.100	< 4.470	< 4.470	32.300
	COPPER	26.800	33.300	7.920	21.900	9.230	< 4.290	63.900
	IRON	38000.000	30000.000	4300.000	10000.000	122.000	108.000	19000.000
	LEAD	21.900	23.700	9.500	6.700	< 4.740	< 4.740	39.400
	MAGNESIUM	5900.000	7400.000	3400.000	3400.000	2700.000	1200.000	6100.000
	MANGANESE	2100.000	560.000	320.000	2600.000	2000.000	1900.000	460.000
	NICKEL	12.500	< 8.760	12.200	19.700	< 8.760	< 8.760	17.500
	POTASSIUM	5600.000	4500.000	2130.000	4200.000	1610.000	1220.000	6100.000
	SILVER	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316
	SODIUM	<15000.000	2490.000	26000.000	<15000.000	<15000.000	<15000.000	2660.000
	VANADIUM	12.400	13.400	< 4.000	4.850	< 4.000	< 4.000	11.200
	ZINC	29.800	69.700	25.900	60.300	105.000	< 19.400	138.000
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
	ENDRIN	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	< 0.008	< 0.008	0.021*	< 0.008	< 0.008	< 0.008	< 0.008
	PCB 1260	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
	ALPHA CHLORDANE	< 0.002	< 0.002	< 0.002	< 0.002	0.004	< 0.002	< 0.002
TCL_VOA	1,1,2,2-TETRACHLOROETHANE	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700	< 4.700
	1,1-DICHLOROETHANE	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100	< 1.100
	BENZENE	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400	< 2.400
	CHLOROETHANE	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100	< 2.100
	CHLOROFORM	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	5.490	4.410	5.490	5.490	3.920	4.310	4.410
	TETRACHLOROETHYLENE	< 0.500	< 0.500	0.564	< 0.500	< 0.500	< 0.500	< 0.500
	TRICHLOROETHYLENE	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500

RC424

*Result not confirmed on a second column
**Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E 1992

POL-1, POL-2, and POL-3. SHL-15 is nominally upgradient from any fill area but is very close to the edge of the fill and may be marginally affected. These conclusions were drawn by plotting the groundwater contours and drawing flow lines at right angles to them. Wells upgradient from the landfill (i.e., SHL-23) or downgradient (i.e., SHL-6) were regarded as unaffected by the landfill.

The impacts of adjoining sites such as POL and the DRMO Yard are being investigated and the results of the investigations may cause some conclusions of the Shepley's Hill Landfill RI to be modified.

The sources of contamination in downgradient wells at Shepley's Hill Landfill can be generally inferred from tracing implied groundwater flow directions. No "hot spots" were identified because data to do so were lacking.

5.1.2.1 Metals and Anions

The groundwater samples collected during the RI were taken without filtering in the field, in accordance with EPA guidelines. As is discussed below, this has complicated the interpretation of the results, because, despite the prolonged development of the wells, and the purging prior to sample collection, many of the RI samples contain levels of particulates that have clearly raised the levels of metals reported in the groundwater (see Tables 5-4 and 5-5).

This can be demonstrated by comparing the RI sample results with those taken from several of the same wells, during an ongoing quarterly sampling program performed by Con-Test Inc., on behalf of the Fort Devens DEH. These samples are filtered in the field, and analyzed for silver, arsenic, barium, cadmium, chromium, iron, lead, selenium, and mercury using EPA protocols. The wells sampled are SHL-3, SHL-4, SHL-5, SHL-6, SHL-7, SHL-8 (shallow), SHL-8 (deep), and SHL-9.

The filtered groundwater showed quantifiable levels of iron in only six of the eight wells, (SHL-3, SHL-4, SHL-5, SHL-7, SHL-9, and SHL-11), at levels of 0.05 mg/l, 5.8 mg/l, 6.5 mg/l, 0.29 mg/l, 7.9 mg/l, and 100 mg/l, respectively. The only other quantifiable levels of metals were for arsenic and barium. Arsenic was reported in SHL-4 (0.035 mg/l), SHL-5 (0.02 mg/l), SHL-9 (0.027 mg/l), and SHL-11 (0.21 mg/l). Only SHL-11 exceeded the health based drinking water standard for arsenic. It also showed a trace of barium (0.12 mg/l). All these wells except SHL-7 must be considered downgradient wells.

In contrast to the above results for filtered groundwater samples for metals, the RI samples collected in August 1991 and December 1991 and not filtered prior to analysis, show highly variable levels of metals in the samples. There is no clear distinction between levels of metals in upgradient wells from those in downgradient wells.

In an endeavor to determine the factors creating apparent high levels of metals in groundwater, the assumption was made that, if the metals vary as the concentration of particulates, then they should vary as a function of the concentration of aluminum silicates, and hence of aluminum, since aluminum compounds are generally only slightly soluble.

When metal levels in the groundwater were plotted against the concentration of aluminum, it was expected that most values would be related to the aluminum values by a simple ratio which would plot as a straight line and anomalous values would then fall above the straight line. This was not expected to apply to more soluble components, such as chloride, sulfate, mercury, and zinc.

E & E produced scatterplots of sixteen sets of SHL metals analyses, including the nearby POL wells (see Appendix K) according to methods described in the Appendix. However, since the POL wells have been shown to lie across a groundwater divide from Shepley's Hill Landfill, the results from the POL wells can be ignored. Metals plotted against aluminum are arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc. Of these, not all showed significant departures from the norm, among which were barium, chromium, and potassium. Cadmium could not be assessed as only two wells showed quantifiable values.

In general, the anomalous wells were as follows:

WELL	ANOMALOUS METALS
SHL-4	Arsenic, calcium, copper, magnesium, manganese, sodium
SHL-6	Sodium
SHL-7	Manganese
SHL-8D	Manganese
SHL-9	Calcium, copper
SHL-11	Arsenic, calcium, magnesium, manganese
SHL-12	Iron, magnesium, nickel, vanadium
SHL-15	Arsenic, beryllium, calcium, iron, lead, manganese, zinc
SHL-19	Arsenic, calcium, copper, iron, magnesium, manganese
SHL-23	Copper, iron, magnesium, vanadium
SHL-25	Sodium

Upgradient wells which show anomalously high metals levels include SHL-6, SHL-12, SHL-15, SHL-23, and SHL-25.

SHL-15 is close to the presently operational area of the landfill, Phase IVB, (Figure 1-6), and may be genuinely contaminated, which renders it useless as a "background" well. SHL-6 and SHL-25 may simply be close enough to roads to be contaminated by road salt. SHL-23 is puzzling, but may show naturally elevated levels of copper, iron, magnesium, and vanadium because of unweathered particles of rock material derived from till. SHL-7 and SHL-8D, while not upgradient of the landfill, do not appear to be directly downgradient of fill either, based on groundwater contours and directions of flow. SHL-12 is contaminated from an unknown source.

The downgradient wells exhibiting anomalously high metals values would imply that the landfill is contributing arsenic (SHL-4, SHL-11, and SHL-19); calcium (SHL-4, SHL-9, SHL-11, and SHL-19); copper (SHL-4, SHL-9, and SHL-19); iron (SHL-19); magnesium (SHL-4 and SHL-11); manganese (SHL-4, SHL-11, and SHL-19); and sodium (SHL-4).

When the locations of the downgradient wells showing anomalous metals concentrations are considered, it is clear that these wells fall into two main "groups": SHL-4, SHL-11, and SHL-19 form one group and SHL-9 the other. SHL-9 is of concern only because of copper, since calcium does not represent a threat to human health or the environment.

Apart from the copper levels in SHL-9, the major current concerns with respect to metals are the anomalously high arsenic, copper, iron, manganese, and sodium in the three closely grouped wells, SHL-4, SHL-11, and SHL-19. These wells are also directly downgradient of the most recently active area of fill.

All three wells (SHL-4, SHL-11, and SHL-19) show elevated chloride (18,000 to 79,000 µg/l) as does an adjoining well (SHL-20). Bromide is also elevated in these four wells (see Figure 5-2), ranging from 84.8 µg/l in SHL-19 (August 1991 only) to 517 µg/l in SHL-22 (August 1991). SHL-15 showed bromide in both sampling rounds, confirming contamination from some nearby source, and bromide was also noted in SHL-5 (71.9 µg/l, August 1991 only) and SHL-20 (200 and 406 µg/l). The bromide may reflect contamination of groundwater with gasoline, since ethylene dibromide was formerly used as an additive in gasoline, which could indicate past spills, leaks, or disposal of gasoline in the vicinity of the landfill. These data confirm that leachate discharge from the landfill does affect groundwater quality at the north end of the landfill.

Both filtered and unfiltered samples from wells affected by turbidity are necessary to evaluate groundwater quality and should be collected during future investigations.

5.1.2.2 Organics

Some organics have been noted in groundwater around the landfill, confirmed hits being made on 20 compounds, 9 of which appear only in 1 well and only once in 2 sample rounds. The confirmed hits are summarized on Table 5-6. The single hits are vinyl chloride (SHL-19, 3.4 µg/l); chlorobenzene (SHL-22, 1.94 µg/l); 1,1,2,2,tetrachloroethane and methylene chloride (SHL-17, 9.0 µg/l and 118.0 µg/l, respectively); tetrachlorethylene (SHL-6, 0.564 µg/l); trichloroethylene (SHL-11, 0.34 µg/l); 1,2-dichloroethane (SHL-4, 14.0 µg/l); Dieldrin (SHL-15, 0.032 µg/l); and PCB 1260 (SHL-12, 2.07 µg/l) (see Table 5-6). Of these wells, SHL-6 and SHL-15 must be regarded as upgradient of the landfill, and SHL-12 and SHL-17 are marginal although possibly affected by

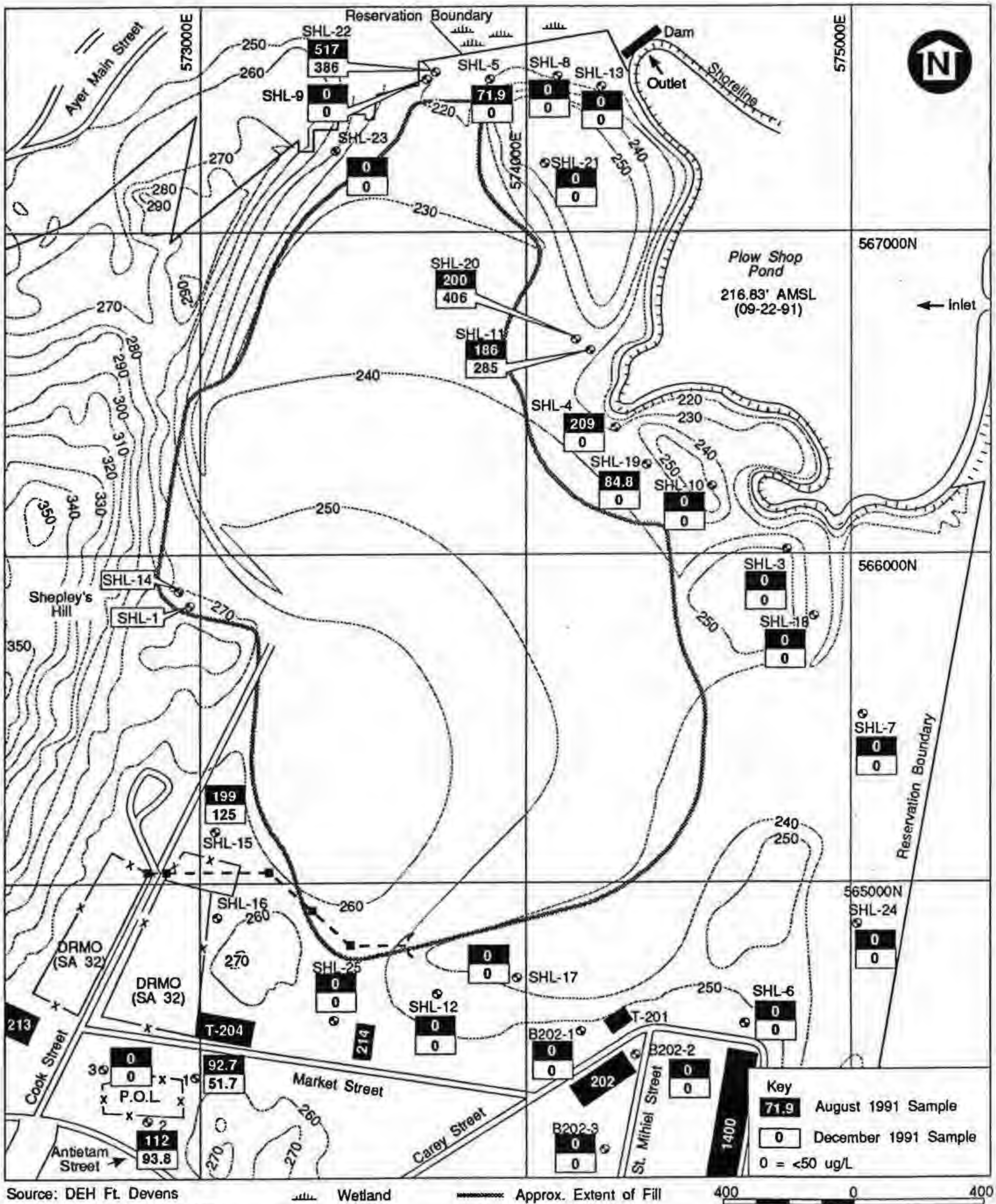


Figure 5-2 CONCENTRATION OF BROMIDE IN GROUNDWATER AT SHEPLEY'S HILL LANDFILL

Table 5-6

SHEPLEY'S HILL LANDFILL
ORGANIC COMPOUNDS IN GROUNDWATER (CONFIRMED)
FIRST AND SECOND SAMPLE ROUNDS

Parameter	SHL Well #											
	3		4		6		8D		9		11	
	8/91	12/91	8/91	12/91	8/91	12/91	8/91	12/91	8/91	12/91	8/91	12/91
Explosives												
1,3,5-Trinitrobenzene	-	-	-	-	-	-	-	-	0.649	-	-	-
1,3-Dinitrobenzene	-	-	-	-	-	-	-	-	-	-	-	0.642
Tetryl	-	-	0.612	-	-	-	-	-	-	-	-	-
Volatiles												
Benzene	-	-	-	-	-	-	-	-	-	-	-	2.06
Chlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
Chloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	14.0	-	-	-	-	-	-	-	-	-
Methylene chloride	-	-	-	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethylene	-	-	-	-	-	0.564	-	-	-	-	-	-
Trichloroethylene	-	-	-	-	-	-	-	-	-	-	-	0.340
Vinyl Chloride	-	-	-	-	-	-	-	-	-	-	-	-
Base Neutral												
Di-Ethyl Phthalate	-	-	12.0	-	-	-	-	-	-	-	-	-
Pesticides/PCBs												
alpha-BHC	-	-	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	-	-	-	-	-	-	-	0.004	0.004	-	0.009	-
Dieldrin	-	-	-	-	-	-	-	-	-	-	-	-
Heptachlor	-	-	-	-	-	-	-	-	-	-	-	-
PCB 1260	-	-	-	-	-	-	-	-	-	-	-	-

RC424

"-" = Below limit of quantification of analytical method

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-6 (cont.)

SHEPLEY'S HILL LANDFILL
ORGANIC COMPOUNDS IN GROUNDWATER (CONFIRMED)
FIRST AND SECOND SAMPLE ROUNDS

Parameter	SHL Well #											
	12		15		17		19		20		22	
	8/91	12/91	8/91	12/91	8/91	12/91	8/91	12/91	8/91	12/91	8/91	12/91
Explosisves												
1,3,5-Trinitrobenzene	-	-	-	-	-	-	-	-	1.350	-	-	-
1,3-Dinitrobenzene	-	-	-	-	-	-	-	0.169	-	-	1.30	1.49
Tetryl	-	-	-	-	-	-	-	-	0.864	-	-	-
Volatiles												
Benzene	-	-	-	-	-	-	-	-	-	1.18	2.06	-
Chlorobenzene	-	-	-	-	-	-	-	-	-	-	1.94	-
Chloroethane	-	-	-	-	-	-	-	-	-	2.18	7.78	-
Chloroform	-	-	-	-	-	-	-	-	5.30	0.734	-	-
1,1-Dichloroethane	-	-	-	-	-	-	1.90	1.40	-	-	4.60	1.20
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	-	-	-	-	118.0	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-	-	9.00	-	-	-	-	-	-
Tetrachloroethylene	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethylene	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl Chloride	-	-	-	-	-	-	3.40	-	-	-	-	-
Base Neutral												
Di-Ethyl Phthalate	-	-	-	-	-	-	-	-	-	-	-	32.0
Pesticides/PCBs												
alpha-BHC	-	-	0.073	-	-	-	-	-	-	0.018	0.046	-
alpha-Chlordane	-	-	-	-	-	-	-	-	-	-	-	-
Dieldrin	-	-	0.032	-	-	-	-	-	-	-	-	-
Heptachlor	-	-	0.016	-	-	-	-	-	-	0.014	0.017	-
PCB 1260	-	2.07	-	-	-	-	-	-	-	-	-	-

RC424

"-" = Below limit of quantification of analytical method

Source: IRDMIS Level 3/E & E, 1992

leachate. Vinyl chloride and 1,2-dichloroethane exceed their respective Federal Primary Drinking Water Standards of 2 µg/l and 5 µg/l. The Arachlor (PCB) 1260 exceeded the proposed standard (0.5 µg/l), which became effective 30 July 1992.

Repeat hits on the second sampling round only occurred in three wells, SHL-19, SHL-20, and SHL-22. In SHL-19, 1,1-dichloroethane was noted at similar levels in both samples (1.9 and 1.4 µg/l). In SHL-20, chloroform was noted at slightly higher levels in August 1991 (5.30 and 0.734 µg/l, respectively). In SHL-22, there were repeat hits of 1,3-dinitrobenzene (1.3 and 1.49 µg/l); alpha-BHC (0.046 and 0.058 µg/l); and 1,1-dichloroethane (4.6 and 1.2 µg/l).

Other organics noted in groundwater included pesticides, Heptachlor in SHL-20, SHL-22, and SHL-15, and alpha Chlordane in SHL-8D, SHL-9, and SHL-11; volatiles, benzene in SHL-11, SHL-20, and SHL-22 and chloroethane in SHL-20 and SHL-22; and a phthalate, diethylphthalate in SHL-4 and SHL-22. In one case (SHL-17) the level of methylene chloride noted in the first round of sampling (118 µg/l) was too high to fall within the range of laboratory contamination demonstrated by the levels in the blanks. The well did not show a repeat of this level on resampling and therefore the result must be regarded as unconfirmed. All other reported levels of methylene chloride and one hit of acetone are attributed to laboratory contamination. The low levels of Heptachlor may also be affected by laboratory contamination because Heptachlor was detected in several method blanks.

The low levels of organics in the groundwater clearly reflect disposal into the landfill in most cases where these organics occur in downgradient wells. The diethyl phthalate may be an artifact of sampling. Previous experience has shown that low levels of phthalates have been derived from latex gloves used in sample handling both in the field and in the laboratory. However, this conclusion is weak and the true source of the phthalate is uncertain. The numerous low level pesticide hits may reflect either disposal into the fill or local application around the landfill.

The wells most affected are SHL-22 (screened depth of 104 to 114 feet AMSL) with a total of ten hits, SHL-20 (screened depth of 186 to 196 feet AMSL) with eight hits, SHL-19 (screened depth of 209 to 219 feet AMSL) and SHL-11 (screened depth of 209 to 224 feet AMSL) with four hits each, SHL-4 (screened depth of 213 to 223 feet AMSL) with three hits, and SHL-9 (screened depth of 198 to 208 feet AMSL) with two hits. All the other wells are either upgradient or possibly not intercepting leachate from the landfill. The organics therefore tend to confirm that the wells most affected by the landfill are either at the north end or the group of wells between the middle of the landfill and Plow Shop Pond (SHL-4, SHL-11, SHL-19, and SHL-20).

5.1.3 Surface Water

Fifteen surface water samples were taken for chemical analysis at Shepley's Hill Landfill. Results are summarized on Table 5-7.

Of the 15 surface water samples collected around Shepley's Hill Landfill, 13 were distributed across Plow Shop Pond, 1 was from the wetland north of the landfill, and 1 was from Nonacoicus Brook just below the dam retaining Plow Shop Pond.

5.1.3.1 Metals and Anions

Within Plow Shop Pond, water quality does not vary much from location to location with some exceptions. These include copper, nickel, silver, and zinc. Silver shows one extraordinarily high level (3.6 µg/l), at the north end of the pond SW-SHL-9, and only one other hit at SW-SHL-6 (0.564 µg/l). Copper shows a band of elevated values (>10 µg/l) parallel to the shore below the landfill stretching from SW-SHL-1 to SW-SHL-8, but missing the two closest to shore (SW-SHL-5 and SW-SHL-6). A similar pattern is observed with both nickel and zinc.

These patterns for copper, nickel, and zinc might imply an effect from groundwater welling up under the pond. This does not, however, accord with the distribution of the metals in sediments (see Section 5.1.4) or with the groundwater data. Ambient water quality criteria for surface water were exceeded for iron, copper, and silver within the pond.

The surface water sample from below the Plow Shop Pond dam (SW-SHL-15) was similar in water quality to the average water quality of the pond (see Table 5-7), as would be expected, although barium, iron, and manganese were somewhat elevated.

The surface water from the wetland north of the landfill (SW-SHL-14) also showed elevated barium, iron, and manganese relative to the pond water, but also relatively elevated copper, nickel, and zinc.

In general, anions, alkalinity and hardness were relatively unvarying across the pond (see Appendix I for water quality data). Exceptions were SW-SHL-12, which showed elevated sulfate, SW-SHL-13 which showed elevated TKN, and SW-SHL-02 which showed elevated nitrate, but no pattern of distribution is discernible.

5.1.3.2 Organics

One confirmed hit of Endrin at the detection limit (0.008 µg/l) was noted in SW-SHL-13 which does not appear to be significant. The consistent levels of methylene chloride are attributable to laboratory contamination but the six low levels (≈1 µg/l) of chloroform in SW-SHL-01 through SW-SHL-06, cannot definitely be accounted for as laboratory contamination. The high temperatures of the water and the extreme volatility of the chloroform make its persistence in the water

Table 5-7

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL
SURFACE WATER (AUGUST 1991) - FILE TYPE: CSW
AOC: 5 SITE TYPE: POND UNITS: UGL

		SITES								
Test	Parameter	SW-SHL-01	SW-SHL-02	SW-SHL-03	SW-SHL-04	SW-SHL-05	SW-SHL-06	SW-SHL-07	SW-SHL-08	SW-SHL-09
TAL_METAL	ARSENIC	4.510	3.220	4.040	4.160	4.970	6.260	3.570	2.990	6.840
	BARIUM	5.530	5.380	3.350	4.320	5.910	6.140	5.770	4.090	5.250
	CALCIUM	12000.000	12000.000	12000.000	12000.000	12000.000	12000.000	11000.000	12000.000	12000.000
	CHROMIUM	< 4.470	< 4.470	< 4.470	< 4.470	< 4.470	< 4.470	< 4.470	< 4.470	< 4.470
	COPPER	14.400	26.300	11.200	48.700	6.020	< 4.290	33.100	14.600	5.170
	IRON	232.000	241.000	214.000	365.000	530.000	460.000	323.000	538.000	538.000
	MAGNESIUM	1900.000	1900.000	2000.000	1900.000	2300.000	2300.000	2000.000	2000.000	2300.000
	MANGANESE	41.600	16.400	11.800	12.800	29.600	13.600	15.400	7.810	53.900
	NICKEL	15.700	27.500	13.000	44.200	< 8.760	< 8.760	41.000	17.900	< 8.760
	POTASSIUM	852.000	778.000	741.000	785.000	933.000	1100.000	852.000	830.000	1100.000
	SILVER	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	0.564	< 0.316	< 0.316	3.600
	SODIUM	20000.000	20000.000	21000.000	21000.000	21000.000	22000.000	23000.000	22000.000	21000.000
	ZINC	21.500	32.200	< 19.400	58.100	< 19.400	< 19.400	39.000	< 19.400	< 19.400
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	0.045*	0.027*	0.044*	0.070*	0.061*	0.065*	0.051*	0.040*	0.013*
	ENDRIN	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
TCL_VOA	CHLOROFORM	1.110	1.410	1.310	1.210	0.996	1.010	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	8.140	7.450	7.250	5.980	7.840	7.750	8.140	7.750	7.940

RC424

* Result not confirmed on a second column
**Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-7 (cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL
SURFACE WATER (AUGUST 1991) - FILE TYPE: CSW
AOC: 5 SITE TYPE: POND UNITS: UGL

		SITES					
Test	Parameter	SW-SHL-10	SW-SHL-11+	SW-SHL-12	SW-SHL-13	SW-SHL-14	SW-SHL-15
TAL_METAL	ARSENIC	3.460	3.110	3.460	2.990	4.280	6.960
	BARIUM	4.390	7.230	11.800	8.480	15.200	13.000
	CALCIUM	13000.000	12000.000	9500.000	12000.000	12000.000	13000.000
	CHROMIUM	< 4.470	< 4.470	< 4.470	< 4.470	4.900	< 4.470
	COPPER	< 4.290	4.860	8.330	9.270	21.600	4.590
	IRON	248.000	288.000	500.000	423.000	1100.000	1100.000
	MAGNESIUM	2000.000	2300.000	2000.000	2100.000	2400.000	2100.000
	MANGANESE	49.700	45.600	139.000	20.300	500.000	490.000
	NICKEL	< 8.760	< 8.760	10.200	< 8.760	36.000	< 8.760
	POTASSIUM	1000.000	911.000	911.000	1040.000	1180.000	1100.000
	SILVER	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316
	SODIUM	23000.000	25000.000	23000.000	21000.000	22000.000	21000.000
	ZINC	< 19.400	< 19.400	< 19.400	< 19.400	28.400	< 19.400
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	0.039*	0.041*	0.026*	0.025*	0.021*	0.031*
	ENDRIN	< 0.008	< 0.008	< 0.008	0.008	< 0.008	< 0.008
TCL_VOA	CHLOROFORM	< 0.830		< 0.830	< 0.830	< 0.830	< 0.830
	METHYLENE CHLORIDE	7.940		8.920	6.860	7.650	7.250

RC424

+ Volatiles for SW-SHL-11 were lost in a laboratory accident
* Result not confirmed on a second column
**Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E, 1992

highly improbable. In addition, it should be noted that chloroform is not reported in the organic-rich sediments directly beneath the water samples.

5.1.4 Sediments

Fifteen sediment samples were collected at the same locations as the surface water samples. Analytical results are summarized on Table 5-8. Percent solids for the sediment samples are included in Appendix I.

5.1.4.1 Metals

The sediment in Plow Shop Pond showed remarkably elevated heavy metals contents, with maximum values of arsenic at 3,200 µg/g, cadmium at 60 µg/g, chromium at 10,000 µg/g, iron at 330,000 µg/g, lead at 632 µg/g, manganese at 8,800 µg/g, and mercury at 130 µg/g.

Plotting the distribution of the metals resulted in three different types of patterns. In the case of arsenic, iron, and manganese, it appears clear that groundwater and possibly run-off from the landfill are the predominant sources of these metals for the sediments. Cadmium is a little more ambiguous, but also appears to originate within the landfill (see Figures 5-3 through 5-6). The distribution of barium is also somewhat difficult to interpret, but, may also come from the landfill (see Figure 5-7) but not in high concentrations, since the maximum concentrations in sediments are below 320 µg/g.

Other metals appear unambiguously to be associated with discharge of the culvert from Grove Pond under the railroad. These include copper, chromium, lead, and mercury (see Figures 5-8 through 5-11).

Several other metals may be associated with the outflow from Grove Pond, including barium and nickel (see Figures 5-11 and 5-12). The apparent migration of several of these metals north along the east side of the pond might imply that they entered the pond when the northern outlet of the pond was actively flowing. This may place the discharges from Grove Pond, which appears to have caused the entry of these metals into Plow Shop Pond some decades ago. If the metals originated from the tannery on Grove Pond which operated from 1944 to 1961, these metals were in the sediments at least 30 years ago. The high organic carbon content of the Plow Shop Pond sediments, 2.19 percent to 24.2 percent, may have trapped the metals in the sediments.

5.1.4.2 Organics

Two low level hits of p,p'-DDE and Heptachlor (0.172 and 0.020 µg/kg respectively) were noted in SE-SHL-02. The VOC reported are acetone, methylene chloride, and methyl ethyl ketone. Although these may seem unlikely to have persisted in the organic-rich sediment in such a warm-water pond (75°F to 94°F), only methylene chloride can definitely be attributed to laboratory contamination. There is no clear pattern of

Table 5-8

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL SEDIMENTS (AUGUST 1991) - FILE TYPE: CSE
AOC: 5 SITE TYPE: POND UNITS: UGG

Test	Parameter	SITES SE-SHL-01	SE-SHL-02+	SE-SHL-03+	SE-SHL-04+	SE-SHL-05+	SE-SHL-06+	SE-SHL-07+	SE-SHL-08+	SE-SHL-09
TCL_BNA	BENZO [A] ANTHRACENE	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300
	CHRYSENE	< 0.450	< 0.450	< 0.450	< 0.450	< 0.450	< 0.450	< 0.450	< 0.450	< 0.450
	FLUORANTHENE	< 0.520	< 0.520	< 0.520	< 0.520	< 0.520	< 0.520	< 0.520	< 0.520	< 0.520
	NAPHTHALENE	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420
	PHENANTHRENE	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410
	PYRENE	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	4.350
TAL_METAL	ALUMINUM	14000.000	17000.000	1600.000	2200.000	14000.000	2700.000	963.000	23000.000	20000.000
	ARSENIC	68.000	260.000	3200.000	2900.000	1800.000	3200.000	36.000	170.000	200.000
	BARIUM	47.400	173.000	210.000	210.000	170.000	280.000	10.300	210.000	310.000
	BERYLLIUM	0.400	1.360	< 0.780	< 0.780	< 0.780	< 0.780	< 0.078	1.150	1.820
	CADMIUM	< 0.424	21.000	34.000	53.000	33.000	55.000	4.380	60.200	18.300
	CALCIUM	2600.000	7000.000	12000.000	13000.000	< 1300.000	< 1300.000	690.000	6100.000	6400.000
	CHROMIUM	270.000	3700.000	310.000	390.000	< 39.000	< 39.000	270.000	950.000	5400.000
	COPPER	39.700	119.000	< 20.000	< 20.000	< 20.000	< 20.000	6.010	54.600	132.000
	IRON	14000.000	4300.000	280000.000	330000.000	>50000.000	34000.000	4000.000	73000.000	45000.000
	LEAD	60.100	338.000	30.700	39.200	46.500	31.800	31.000	202.000	612.000
	MAGNESIUM	4300.000	3050.000	550.000	730.000	2600.000	850.000	164.000	6900.000	3800.000
	MANGANESE	280.000	< 84.000	3800.000	3900.000	< 84.000	< 84.000	100.000	8800.000	3400.000
	MERCURY	> 1.000	27.000	2.110	1.700	0.550	3.500	3.500	6.070	33.000
	NICKEL	11.600	69.700	< 25.000	< 25.000	< 25.000	< 25.000	6.770	70.100	64.900
	POTASSIUM	2200.000	1520.000	185.000	244.000	996.000	324.000	90.500	2350.000	1740.000
	SODIUM	238.000	< 52.000	< 520.000	< 520.000	< 520.000	< 520.000	123.000	< 52.000	799.000
	VANADIUM	20.100	76.300	< 13.000	< 13.000	< 13.000	< 13.000	8.790	74.800	150.000
	ZINC	< 80.000	< 80.000	< 80.000	< 80.000	< 80.000	< 80.000	42.800	< 80.000	< 80.000
TCL_PEST	P,P'-DDE	< 0.040	0.172	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
	HEPTACHLOR	< 0.012	0.020	0.092*	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
TCL_VOA	ACETONE	0.058	< 0.010	0.286	0.152	0.543	< 0.010	< 0.010	0.369	0.400
	METHYLENE CHLORIDE	0.023	< 0.006	0.050	0.053	0.036	0.082	0.034	0.072	0.121
	METHYLETHYL KETONE	< 0.010	< 0.010	0.079	< 0.010	0.128	0.089	0.023	< 0.010	0.129
TOC	TOTAL ORGANIC CARBON	31800.000	191000.000	117000.000	104000.000	80900.000	138000.000	231000.000	29500.000	21900.000

RC424

* Result not confirmed on a second column
\+ Detection limits for BNA parameters for these samples are estimated due to low surrogate recoveries

Source: USATHAMA IRDMIS Level 3/E & E 1992

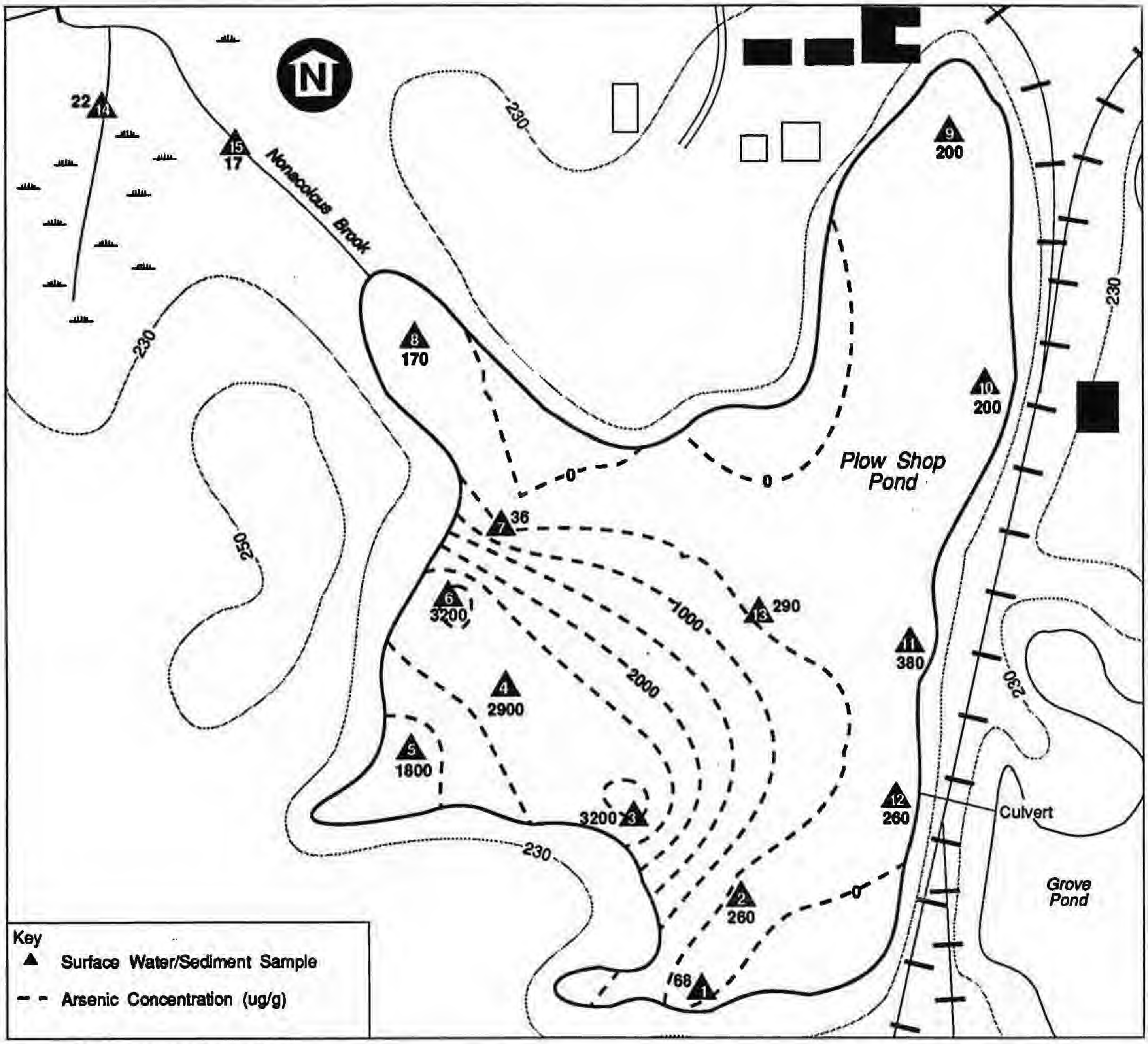
Table 5-8 (Cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR SHEPLEY'S HILL LANDFILL SEDIMENTS (AUGUST 1991) - FILE TYPE: CSE
AOC: 5 SITE TYPE: POND UNITS: UGG

		SITES					
Test	Parameter	SE-SHL-10	SE-SHL-11	SE-SHL-12	SE-SHL-13	SE-SHL-14	SE-SHL-15
TCL_BNA	BENZO [A] ANTHRACENE	< 0.300	< 0.300	1.090	< 0.300	< 0.300	< 0.300
	CHRYSENE	< 0.450	< 0.450	1.540	< 0.450	< 0.450	< 0.450
	FLUORANTHENE	< 0.520	< 0.520	3.410	< 0.520	< 0.520	< 0.520
	NAPHTHALENE	< 0.420	< 0.420	1.600	< 0.420	< 0.420	< 0.420
	PHENANTHRENE	< 0.410	< 0.410	2.510	< 0.410	< 0.410	< 0.410
	PYRENE	< 0.420	3.530	2.620	< 0.420	< 0.420	< 0.420
TAL_METAL	ALUMINUM	19000.000	22000.000	9900.000	24000.000	3000.000	< 1500.000
	ARSENIC	200.000	380.000	260.000	290.000	22.000	17.000
	BARIUM	176.000	186.000	76.300	202.000	29.000	9.680
	BERYLLIUM	2.190	2.360	0.895	2.720	< 0.078	< 0.078
	CADMIUM	23.700	12.700	4.930	53.400	< 0.424	< 0.424
	CALCIUM	8100.000	7800.000	2900.000	10000.000	1300.000	1400.000
	CHROMIUM	6900.000	10000.000	4700.000	9300.000	11.800	31.500
	COPPER	113.000	122.000	60.900	128.000	4.740	5.330
	IRON	33000.000	33000.000	19000.000	36000.000	5100.000	1400.000
	LEAD	439.000	542.000	134.000	632.000	27.900	7.760
	MAGNESIUM	2580.000	3090.000	2400.000	2880.000	770.000	620.000
	MANGANESE	1500.000	1400.000	310.000	1600.000	84.000	280.000
	MERCURY	53.000	130.000	72.000	38.000	0.231	0.099
	NICKEL	79.300	53.500	12.400	75.400	< 2.460	6.350
	POTASSIUM	1210.000	1310.000	704.000	1330.000	274.000	570.000
	SODIUM	896.000	589.000	266.000	825.000	88.500	64.200
	VANADIUM	166.000	102.000	24.300	165.000	5.140	18.600
	ZINC	< 80.000	< 80.000	< 80.000	< 80.000	28.400	20.500
TCL_PEST	P,P'-DDE	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
	HEPTACHLOR	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
TCL_VOA	ACETONE	0.146	0.146	< 0.054	0.263	< 0.010	< 0.010
	METHYLENE CHLORIDE	< 0.006	0.073	0.021	0.098	< 0.006	0.011
	METHYLETHYL KETONE	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
TOC	TOTAL ORGANIC CARBON	242000.000	218000.000	49100.000	222000.000	22000.000	2400.000

RC424

Source: USATHAMA IRDMIS Level 3/E & E 1992



Source: USGS, 1966, Revised 1979

Scale In Feet
250 0 250

Legend

—275— Contour
Building, Permanent
Building, Temporary
Road, Paved
Railroad
Wetland

Figure 5-3 DISTRIBUTION OF ARSENIC IN SEDIMENTS IN PLOW SHOP POND

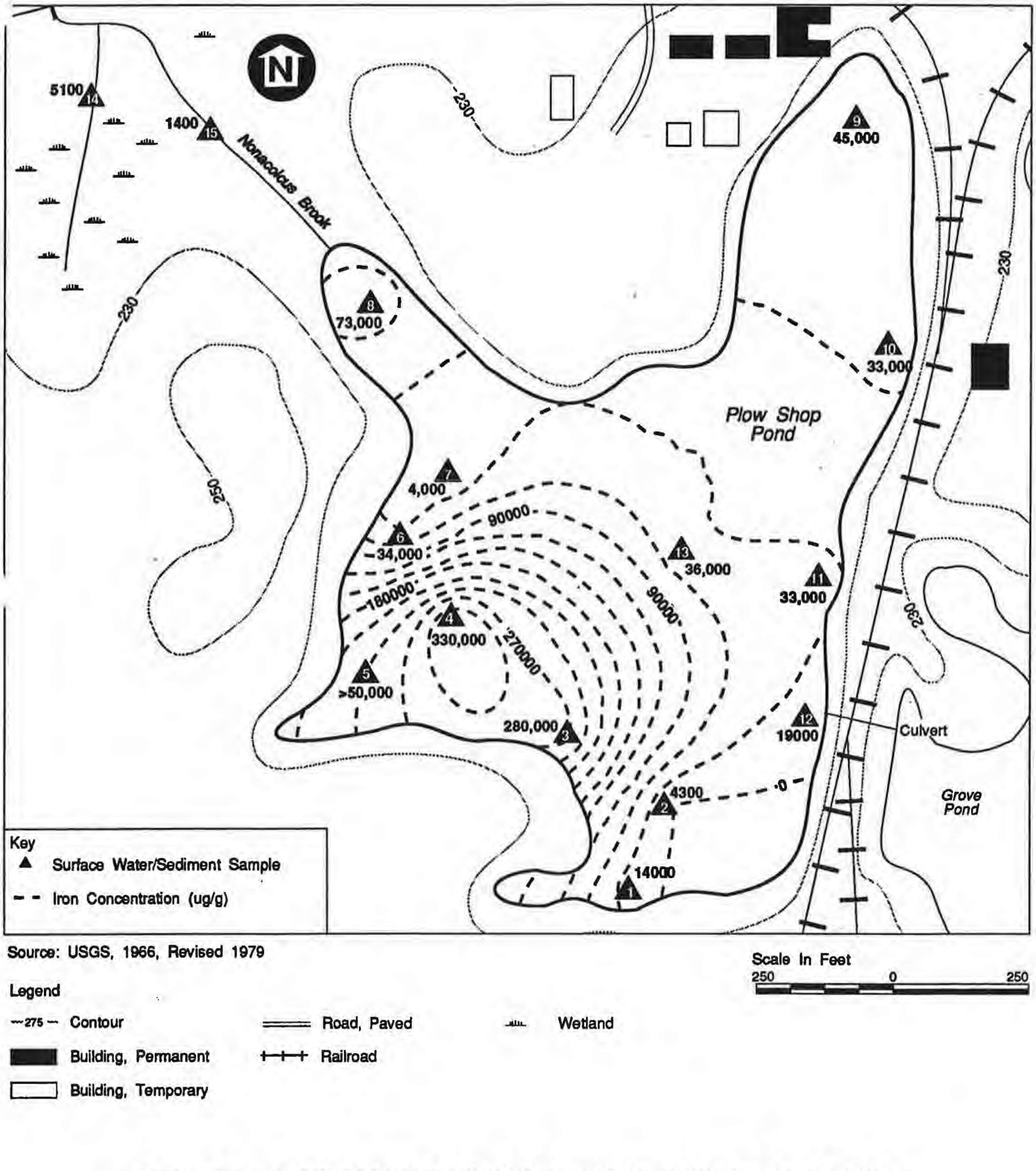


Figure 5-4 DISTRIBUTION OF IRON IN SEDIMENTS IN PLOW SHOP POND

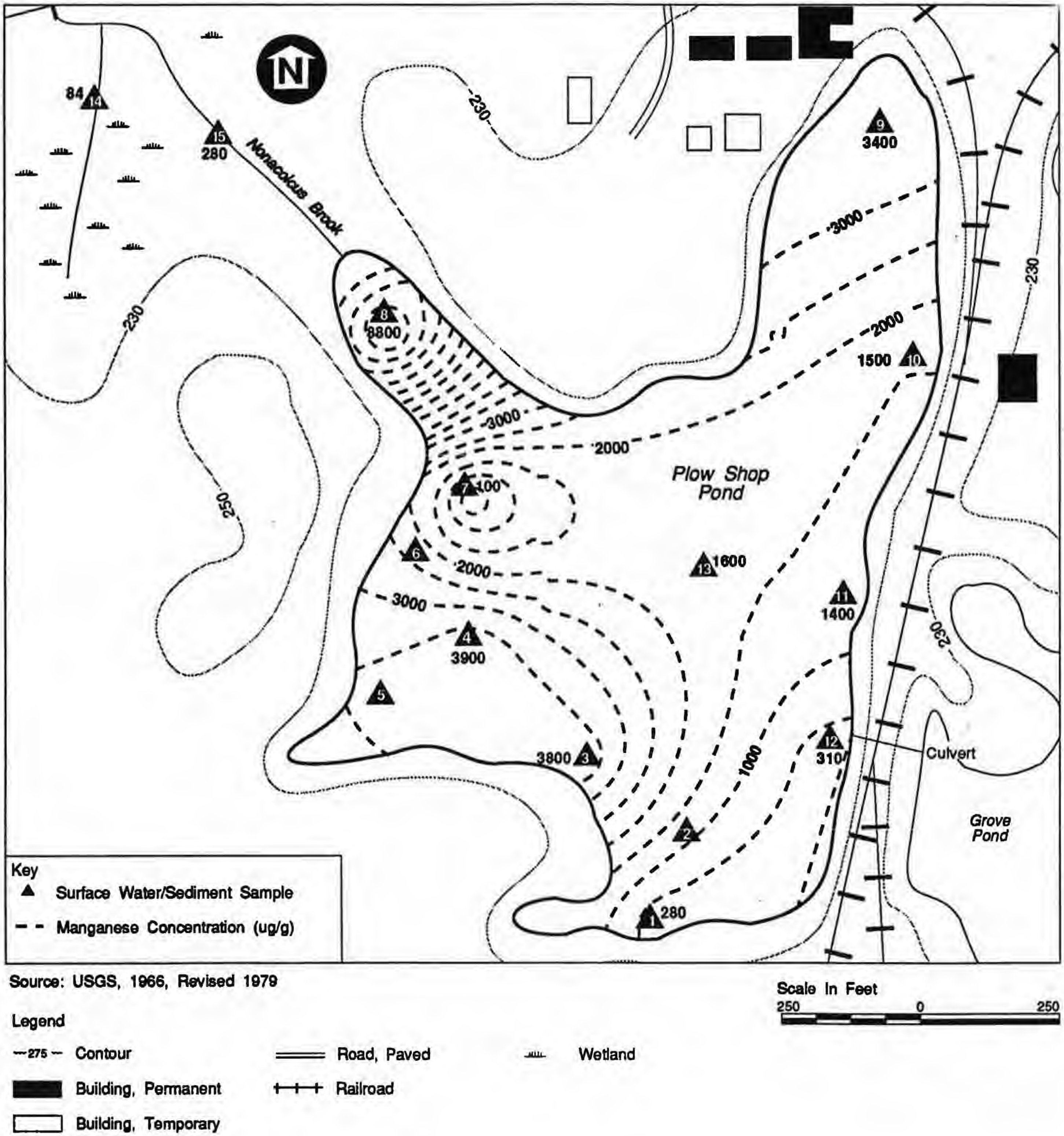


Figure 5-5 DISTRIBUTION OF MANGANESE IN SEDIMENTS IN PLOW SHOP POND

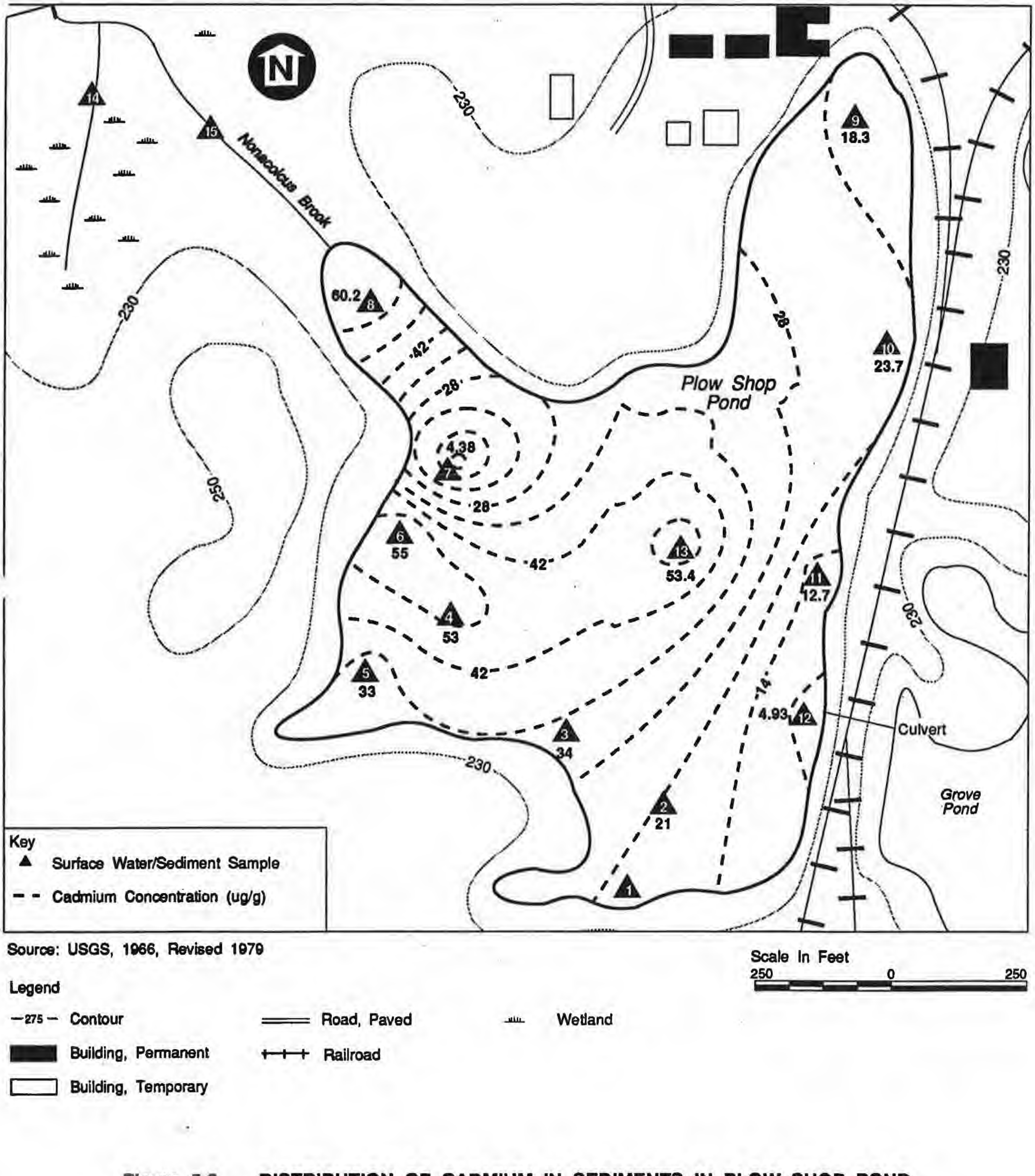


Figure 5-6 DISTRIBUTION OF CADMIUM IN SEDIMENTS IN PLOW SHOP POND

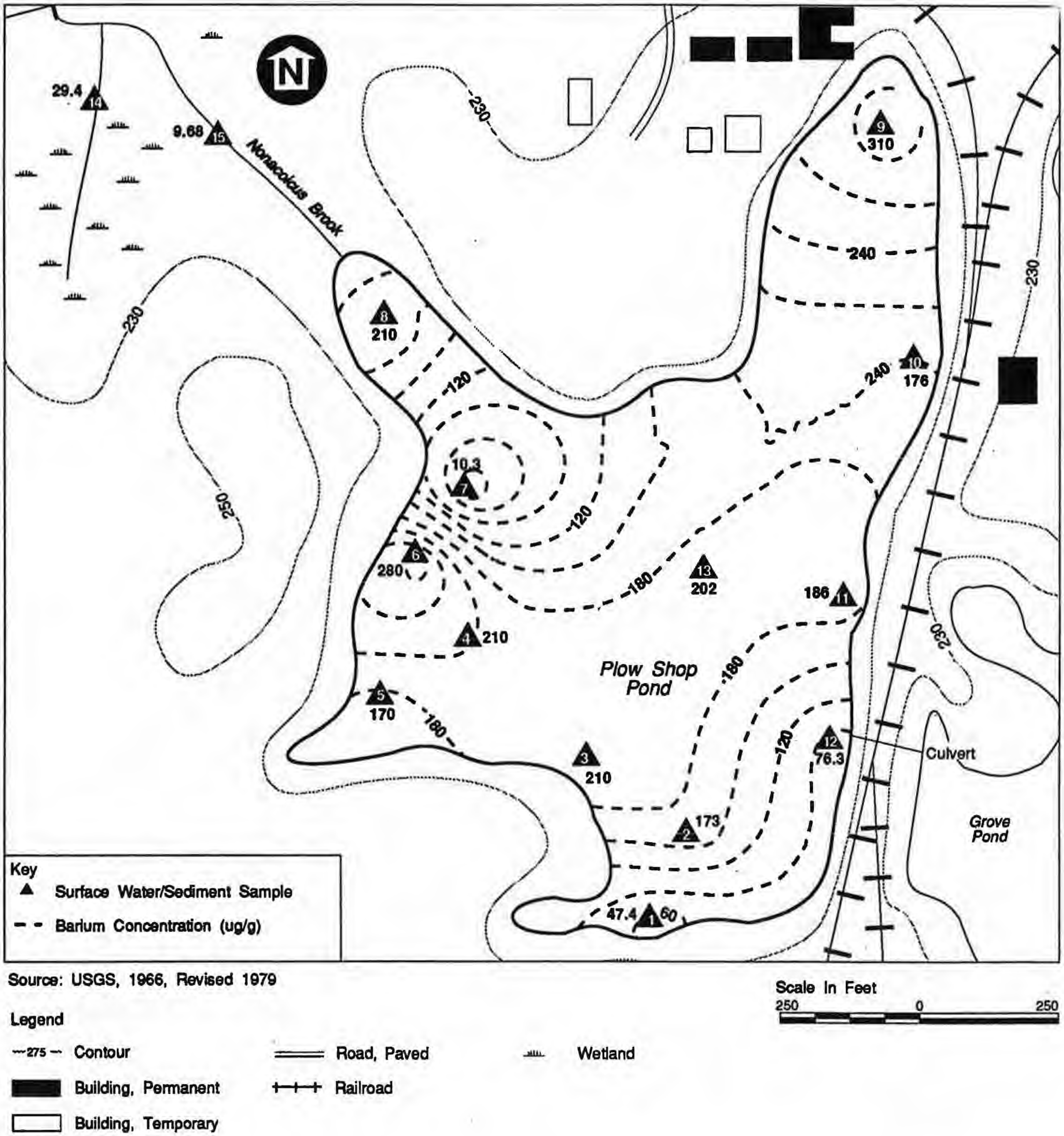


Figure 5-7 DISTRIBUTION BARIUM IN SEDIMENTS IN PLOW SHOP POND

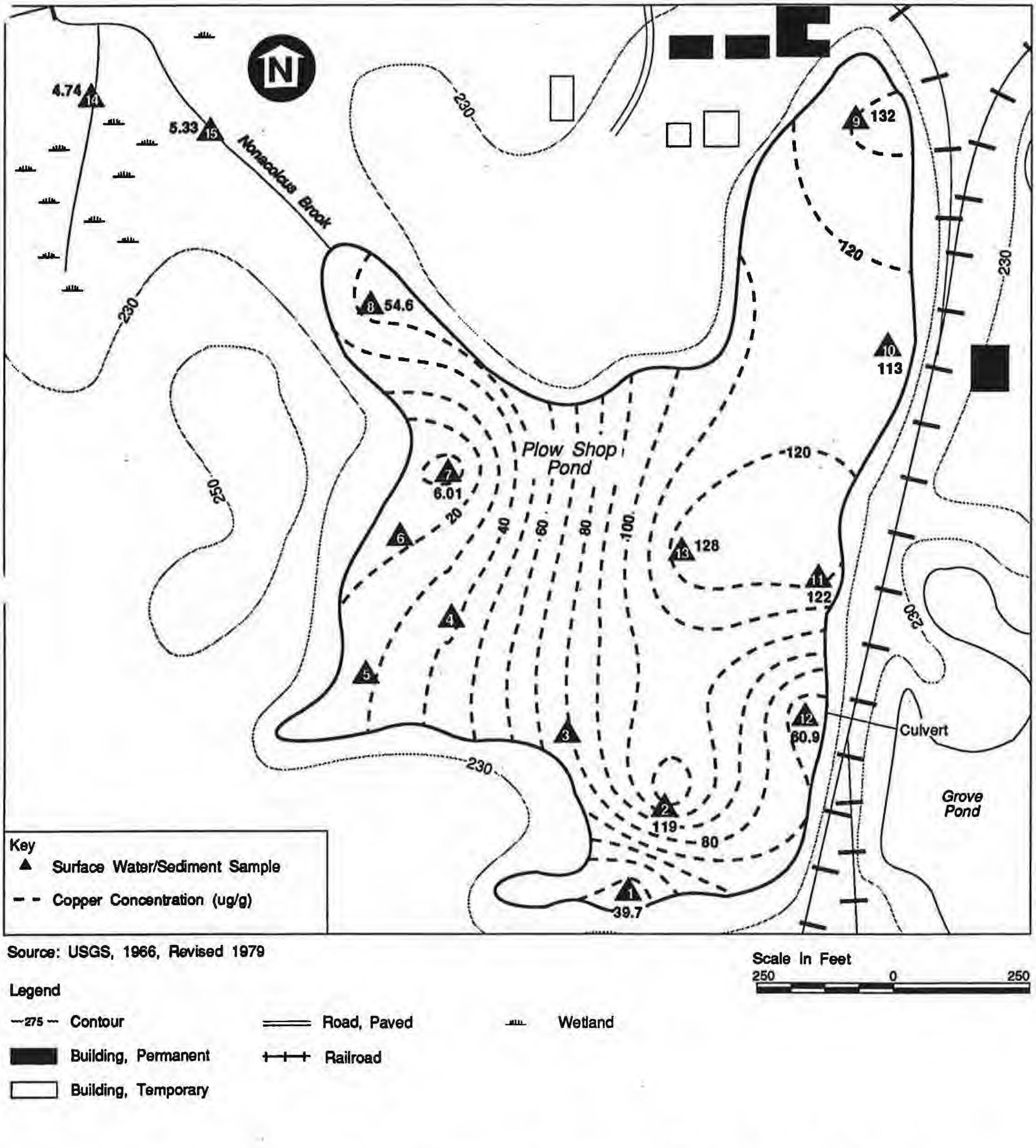


Figure 5-8 DISTRIBUTION OF COPPER IN SEDIMENTS IN PLOW SHOP POND

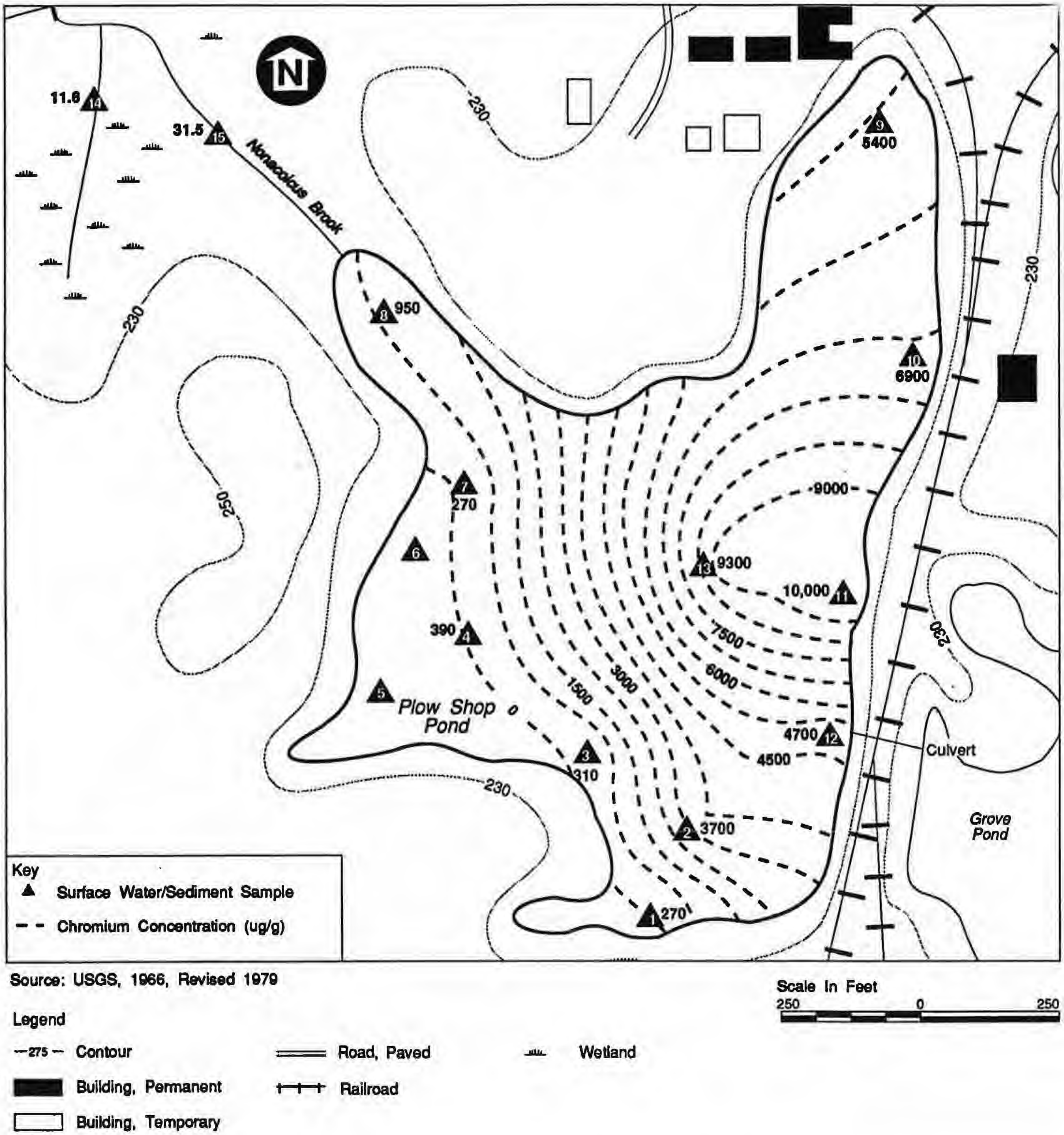


Figure 5-9 DISTRIBUTION OF CHROMIUM IN SEDIMENTS IN PLOW SHOP POND

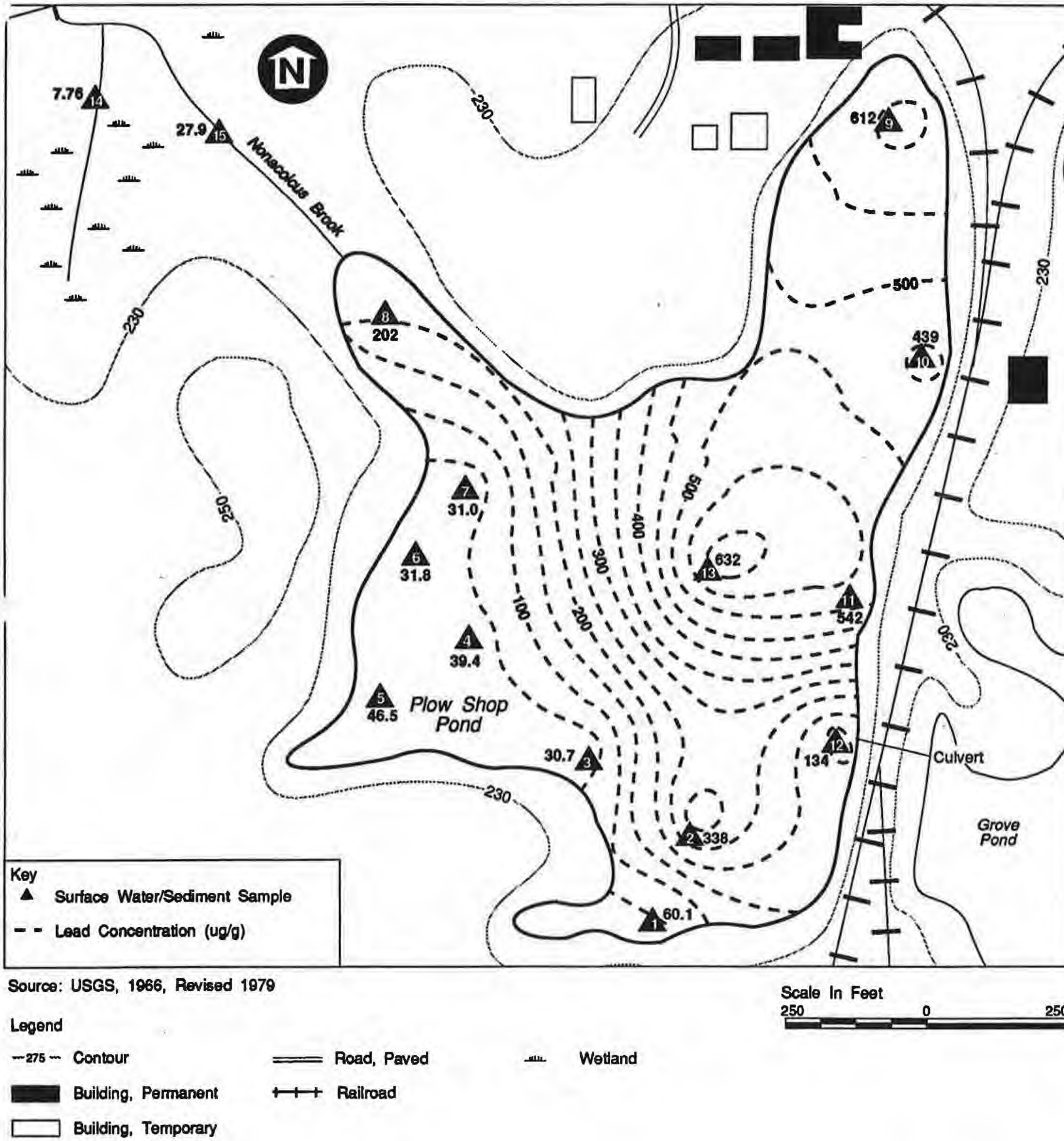


Figure 5-10 DISTRIBUTION OF LEAD IN SEDIMENTS IN PLOW SHOP POND

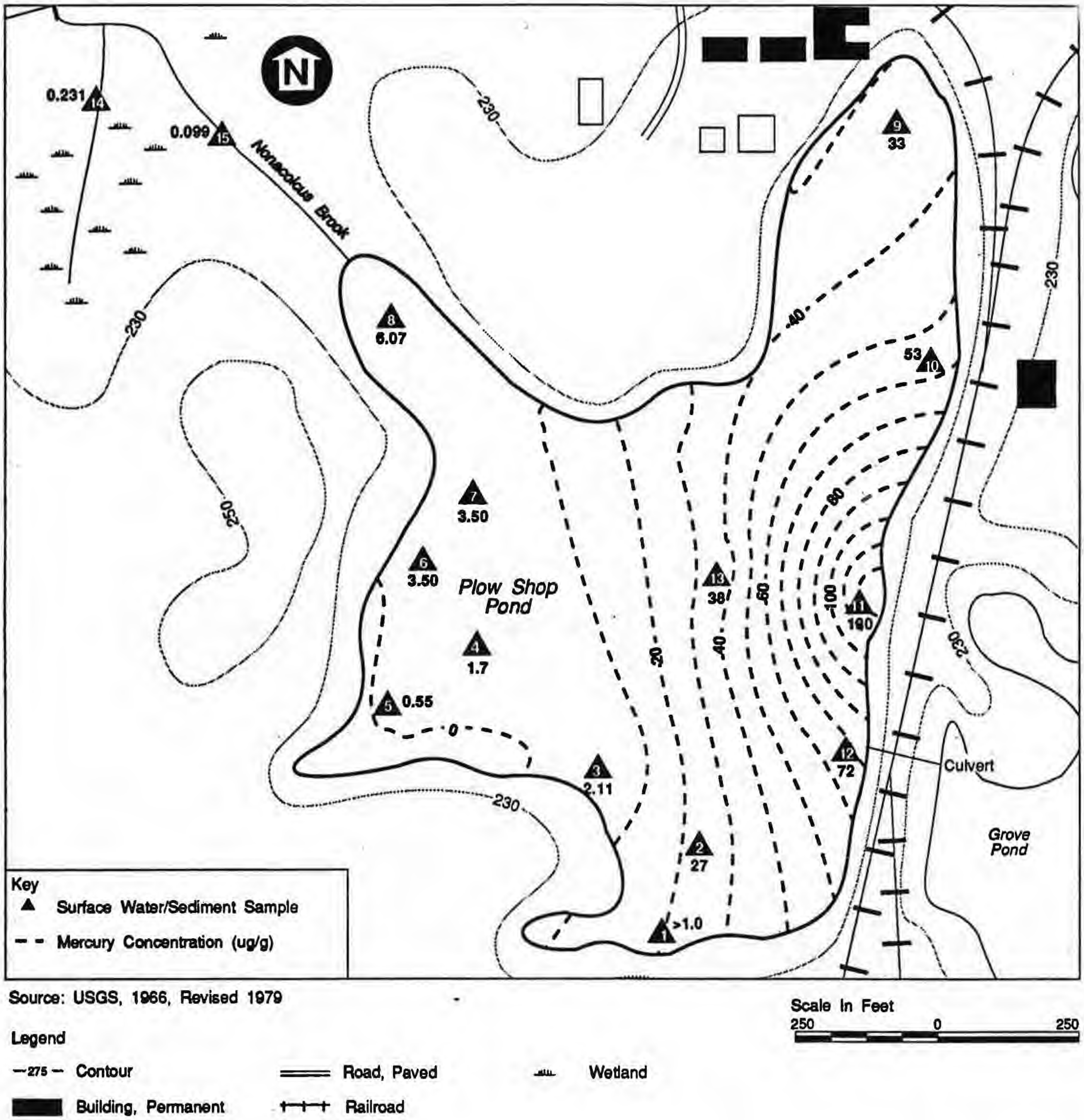


Figure 5-11 DISTRIBUTION OF MERCURY IN SEDIMENTS IN PLOW SHOP POND

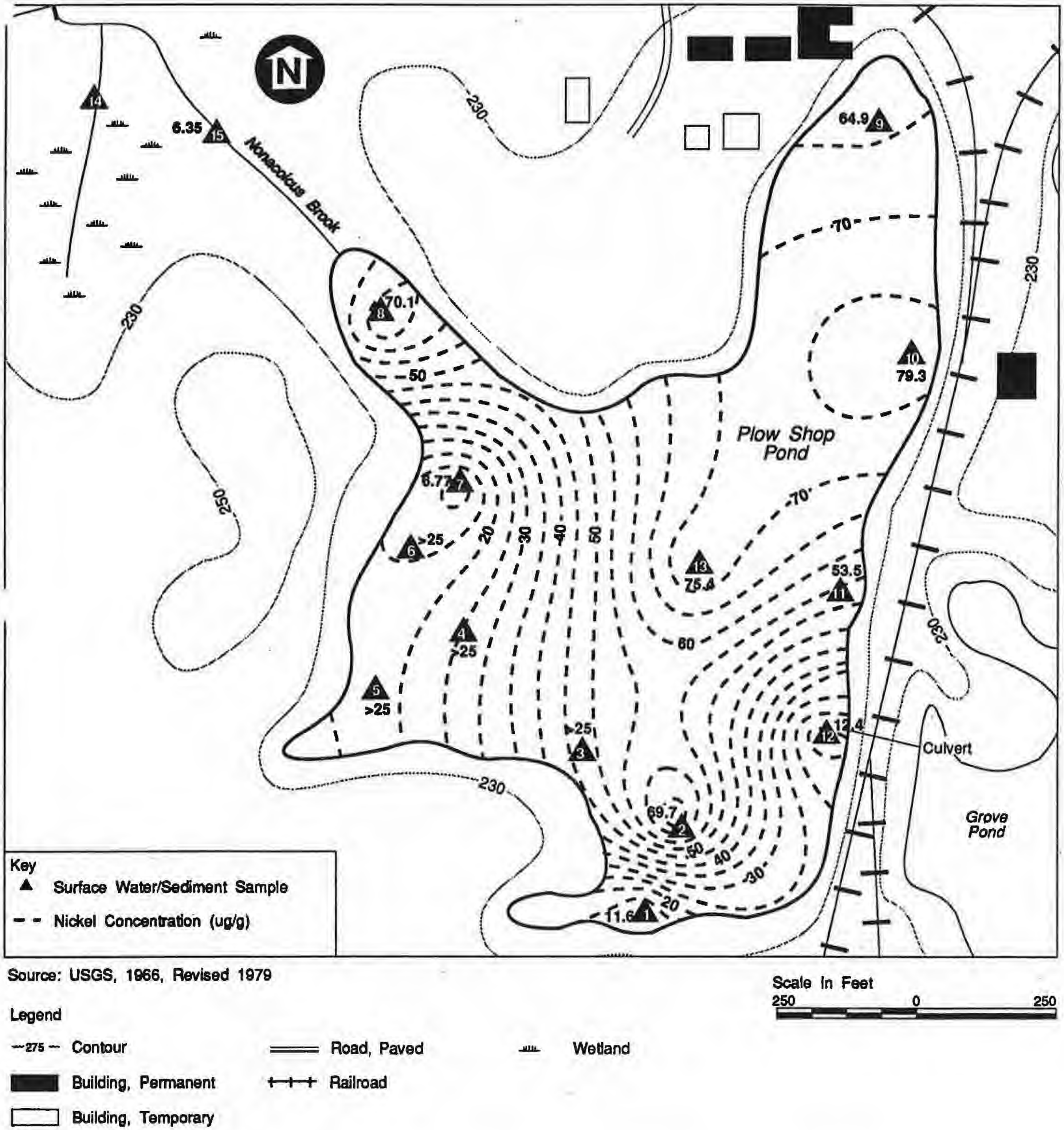


Figure 5-12 DISTRIBUTION OF NICKEL IN SEDIMENTS IN PLOW SHOP POND

distribution linking the volatiles to the landfill, nor does the water quality in the wells adjoining the pond between the pond and the landfill support the idea of the volatiles originating in the landfill.

Low levels of polynuclear aromatic hydrocarbons (PAHs) occur in three samples, SE-SHL-09, SE-SHL-11, and SE-SHL-12 (total PAH of 4.35, 3.53, and 12.8 µg/kg respectively). SE-SHL-12 contains six PAHs, benzo-a-anthracene, chrysene, fluoranthene, napthalene, phenanthrene, and pyrene. The other two contain pyrene only. The PAHs may be derived from: Grove Pond; the railroad, which used creosote treated railroad ties; or former coal storage piles.

5.1.5 Air Quality

Air monitoring was performed on and around Shepley's Hill Landfill from 12 to 25 August 1991. None of the samples showed concentrations of metals in respirable particulate matter or of volatiles that were significantly above background.

The full text of the Air Monitoring Report is included as Appendix G of this report.

5.1.6 Quality Assurance/Quality Control Results

Samples and analytical requirements for Shepley's Hill Landfill are summarized on Table 5-9. Three leachate soil samples were analyzed for TCL volatile organic compounds (VOCs), base neutral/acid extractables (BNAs), and pesticide/polychlorinated biphenyls (Pest/PCBs); and TAL metals. The leachate soils and seven subsurface soil boring samples were also analyzed for total organic carbon (TOC). Two rounds of groundwater samples at 25 wells were analyzed for TCL VOCs, BNAs, and Pest/PCBs; TAL metals; explosives; and common anions. The second round of groundwater samples were analyzed for alkalinity and total Kjeldahl nitrogen (TKN). Fifteen surface water and sediment samples were analyzed for TCL VOCs, BNAs, and Pest/PCBs; TAL metals; and explosives. Surface water samples were analyzed for water quality parameters (see Appendix I), and sediment samples were analyzed for TOCs.

In support of the risk assessment, E & E collected air samples for particulates and 10 samples for volatile organics (see Appendix G). Analytical results for target compounds detected in the samples are summarized on Tables 5-3 to 5-8. A complete set of analytical data is provided on a computer diskette in Appendix C.

Quality control (QC) samples were collected in the field to assess overall precision, accuracy, and representativeness of the sampling and analytical efforts. The analytical results for the QC samples are provided in tables in Appendix D. Three rinsate samples were collected, one each during groundwater sampling on 6 August 1991 and 9 December 1991, respectively, and one during sediment sampling on 15 August 1991 (see Table D-1). A total of thirteen trip blanks were shipped with groundwater, surface water, or waste samples on 1, 6, 7, 13, 14, 15, 23,

Table 5-9

SUMMARY OF RI ANALYTICAL REQUIREMENTS
SHEPLEY'S HILL LANDFILL

Site Name	Analysis	Number of Samples Round One	Number of Samples Round Two
Shepley's Hill	TCL (25 groundwater wells)	25	25
AOC 4,5,18	TCL (surface water)*	15	0
	TCL (pond sediment)	15	0
	TCL (leachate soil)	3	0
	TAL (28 groundwater wells)	25	25
	TAL (surface water)	15	0
	TAL (pond sediment)	15	0
	TAL (leachate soil)	3	0
	Explosives (25 groundwater)	25	25
	Explosives (surface water)	15	0
	Explosives (pond sediment)	15	0
	Air Quality Particulates	7	0
	Air Quality Organics	10	0
	TOC (pond sediment)	15	0
	TOC (leachate soil)	3	0
	TOC (well borings)	7	0
	Ions (25 groundwater)[a]	25	25
	Water Quality (surface water)[b]	15	0

RC424

TAL: Target Analyte List
TCL: Target Compound List
TOC: Total Organic Carbon

* One surface water was not analyzed for TCL volatiles due to a laboratory accident.
a Ions: chloride, fluoride, sulfate, nitrate, nitrite, bromide, and total Kjeldahl nitrogen (Cations: calcium, potassium, and magnesium are included in TAL).
b Water quality parameters include chloride, total Kjeldahl nitrogen, nitrate-nitrogen, sulfates, total phosphorous, hardness, alkalinity, and total suspended solids.

Source: E & E, 1992

and 28 August 1991; and 3, 4, 5, 6, and 7 December 1991 (see Table D-2). Laboratory method blank results are also presented in Table D-3. Field duplicates were taken for leachate soil at SEL-SHL-3 (see Table D-4); for first round groundwater samples at wells SHL-8S and SHL-21 (see Tables D-5 to D-6); and for second round groundwater samples at well SHL-15 (see Table D-7). Field duplicates were collected with the surface water and sediment at locations SW-SHL-8 and SE-SHL-8 (see Tables D-8 to D-9).

Matrix spike and matrix spike duplicate (MS/MSD) samples for organics or matrix spike (MS) and duplicate samples for inorganics were also collected at several locations to evaluate potential matrix effects on the quality of the analytical data. For the first round groundwater samples from wells SHL-8D and SHL-17, MS/MSD analyses were completed for VOCs, Pest/PCBs, explosives, and anions; MS/duplicate analysis was completed for metals. For the second round groundwater MS/MSDs for BNAs, Pest/PCBs, and explosives were completed on SHL-23, and MS/duplicate analyses for metals were completed on SHL-17. For sediments, an MS/MSD for VOCs, Pest/PCBs, and TOC, and an MS/duplicate analyses for metals was completed on sample SE-SHL-8 DUP.

The MS/MSD results for Shepley's Hill Landfill and Cold Spring Brook Landfill are presented in Tables D-16 through D-40. All results are acceptable with the exception of a few values outside EPA CLP limits indicated on the table. No effect on data usability was determined. The few values outside EPA CLP limits did not indicate any potential bias due to matrix effects. The laboratory QC samples confirmed that the analytical batches were in control.

All field and analytical activities were conducted in accordance with the Quality Assurance Project Plan, Site Investigations/Remedial Investigations at Fort Devens, Massachusetts. The original sampling and analytical requirements are summarized on Table 2-6. The actual field samples collected are summarized on Table 5-9 and the actual field QC samples taken are summarized on Table D-41.

The 28 groundwater wells to be sampled as listed in Table 2-6, include 3 from the POL area, adjacent to but southwest of the landfill, which were not sampled.

One surface water sample was not analyzed for TCL volatiles because of a laboratory accident. The 18 surface water samples were intended to include seeps of "leachate" on the landfill. These seeps were dry at the time of sampling, and are almost certainly not leachate. Because of their locations and elevations these seeps are almost certainly caused by discharges of water from above the PVC landfill cap membrane, and the water from them never enters the fill to create leachate. Soils at the seep locations showed no indication of contamination. (See Section 5.1.1)

All required QC samples were collected with the exception of the rinsate sample on the leachate soil. The rinsate was instead taken with the Cold Spring Brook leachate samples where it was not required. The Cold Spring Brook rinsate is acceptable to use to evaluate potential field contamination because the sampling techniques were equivalent. In addition, trip blanks were not taken with the soil samples. As shown on Table 2-6, soil trip blanks were not originally required. The requirement as indicated in the QAPjP was added based on comments received after the completion of the fieldwork. Overall, the rinsate and trip blanks indicated acceptable field decontamination practices. All compounds detected in the field blanks resulted from laboratory background contamination.

All field and laboratory QC blank results were compared to the sample results and any compounds attributable to potential background contamination are identified below. Field duplicate results that indicate potential sample inhomogeneity and, therefore, estimated analytical results, are also discussed. In addition, all analytical lots were evaluated for laboratory QC parameters and their potential effects on data usability. Specific issues affecting data usability are detailed in the following paragraphs. Analytical results with no laboratory QC issues reported in the analytical case narrative or USATHAMA acceptance letters were considered usable for all purposes.

5.1.6.1 Volatiles

All samples with the exception of SW-SHL-11, were analyzed within holding times according to USATHAMA certified methods. Volatile fractions for SW-SHL-11 were lost due to a laboratory accident. Methylene chloride and acetone in the samples (including the field duplicates) are attributable to laboratory background contamination with the exception of the first round result (118 µg/l) for groundwater sample SHL-17. Chloromethane was detected in the trip blanks but not in the samples. Chloroform was detected in two trip blanks in the second round of groundwater sampling. Therefore, the low level of chloroform detected in SHL-20 in the second round may be suspect even though the chloroform was also detected in the first round at SHL-20.

5.1.6.2 Base Neutral/Acid Extractables (BNAs)

All samples were within holding times according to USATHAMA certified methods except sample SE-SHL-9, which was re-extracted and re-analyzed beyond holding time due to difficulties with the sample matrix. Detection limits and results for this sample should be considered estimated. Several other sediment samples (SE-SHL-02 to SE-SHL-08) were also re-extracted and re-analyzed because of low surrogate recoveries with no detectable results. The surrogate recoveries improved slightly in the second analysis but all results were again non-detected. The first lot analyses for these samples were reported, but the detection limits should be considered estimated.

Low surrogate recoveries were also reported for several groundwater samples in the first round, including SHL-04, SHL-8S, SHL-11, and

SHL-19. High surrogate recoveries were reported for SHL-13. All results were non-detected, but the detection limit should be considered estimated.

No BNA compounds were detected in the rinsate blanks. Bis-2-ethylhexyl phthalate was detected in one water method blank; therefore, trace levels found in the samples may be suspect. Benzoic acid was consistently detected in the soils method blank, but was not found in any of the samples. No BNA compounds were detected in the field duplicate samples.

5.1.6.3 Pesticide/PCBs

All samples were analyzed within holding times according to USATHAMA methods except SE-SHL-2, which was re-extracted and re-analyzed beyond holding times by one day due to a lab accident. Confirmed results and detection limits for this sample should be considered estimated. For leachate soil samples, SEL-SHL-01 to SEL-SHL-03, detection limits for select pesticides were elevated due to low surrogate recoveries. In the first round, low pesticide surrogate recoveries were reported for SHL-03, SHL-17, SHL-18, and POL-1; and low PCB recoveries were reported for SHL-22 and SHL-24. Therefore detection limits and results for these samples should be considered estimated.

No pesticides were detected in the rinsate samples, but several pesticides including heptachlor, endrin, alpha- and beta-BHC, p,p'-DDT and endosulfan sulfate were detected as unconfirmed hits in several method blank samples. Low levels of these compounds reported in the samples should be considered due to laboratory background. Low level hits of several pesticides were detected in the sample on the first column analyses, but were not confirmed on a second column. These values are reported and flagged, but should be considered suspect. No confirmed pesticides were found in the field duplicates, but several unconfirmed hits in SHL-8S (Table D-5) indicate a somewhat high variability for unconfirmed results.

5.1.6.4 Explosives

All analytical results were acceptable. No explosives were detected in the blanks or field duplicates. However, low levels of explosives were reported in the first round of groundwater sampling at SHL-20, but the detection limits in the second round were elevated above these levels.

5.1.6.5 Metals

All samples were analyzed within holding times on the first analysis. Several mercury samples had to be reanalyzed at a higher dilution because the initial results exceeded quantitation limits. These were sediment samples SE-SHL-04, SE-SHL-05, and SE-SHL-8 to SE-SHL-15.

Because holding times were exceeded for the second analysis, the analytical results for mercury for these samples should be considered estimated, and may be on the low side. Most of these samples exceed levels of concern, despite the need for the repeat analysis, so this factor does not affect the conclusions drawn on the basis of the mapped distribution.

Several metals including barium, calcium, zinc, copper, and iron were detected in the rinsate blank samples. Several metals including aluminum, iron, copper, vanadium, and barium were also detected in the laboratory method blanks. The results indicate the rinsate blanks were contaminated due to laboratory background. Low levels of these metals in the samples should also be considered suspect due to potential laboratory background contamination.

Field duplicate results indicate excellent precision for most metals for all leachate soil, groundwater, and surface water samples. Relative Percent Differences (RPDs) under 100 percent ranged from 0 to 40 percent for SEL-SHL-3, from 16 to 56 percent for SHL-8S, from 0 to 60 percent for SHL-21, and from 4 to 79 percent for SHL-15. Only zinc in SHL-8S and vanadium and copper in SHL-15 had RPD values greater than 100 percent, indicating a potential field variability for those compounds. For sediments, RPDs were high for sample SE-SHL-8 but very consistent ranging from 131 to 140 percent for all compounds. The results indicate the variability is due to different amounts of percent moisture determined for the original and duplicate. For SE-SHL-8, the percent moisture was much higher in the original sample, indicating a potential sampling bias for the sediment samples.

Results uncorrected for percent moisture as well as the laboratory duplicates agree very well, indicating no inherent matrix effects. In all cases, the sampling bias would be toward the high side, allowing for a conservative estimate of current contamination levels.

5.1.6.6 General Analytical Parameters

All other analyses were completed within holding times under USATHAMA methods with acceptable QC parameters. Nitrate was detected in several rinsate samples but not in any laboratory method blanks. Low levels of nitrate in the samples should be considered estimated. Field duplicate results indicate acceptable precision and accuracy for all parameters.

5.2 COLD SPRING BROOK LANDFILL

5.2.1 Soils

Three soils samples were collected for chemical analysis from the cover materials above the fill at Cold Spring Brook Landfill. Results are summarized on Table 5-10.

Table 5-10

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK
SURFACE SOILS (AUGUST 1991) - FILE TYPE: CSO

AOC: 40 SITE TYPE: AREA UNITS: UGG

Test	Parameter	SITES SL-CSB-1	SL-CSB-2	SL-CSB-3
TCL_BNA	ANTHRACENE	< 0.540	0.514	< 0.540
	BENZO [A] ANTHRACENE	< 0.300	1.040	< 0.300
	BENZO [A] PYRENE	< 0.380	1.300	< 0.380
	BENZO [B] FLUORANTHENE	< 0.360	0.969	< 0.360
	BENZO [G,H,I] PERYLENE	< 0.240	0.373	< 0.240
	BENZO [K] FLUORANTHENE	< 0.800	1.720	< 0.800
	CHRYSENE	< 0.450	1.200	< 0.450
	FLUORANTHENE	0.732	2.560	< 0.520
	INDENO[1,2,3-C,D]PYRENE	< 0.210	0.275	< 0.210
	PHENANTHRENE	< 0.410	1.110	< 0.410
	PYRENE	0.600	2.490	< 0.420
TAL_METAL	ALUMINUM	<15000.000	10000.000	20000.000
	ARSENIC	45.000	22.000	31.000
	BARIUM	< 23.000	23.600	77.000
	BERYLLIUM	< 0.780	0.128	0.126
	CALCIUM	<13000.000	< 1300.000	4700.000
	CHROMIUM	< 39.000	24.300	54.300
	COPPER	< 20.000	13.000	18.300
	IRON	20000.000	16000.000	21000.000
	LEAD	60.300	35.200	23.500
	MAGNESIUM	8200.000	4800.000	10000.000
	MANGANESE	< 840.000	230.000	430.000
	MERCURY	0.382	0.095	< 0.026
	NICKEL	< 25.000	15.200	30.200
	POTASSIUM	2300.000	1300.000	4600.000
	SILVER	0.140	< 0.086	< 0.086
	SODIUM	790.000	123.000	1300.000
	VANADIUM	28.000	16.000	28.600
	ZINC	110.000	< 80.000	< 80.000
TCL_PEST	P,P'-DDD	0.101	< 0.040	< 0.040
	P,P'-DDT	0.232	< 0.160	< 0.160
TCL_VOA	METHYLENE CHLORIDE	0.006	0.006	0.006
TOC	TOTAL ORGANIC CARBON	15200.000	5010.000	5300.000

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992

5.2.1.1 Metals

When compared to background levels in soils, the samples showed elevated arsenic, barium, calcium, nickel, potassium, sodium, (both the maximum and the average); and elevated average levels of chromium, copper, iron, magnesium, manganese, mercury, vanadium, and zinc.

5.2.1.2 Organics

One sample, SL-CSB-2, showed low levels of polynuclear aromatic hydrocarbons, (PAHs), totaling 13.6 µg/g and averaging 1.23 µg/g per compound. The following PAHs were noted, anthracene, benzo[A]anthracene, benzo[B]fluoranthene, benzo[G,H,I]perylene, benzo[K]fluoranthene, chrysene, fluoranthene, indeno[1,2,3-C,D]pyrene, phenanthrene, and pyrene.

Another sample, SL-CSB-1, showed very low levels of fluoranthene and pyrene (<1 µg/g), and very low levels of DDT insecticide residues (<0.25 µg/g).

5.2.2 Groundwater

Two rounds of groundwater samples were collected at seven existing monitoring wells and the Patton Well. The first round was collected in August 1991 and the results are summarized on Table 5-11. The second round was collected in December 1991 and the results are summarized on Table 5-12.

All the existing wells at Cold Spring Brook Landfill (CSB-1, CSB-2, CSB-3, CSB-4, CSB-6, CSB-7, and CSB-8) were sampled twice, although because of its very low yield, CSB-4 was sampled only for VOCs in the first round and VOCs and BNAs in the second round. The groundwater contours and flow direction for August 1991 as well as the sample locations are shown on Figure 5-13.

5.2.2.1 Metals

The RI samples for metals analysis collected in August 1991 and December 1991 were left unfiltered in compliance with EPA guidance documents. A concurrent series of samples are being collected by Con-Test quarterly, filtered in the field, and analyzed for arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Because only volatiles analyses were performed on the RI samples from CSB-4 and because CSB-5 was destroyed sometime between 24 April 1991 and 9 July 1991, the analyses of the Con-Test field-filtered samples are the only analyses available from these wells for discussion. For Con-Test quarterly sampling results from January 1991 through April 1992 see Appendix U.

When the monitoring wells were sampled for the RI, the nearby Patton Well, used by the Fort Devens water distribution system, was also sampled. Although this well is apparently partially withdrawing water

Table 5-11

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK GROUNDWATER (AUGUST 1991)
FIRST ROUND - FILE TYPE: CGW
AOC: 40 SITE TYPE: WELL UNITS: UGL

		SITES							
Test	Parameter	CSB-1	CSB-2	CSB-3	CSB-4	CSB-6	CSB-7	CSB-8	PATTON
ANIONS	CHLORIDE	2170.000	23000.000	1850.000		64000.000	74000.000	390000.000	25000.000
	FLUORIDE	< 71.000	< 71.000	< 71.000		189.000	200.000	< 710.000	1200.000
	NITRATE	3900.000	62.600	1400.000		360.000	162.000	27.400	500.000
	SULFATE	9600.000	22000.000	9700.000		15000.000	16000.000	27000.000	16000.000
	BROMIDE	< 50.000	< 50.000	< 50.000		< 50.000	< 50.000	68.800	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	7.940	< 0.388	< 0.388		< 0.388	< 0.388	< 0.388	< 0.388
TAL_METAL	ALUMINUM	1490.000	372.000	47000.000		5300.000	19000.000	40000.000	000.000
	ARSENIC	4.710	5.440	220.000		4.740	79.000	85.000	3.960
	BARIUM	25.100	22.500	250.000		12.000	140.000	290.000	11.600
	BERYLLIUM	< 0.341	< 0.341	1.080		< 0.341	0.584	0.984	< 0.341
	CADMIUM	< 2.670	3.530	< 2.670		< 2.670	< 2.670	< 2.670	< 2.670
	CALCIUM	11000.000	27000.000	19000.000		12000.000	6800.000	25000.000	41000.000
	CHROMIUM	< 4.470	9.790	150.000		8.520	14.700	68.200	< 4.470
	COPPER	19.400	27.200	94.800		31.900	20.900	90.000	51.300
	IRON	2500.000	1300.000	57000.000		3100.000	18000.000	34000.000	122.000
	LEAD	11.000	14.300	85.000		6.110	37.600	62.000	7.540
	MAGNESIUM	1400.000	4500.000	23000.000		2600.000	4400.000	10000.000	6400.000
	MANGANESE	510.000	4800.000	1600.000		29.900	720.000	1000.000	300.000
	NICKEL	< 8.760	13.800	90.600		32.300	< 8.760	61.700	9.650
	POTASSIUM	1110.000	4400.000	8900.000		1120.000	2020.000	5800.000	2080.000
	SILVER	< 0.316	< 0.316	0.683		< 0.316	< 0.316	< 0.316	< 0.316
	SODIUM	2560.000	16000.000	3170.000		<150000.00	<150000.00	210000.000	21000.000
	VANADIUM	< 4.000	< 4.000	56.900		< 4.000	10.700	23.900	< 4.000
	ZINC	127.000	89.000	111.000		45.200	33.600	230.000	131.000
TCL_PEST	ENDRIN	< 0.008	0.011*	< 0.008		< 0.008	< 0.008	< 0.008	< 0.008
	HEPTACHLOR	0.016*	0.040*	0.012		< 0.008	< 0.008	0.032*	< 0.008
	ALPHA CHLORDANE	< 0.002	0.006*	< 0.002		< 0.002	< 0.002	< 0.002	0.004*
TCL_VOA	METHYLENE CHLORIDE	7.600	8.900	9.400	7.350	9.610	9.800	8.900	8.920
TPHC	TOTAL PETROLEUM HYDROCARBON	< 1150.000	2530.000	< 1120.000		< 1130.000	< 1130.000	< 1120.000	<1160.000

RC424

* Result not confirmed on a second column

Source: USATHAMA IRDMIS Level 3/E & E, Inc.

Table 5-12

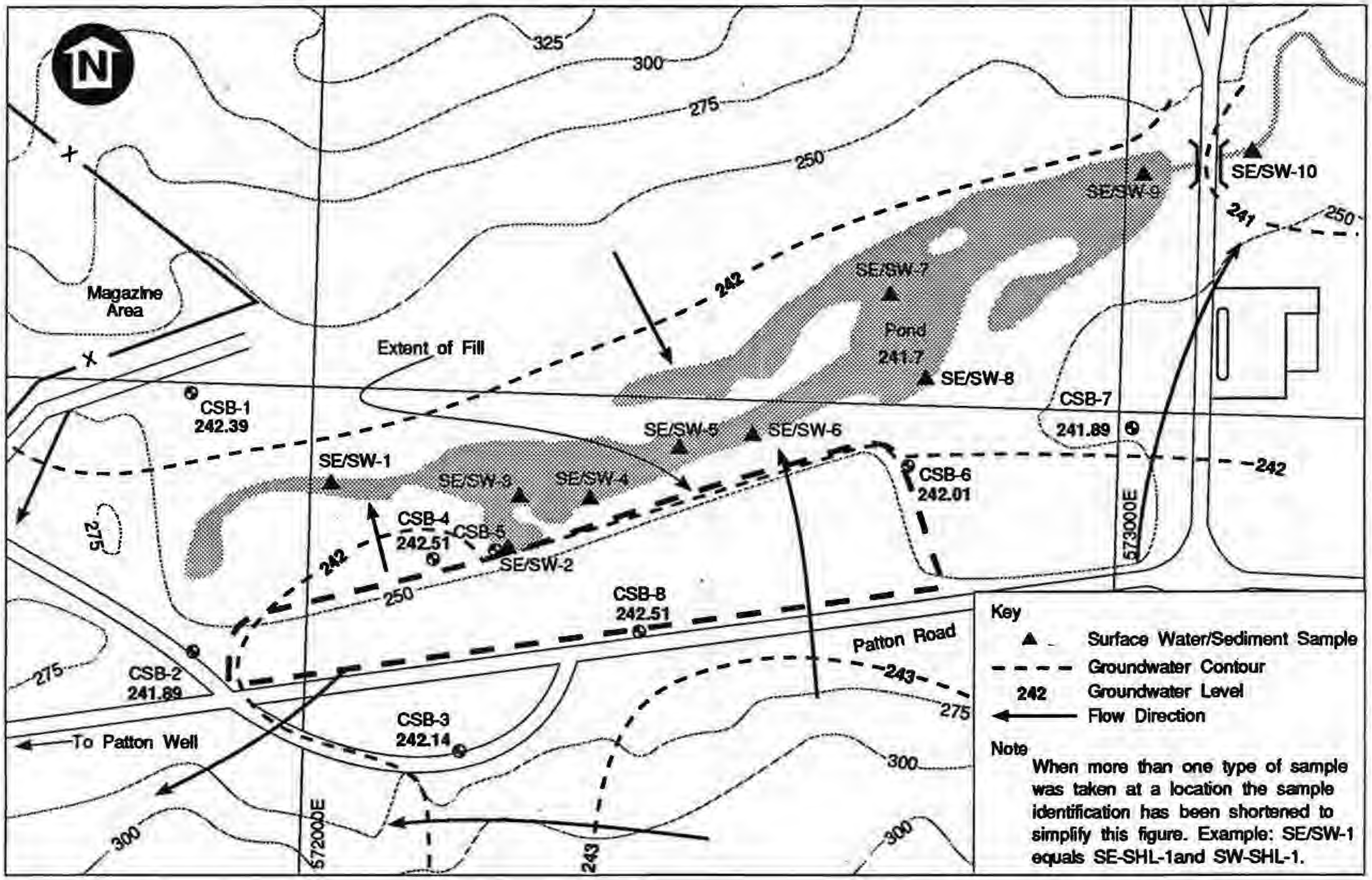
INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK GROUNDWATER (DECEMBER 1991)
SECOND ROUND - FILE TYPE: CGW
AOC: 40 SITE TYPE: WELL UNITS: UGL

		SITES							
Test	Parameter	CSB-1	CSB-2	CSB-3	CSB-4	CSB-6	CSB-7	CSB-8	PATTON
	ALKALINITY*	30.000	103.000	35.000		18.000	2.000	280.000	106.000
	TOTAL KJELDAHL NITROGEN	182.000	769.000	501.000		115.000	91.300	245.000	182.000
	TOTAL PETROLEUM HYDROCARBONS	< 1210.000	< 1120.000	< 1220.000		< 1200.000	< 1260.000	< 1220.000	< 1200.000
ANIONS	CHLORIDE	2900.000	26000.000	1240.000		49000.000	38000.000	250000.000	27000.000
	FLUORIDE	< 71.000	< 71.000	< 71.000		< 71.000	< 71.000	< 71.000	19000.000
	NITRATE	1100.000	21.000	4600.000		290.000	63.800	20.900	420.000
	SULFATE	8400.000	23000.000	8800.000		9200.000	8100.000	22000.000	15000.000
	BROMIDE	< 50.000	52.200	< 50.000		< 50.000	< 50.000	< 50.000	< 50.000
EXPLOSIVES	1,3,5-TRINITROBENZENE	1.350	< 0.388	< 0.388		< 0.388	< 0.388	< 0.388	< 0.388
	1,3-DINITROBENZENE	2.860	< 0.270	< 0.270		< 0.270	< 0.270	< 0.270	< 0.270
TAL_METAL	ALUMINUM	5600.000	5400.000	25000.000		5300.000	9100.000	29000.000	145.000
	ARSENIC	10.900	16.700	67.000		3.490	29.000	39.000	< 3.090
	BARIUM	33.400	29.500	210.000		10.900	63.000	290.000	7.670
	BERYLLIUM	< 0.341	< 0.341	0.675		< 0.341	< 0.341	0.633	< 0.341
	CADMIUM	< 2.670	< 2.670	< 2.670		< 2.670	< 2.670	< 2.670	6.530
	CALCIUM	14000.000	51000.000	24000.000		12000.000	5000.000	23000.000	47000.000
	CHROMIUM	6.120	11.700	56.000		9.930	9.150	34.400	8.590
	COPPER	11.400	24.900	35.600		7.770	16.700	26.200	31.300
	IRON	6300.000	9500.000	27000.000		2900.000	10000.000	19000.000	204.000
	LEAD	5.580	13.600	30.700		5.850	15.100	25.000	< 4.740
	MAGNESIUM	3100.000	14000.000	9900.000		2700.000	2900.000	5500.000	6100.000
	MANGANESE	2400.000	6200.000	820.000		27.400	350.000	550.000	350.000
	NICKEL	< 8.760	19.600	37.300		< 8.760	< 8.760	19.200	9.560
	POTASSIUM	1550.000	6800.000	5100.000		1200.000	1470.000	3900.000	2450.000
	SILVER	< 0.316	< 0.316	1.190		< 0.316	< 0.316	< 0.316	< 0.316
	SODIUM	3320.000	19000.000	<15000.000		30000.000	24000.000	180000.000	<150000.00
	VANADIUM	< 4.000	< 4.000	13.600		< 4.000	4.180	10.600	< 4.000
	ZINC	92.000	20.900	46.600		< 19.400	22.000	45.300	147.000
TCL_VOA	METHYLENE CHLORIDE	5.200	5.100	5.100	5.200	5.290	5.200	5.100	4.900

RC424

*Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E 1992



Source: E&E, 1991

Scale in Feet
200 0 200

Legend

- Monitoring Well
- Channel and Culvert
- 275 Contour (25ft.)
- Road, Surfaced
- Road, Unimproved
- Fence

Figure 5-13 GROUNDWATER CONTOURS AND FLOW DIRECTION AT COLD SPRING BROOK 8/30/91

1ARVFig.5-13.CDR

from under the west end of the landfill, its water quality is not similar to that in the monitoring wells. This implies that there is no detectable impact of the landfill on the Patton Well. It is much more heavily pumped and consequently has much lower turbidity and very much lower aluminum and iron, (less than two percent of the average iron content in the monitoring wells and close to one percent of the average aluminum content of the monitoring wells). This has resulted in generally lower levels of insoluble metals in the Patton Well (i.e., arsenic, barium, and lead), but relatively similar levels of anions (i.e., chloride, nitrate, and sulfate), but greatly increased fluoride from an unknown source.

When comparisons are made between monitoring wells, it becomes evident that CSB-1 and CSB-7, which are consistently unaffected by flow originating in or passing through the landfill, are nevertheless affected by upgradient sources. CSB-1 is clearly affected by low levels of explosives derivatives 1,3,5-trinitrobenzene (7.94 and 1.35 µg/l), and 1,3-dinitrobenzene (2.86 µg/l). CSB-7 on the other hand is clearly affected by chloride and sodium as are CSB-2, CSB-6, CSB-8, and the Patton Well, all presumably affected by road salt. Those wells closest to the road may also be affected by sulfate, perhaps from the same source.

When comparison is made between "upgradient" monitoring wells (CSB-1 and CSB-7) and "downgradient" monitoring wells (the remainder), for heavy metals content, it becomes clear that the variation in heavy metals is predominantly due to variation in iron and aluminum content, which is related to particulate matter in the water. This can readily be seen by comparing CSB-1 and CSB-2 (a downgradient well) and CSB-2 with the other upgradient well, CSB-7. In the first case, CSB-1 and CSB-2 are very similar in water quality, with respect to heavy metals; chromium, copper, lead, nickel, and possibly arsenic, are slightly elevated in CSB-2, and only manganese is sharply and clearly increased. In the second case, all the heavy metals are higher in the "background" well (CSB-7), with the exceptions of copper and manganese. Even these metals appear to be elevated only at the west end of the fill because CSB-6 is low in all the metals of concern, despite being very close to the east edge of the landfill and downgradient from it.

When comparing the data on filtered groundwater samples (which do not include results for manganese, copper, nickel, and zinc), with the unfiltered samples, the implication is that chromium is not derived from the landfill because it is not detected in filtered samples, but that possibly arsenic is derived from the landfill. Both times CSB-5 was sampled during 1991, the filtered sample exceeded drinking water standards (at 110 µg/l and 140 µg/l respectively) (Con-Test 1991). CSB-4 also showed detectable arsenic previously.

5.2.2.2 Organics

Apart from the low levels of nitrobenzenes in CSB-1, some low levels of pesticides have been noted in the August 1991 samples. Endrin was detected in CSB-2 (0.11 µg/l); Heptachlor was noted in CSB-1, CSB-2, CSB-3, and CSB-8 at 0.016, 0.040, 0.012, and 0.032 µg/l, respectively; and alpha-Chlordane was noted in CSB-2 and the Patton Well, (0.006 and 0.004 µg/l, respectively). None of these compounds except nitrobenzenes was confirmed on a second column, which renders their detection unreliable. Because groundwater in CSB-1 does not flow from the landfill, the nitrobenzenes are not derived from that source. Heptachlor was also detected in several laboratory method blanks, and the levels may be attributable to background contamination. The Methylene chloride levels found in all the wells on both sampling rounds are also attributable to laboratory contamination.

5.2.3 Surface Water

Ten surface water samples were taken at Cold Spring Brook Landfill, nine in the pond adjacent to the landfill and one in the brook below the outlet from the pond. Results are summarized on Table 5-13. Because the pond is very narrow, groundwater discharging into it from the landfill side may impact surface water across the entire width of the pond. Run-off from the landfill may have a similar impact. No sample of surface water taken could be considered outside the range of impact of the landfill. Therefore, there is no background sample.

5.2.3.1 Metals and Anions

The only discernible trend in metals and anions is a rapid reduction in both sulfate and arsenic from the west end of the pond to the east (see Appendix I for water quality results). There is also a reduction in both iron and manganese. Since the west end of the landfill is indicated as having the greater impact on groundwater, and three of these analytes were indicated as potentially discharging from the landfill. It appears that surface water quality confirms this suspicion and the landfill is affecting the levels of iron, manganese, arsenic, and sulfate in the surface water. Ambient water quality criteria for surface water are exceeded for iron throughout the pond, and at one location (SW-CSB-02) for silver.

5.2.3.2 Organics

The only organic found in surface water was alpha benzene hexachloride (α-BHC), a pesticide. This does not appear to indicate a source within the landfill, particularly as it was not found in the groundwater. Alpha-BHC was not confirmed on second column for any samples and was found in several method blanks. It is very probably a laboratory contaminant and not present in the pond. Based upon the QC results, alpha-BHC is not considered a contaminant.

5.2.4 Sediments

Ten sediment samples were taken at Cold Spring Brook at the same locations as the surface water samples. The analytical results are

Table 5-13

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK SURFACE WATER (AUGUST 1991) - FILE TYPE: CSW
AOC: 40 SITE TYPE: POND UNITS: UGL

		SITES								
Test	Parameter	SW-CSB-01	SW-CSB-02	SW-CSB-03	SW-CSB-04	SW-CSB-05	SW-CSB-06	SW-CSB-07	SW-CSB-08	SW-CSB-09
TAL_METAL	ARSENIC	17.700	10.400	10.100	7.780	4.860	5.790	5.090	4.510	5.550
	BARIUM	11.000	11.800	11.400	10.400	9.900	9.710	9.800	9.170	13.400
	CALCIUM	24000.000	31000.000	31000.000	28000.000	25000.000	19000.000	20000.000	25000.000	24000.000
	CHROMIUM	< 4.470	< 4.470	4.760	4.670	< 4.470	< 4.470	< 4.470	< 4.470	< 4.470
	COPPER	4.690	< 4.290	5.460	5.630	4.960	< 4.290	6.750	5.260	5.240
	IRON	3200.000	1800.000	1900.000	1400.000	1200.000	1200.000	1200.000	1100.000	1300.000
	MAGNESIUM	2900.000	3200.000	3300.000	3300.000	2900.000	3000.000	3000.000	2900.000	3000.000
	MANGANESE	400.000	223.000	228.000	162.000	63.700	85.600	70.900	53.300	108.000
	POTASSIUM	1730.000	1910.000	2010.000	1910.000	1490.000	1530.000	1530.000	1560.000	1560.000
	SILVER	< 0.316	0.708	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316
	ZINC	< 19.400	28.500	< 19.400	86.300	35.500	< 19.400	< 19.400	< 19.400	< 19.400
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	0.020*	0.017*	0.016*	0.015*	0.014*	0.013*	0.015*	< 0.006	0.017*
TCL_VOA	METHYLENE CHLORIDE	7.840	7.350	8.140	7.450	7.750	6.670	7.350	7.060	6.370

RC424

* Result not confirmed on a second column
** Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-13 (cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK
SURFACE WATER (AUGUST 1991) - FILE TYPE: CSW
AOC: 40 SITE TYPE: POND UNITS: UGL

Test	Parameter	SITES SW-CSB-10
TAL_METAL	ARSENIC	5.210
	BARIUM	10.100
	CALCIUM	19000.000
	CHROMIUM	< 4.470
	COPPER	< 4.290
	IRON	1300.000
	MAGNESIUM	3200.000
	MANGANESE	118.000
	POTASSIUM	1560.000
	SILVER	< 0.316
	ZINC	< 19.400
TCL_PEST	ALPHA-BENZENEHEXACHLORIDE	0.015*
TCL_VOA	METHYLENE CHLORIDE	9.800

RC424

* Result not confirmed on a second column
** Result reported in mg/l

Source: USATHAMA IRDMIS Level 3/E & E, 1992

summarized on Table 5-14. Percent solids for the sediment samples are included in Appendix I.

5.2.4.1 Metals

Most of the sediments in Cold Spring Brook Pond exceed the median value of a number of non-enforceable criteria and background levels of metals used for comparison (see Table 5-15). Six of ten sediments exceed the median for manganese; nine of ten sediments exceed the median criteria for arsenic; and six of ten, the median criterion for lead, although, of these, only two exceed the median criterion by a wide margin.

The two samples showing the highest levels of metals are SE-CSB-02 immediately adjacent to the fill, where broken, rusted drums are resting in the water of the pond, and SE-CSB-09 at the east end of the pond next to Patton Road. These samples are also notably the most organic-rich samples with 17 percent and 10.1 percent TOC, respectively.

Distribution of arsenic, lead, mercury, and zinc are shown in Figures 5-14 to 5-17. Distribution does not follow a consistent spatial pattern, but the landfill does appear to contribute arsenic, lead, and zinc to the sediments, and probably mercury also. The distribution of metals in the sediments of Cold Spring Brook Pond shows a pattern that appears to reflect a combination of metals originating at the west end of the pond and differential migration and accumulation in sediment in response to total organic carbon content of the sediment. High metals concentrations in the sediments correlate with high TOCs. Because the TOC level is not highest near the landfill, and does not decline in a regular way with distance from it, the metals levels in the sediments do not show a simple spatial distribution around the landfill. This conclusion is derived from a discussion of contaminant fate and transport (see Section 6.2.4 and Figure 6-1).

5.2.4.2 Organics

Low levels of total PAHs were noted in SE-CSB-02 (3.97 µg/g), SE-CSB-06 (8.07 µg/g), SE-CSB-08 (1.17 µg/g), SE-CSB-09 (79.6 µg/g), and SE-CSB-10 (4.78 µg/g). The highest level is in the sample adjacent to the road (SE-CSB-09), which might indicate a source in drainage from the road. The next highest level (in SE-CSB-06) is in a sample immediately adjacent to the landfill, but samples on either side of it are non-detect, which implies a local source for the PAHs in SE-CSB-06.

Other organics noted include low level residues of DDT insecticide, (in eight of ten samples); acetone (0.167 to 0.016 µg/g in eight of ten samples); and methyl ethyl ketone (2-butanone), in one sample only (SE-CSB-03) at a very low level (0.025 µg/g). Total petroleum hydrocarbons were noted in SE-CSB-01 (291 µg/g), SE-CSB-06 (213 µg/g), SE-CSB-09 (2,100 µg/g), and in SE-CSB-10 (601 µg/g). There appear to be several probable sources of PAHs, within the landfill (SE-CSB-02, SE-CSB-06, and SE-CSB-08) and from Patton Road drainage (SE-CSB-09 and

Table 5-14

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK SEDIMENTS (AUGUST 1991)
FILE TYPE: CSE

AOC: 40 **SITE TYPE: POND** **UNITS: UGG**

Test	Parameter	SITES								
		SE-CSB-01	SE-CSB-02	SE-CSB-03	SE-CSB-04	SE-CSB-05	SE-CSB-06	SE-CSB-07	SE-CSB-08	SE-CSB-09
TCL_BNA	ACENAPHTHYLENE	< 0.460	< 0.460	< 0.460	< 0.460	< 0.460	< 0.460	< 0.460	< 0.460	2.880
	ANTHRACENE	< 0.540	< 0.540	< 0.540	< 0.540	< 0.540	< 0.540	< 0.540	< 0.540	3.060
	BENZO [A] ANTHRACENE	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	0.734	< 0.300	< 0.300	4.310
	BENZO [A] PYRENE	< 0.380	< 0.380	< 0.380	< 0.380	< 0.380	1.090	< 0.380	< 0.380	5.960
	BENZO [B] FLUORANTHENE	< 0.360	< 0.360	< 0.360	< 0.360	< 0.360	0.878	< 0.360	< 0.360	5.300
	BENZO [G,H,I] PERYLENE	< 0.240	< 0.240	< 0.240	< 0.240	< 0.240	< 0.240	< 0.240	< 0.240	1.430
	BENZO [K] FLUORANTHENE	< 0.800	< 0.800	< 0.800	< 0.800	< 0.800	< 0.800	< 0.800	< 0.800	9.620
	BIS(2-ETHYLHEXYL)PHTHALATE	< 0.390	< 0.390	< 0.390	< 0.390	< 0.390	< 0.390	< 0.390	< 0.390	2.000
	CHRYSENE	< 0.450	< 0.450	< 0.450	< 0.450	< 0.450	1.140	< 0.450	< 0.450	7.510
	FLUORANTHENE	< 0.520	3.970	< 0.520	< 0.520	< 0.520	2.050	< 0.520	< 0.520	14.700
	INDENO[1,2,3-C,D]PYRENE	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	< 0.210	1.640
	PHENANTHRENE	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	< 0.410	5.880
	PYRENE	< 0.420	< 0.420	< 0.420	< 0.420	< 0.420	2.180	< 0.420	1.170	15.300
TAL_METAL	ALUMINUM	6900.000	12000.000	5500.000	4800.000	3800.000	17000.000	5100.000	7600.000	17000.000
	ARSENIC	69.000	160.000	20.000	32.000	6.500	43.000	35.000	34.000	52.000
	BARIUM	25.700	67.400	19.300	22.400	13.800	52.300	25.400	22.700	58.600
	BERYLLIUM	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	0.408	< 0.078	< 0.078	< 0.078
	CALCIUM	< 1300.000	13000.000	< 1300.000	5400.000	1400.000	< 1300.000	3600.000	< 1300.000	7500.000
	CHROMIUM	20.100	< 3.900	10.100	< 3.900	7.240	38.300	< 3.900	< 3.900	50.700
	COPPER	9.160	20.400	< 1.950	6.670	< 1.950	19.600	< 1.950	6.070	34.900
	IRON	14000.000	45000.000	8500.000	12000.000	3800.000	20000.000	9800.000	12000.000	31000.000
	LEAD	50.400	174.000	14.200	32.000	11.400	78.700	57.300	47.200	345.000
	MAGNESIUM	2700.000	3100.000	2100.000	1800.000	1400.000	5100.000	923.000	1400.000	7000.000
	MANGANESE	440.000	3000.000	500.000	750.000	130.000	500.000	370.000	370.000	450.000
	MERCURY	0.112	0.225	< 0.026	< 0.026	< 0.026	0.138	0.154	0.117	0.724
	NICKEL	12.500	< 2.460	< 2.460	< 2.460	< 2.460	13.400	< 2.460	< 2.460	26.300
	POTASSIUM	565.000	993.000	348.000	389.000	308.000	2100.000	430.000	294.000	3000.000
	SODIUM	< 52.000	< 52.000	119.000	< 52.000	76.800	217.000	< 52.000	< 52.000	403.000
	VANADIUM	18.800	36.900	7.540	10.200	5.570	24.900	13.900	12.200	41.100
	ZINC	< 80.000	690.000	32.700	< 80.000	14.600	< 80.000	78.300	55.600	< 80.000
TCL_PEST	P,P'-DDD	0.297	0.625	0.034	0.102	0.083	0.723	< 0.101	0.596	1.290
	P,P'-DDE	0.080	0.202	0.017	0.042	0.047	0.138	< 0.040	0.149	< 0.040
	ENDRIN	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	0.165	< 0.075	< 0.075	< 0.075
TCL_VOA	ACETONE	0.047	0.167	0.062	0.048	0.016	0.036	0.047	0.028	< 0.010
	METHYLENE CHLORIDE	0.024	0.061	0.012	0.017	0.010	0.026	0.024	0.019	0.047
	METHYLETHYL KETONE	< 0.010	< 0.010	0.025	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
TOC	TOTAL ORGANIC CARBON	52300.000	170000.000	13600.000	24600.000	10300.000	57600.000	51300.000	51900.000	101000.000
TPHC	TOTAL PETROLEUM HYDROCARBONS	291.000	< 74.400	< 74.600	< 74.500	< 74.500	213.000	< 74.200	< 74.400	2100.000

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-14 (Cont.)

INSTALLATION RESTORATION PROGRAM
CHEMICAL SUMMARY REPORT FOR COLD SPRING BROOK
SEDIMENTS (AUGUST 1991) - FILE TYPE: CSE
AOC: 40 SITE TYPE: POND UNITS: UGG

		SITE	
Test	**Parameter**		**SE-CSB-10**
TCL_BNA	ACENAPHTHYLENE	<	0.460
	ANTHRACENE	<	0.540
	BENZO [A] ANTHRACENE		0.385
	BENZO [A] PYRENE		0.469
	BENZO [B] FLUORANTHENE		0.377
	BENZO [G,H,I] PERYLENE	<	0.240
	BENZO [K] FLUORANTHENE	<	0.800
	BIS(2-ETHYLHEXYL)PHTHALATE		0.381
	CHRYSENE		0.539
	FLUORANTHENE		1.170
	INDENO[1,2,3-C,D]PYRENE	<	0.210
	PHENANTHRENE		0.432
	PYRENE		1.030
TAL_METAL	ALUMINUM		6200.000
	ARSENIC		13.000
	BARIUM		12.100
	BERYLLIUM	<	0.078
	CALCIUM		1100.000
	CHROMIUM		14.700
	COPPER		6.090
	IRON		6600.000
	LEAD		53.100
	MAGNESIUM		2700.000
	MANGANESE		110.000
	MERCURY		0.040
	NICKEL		4.510
	POTASSIUM		770.000
	SODIUM		74.400
	VANADIUM		10.000
	ZINC		34.600
TCL_PEST	P,P'-DDD	<	0.101
	P,P'-DDE	<	0.040
	ENDRIN	<	0.075
TCL_VOA	ACETONE	<	0.010
	METHYLENE CHLORIDE		0.009
	METHYLETHYL KETONE	<	0.010
TOC	TOTAL ORGANIC CARBON		7510.000
TPHC	TOTAL PETROLEUM HYDROCARBONS		601.000

RC424

Source: USATHAMA IRDMIS Level 3/E & E, 1992

Table 5-15

SEDIMENT CRITERIA FOR METALS (µg/g)

Parameter	EPA Region V Guidelines	NYSDEC* Criteria	Great Lakes Background	Cold Spring Brook Median	Median of Criteria
Aluminum	N/A	N/A	N/A	6,550	—
Arsenic	3-8	5	12	34.5**	9
Barium	20-60	N/A	N/A	25.5	33
Cadmium	<6	0.8	2.5	ND	1.7
Chromium	25-75	26	75	8.67	38
Copper	25-50	19	65	6.38	28
Iron	17,000-25,000	24,000	59,000	13,000	22,500
Lead	40-60	27	55	57.75**	50
Mercury	<1	0.11	0.6	0.115	0.36
Manganese	300-500	428	1,200	445**	434
Nickel	20-50	22	75	<2.46	28.5
Zinc	90-200	85	145	<80	115

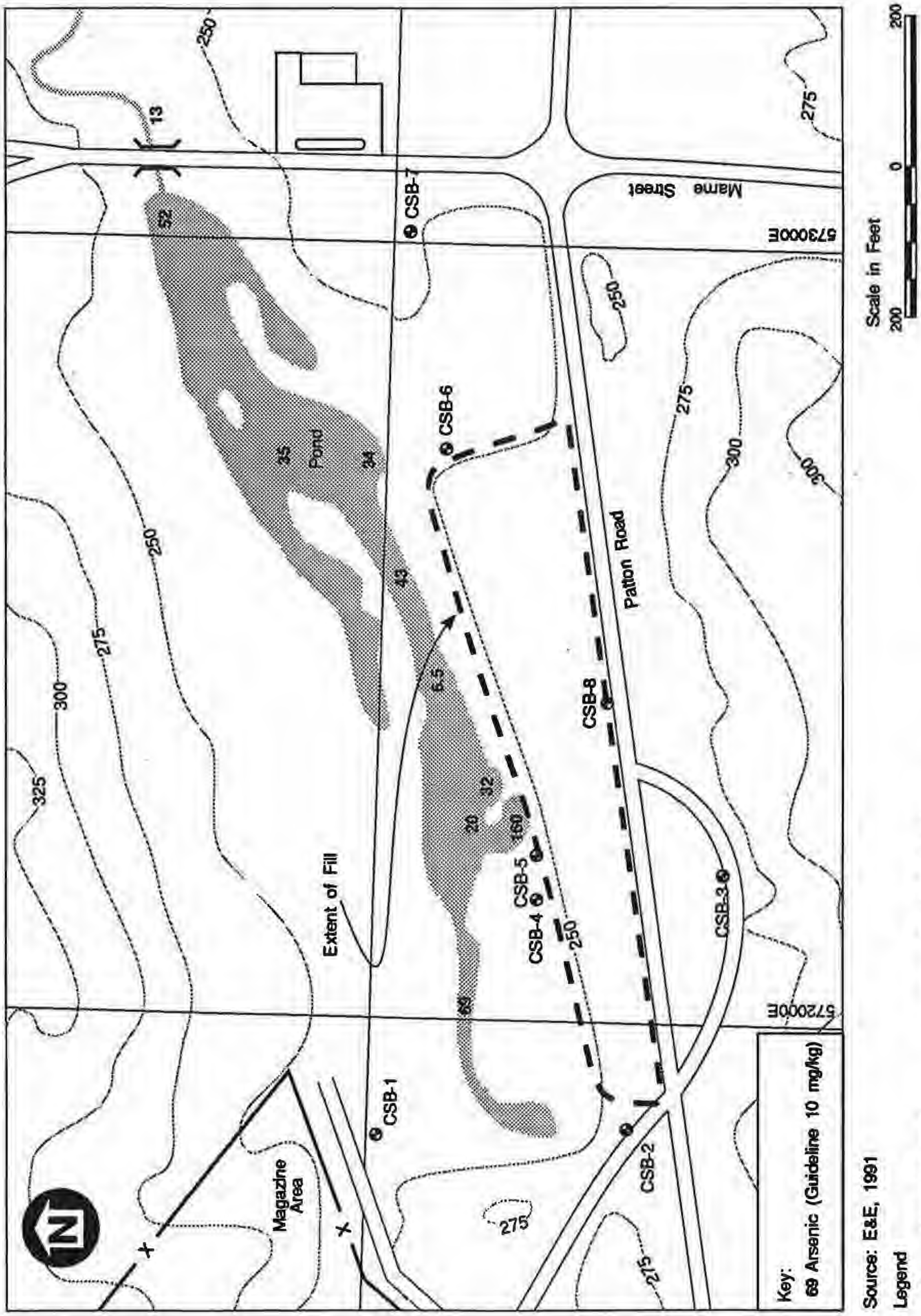
RC424

NOTES:

The median value is calculated from EPA Region V guidelines, NYSDEC criteria, Great Lakes background, and Cold Spring Brook background.

N/A = Not Available
ND = Not Detected

* New York State Department of Environmental Conservation
**Exceeds median of criteria
Source: E & E, 1992



1AR/Fig.5-14.CDR

Figure 5-14 DISTRIBUTION OF ARSENIC IN SEDIMENT AT COLD SPRING BROOK

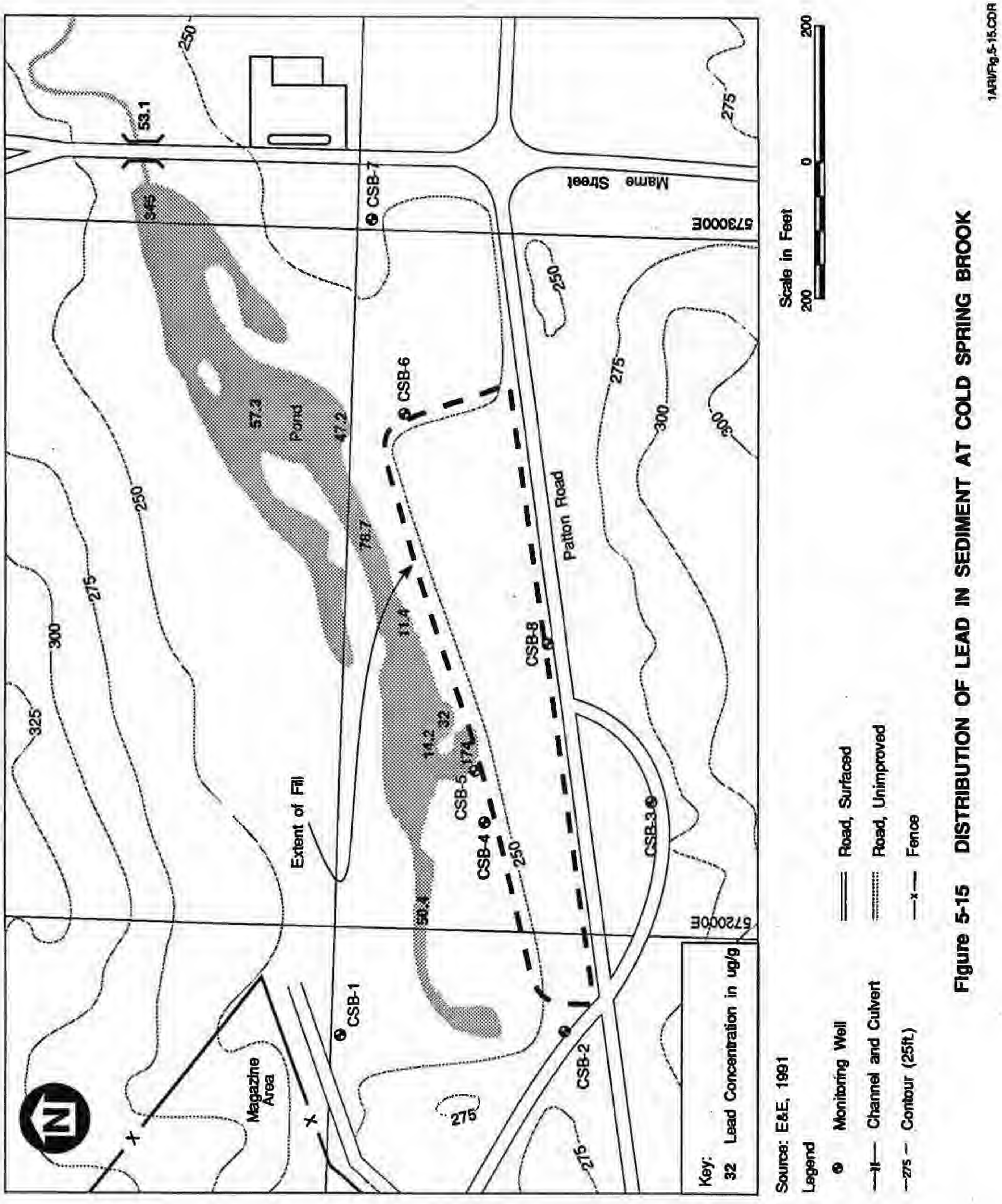


Figure 5-15 DISTRIBUTION OF LEAD IN SEDIMENT AT COLD SPRING BROOK

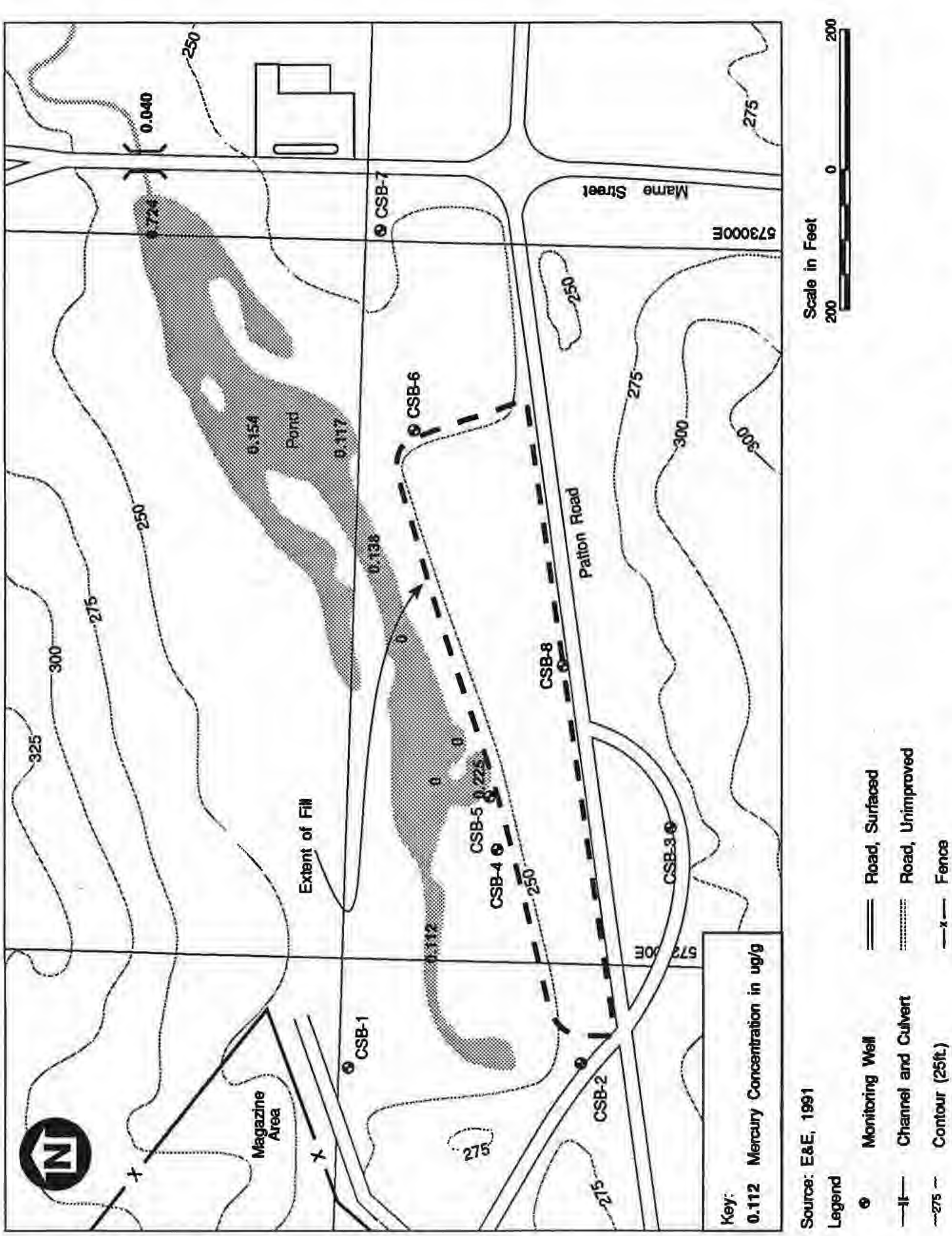


Figure 5-16 DISTRIBUTION OF MERCURY IN SEDIMENT AT COLD SPRING BROOK

1ARI/Fig.5-16.CDR

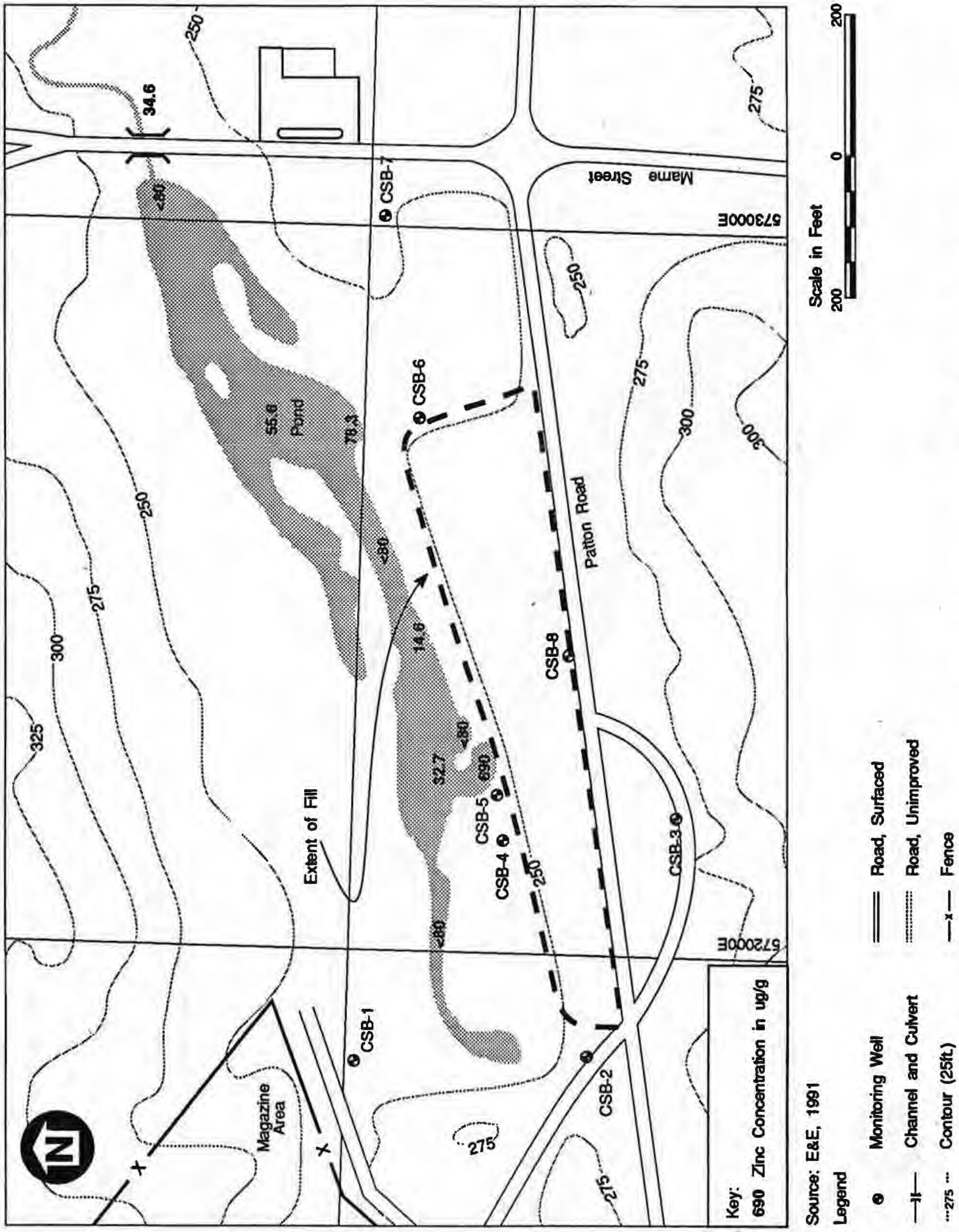


Figure 5-17 DISTRIBUTION OF ZINC IN SEDIMENT AT COLD SPRING BROOK

1ARI/Fig.5-17.CDF

10). The higher levels of PAHs (SE-CSB-06, 09, and 10) are associated with elevated petroleum hydrocarbons, which may indicate a similar origin for both.

5.2.5 Air Quality

One sample of volatiles and one of particulates were gathered from a location on top of the fill at Cold Spring Brook Landfill. Neither one showed any indicated that the ambient air quality above the landfill was different from background as measured at Shepley's Hill Landfill, 6,000 feet further north.

The full text of the Air Monitoring Report is included as Appendix G of this report.

5.2.6 Quality Assurance/Quality Control Results

Sample and analytical requirements for Cold Spring Brook Landfill are summarized on Table 5-16. Three surface soil samples were analyzed for TCL VOCs, BNAs, and Pest/PCBs; TAL metals; and TOC. Two rounds of groundwater samples at seven wells were analyzed for TCL VOCs, BNAs, and Pest/PCBs; TAL metals; explosives; TPHC; and common anions. Because insufficient water volume was available in CSB-4, only TCL VOCs were analyzed in the first round and TCL VOCs and BNAs were analyzed in the second round. The second round samples for all other CSB wells were also analyzed for alkalinity and TKN. Ten surface water and sediment samples were analyzed for TCL VOCs, BNAs, and pest/PCBs, TAL metals, explosives, and TPHC. Surface water samples were also analyzed for water quality parameters (see Appendix I) and sediment samples were also analyzed for TOC. Two air samples for particulate and volatile organics were taken for support of the risk assessment (see Appendix G). Analytical results for target compounds detected in the samples are summarized on Tables 5-10 to 5-14. A complete set of analytical data is provided on computer diskette in Appendix C.

QC samples were collected in the field to assess overall precision, accuracy, and representativeness of the sampling and analytical efforts. A total of three rinsate samples were collected, one during leachate soil sampling on 21 August 1991, one during groundwater sampling on 22 August 1991, and one during sediment sampling on 23 August 1991 (see Table D-1). A total of seven trip blanks were shipped with groundwater or surface water samples on 20, 21, 22, and 23 August 1991 and 7, 9, and 10 December 1991 (see Table D-2). Laboratory method blank results are also presented in Table D-3. Field duplicates were collected for leachate soil at SL-CSB-2 (see Table D-10), for the first round groundwater at CSB-4 (see Table D-11), and for the second round groundwater at CSB-1 and CSB-7 (see Tables D-12 and D-13). Field duplicates were collected with the surface water and sediments at locations SW-CSB-6 and SE-CSB-6 (see Tables D-14 and D-15).

MS/MSD samples for organics or MS/duplicate samples for inorganics were collected at several locations to evaluate potential matrix effects

Table 5-16

SUMMARY OF RI ANALYTICAL REQUIREMENTS
COLD SPRING BROOK LANDFILL

Site Name	Analysis	Number of Samples Round One	Number of Samples Round Two
Cold Spring	TCL (8 groundwater wells)	8	8
Brook Landfill	TCL (surface water)	10	0
AOC 40	TCL (pond sediment)	10	0
	TCL (surface soil)	3	0
	TAL (8 groundwater wells)*	7	7
	TAL (surface water)	10	0
	TAL (pond sediment)	10	0
	TAL (surface soil)	3	0
	Explosives (8 groundwater)*	7	7
	Explosives (surface water)	10	0
	Explosives (pond sediment)	10	0
	TOC (surface soil)	3	0
	Air Quality Particulates	2	0
	Air Quality Organics	2	0
	TOC (pond sediment)	10	0
	Ions (8 groundwater wells)[a]*	7	7
	TPHC (8 groundwater wells)	7	7
	TPHC (surface water)	10	0
	TPHC (pond sediment)	10	0
	Water Quality (surface water)[b]	10	0

RC424

TAL: Target Analyte List
TCL: Target Compound List
TOC: Total Organic Carbon
TPHC: Total Petroleum Hydrocarbons

* Only limited volume could be obtained from well CSB-4

a Ions: chloride, fluoride, sulfate, nitrate, nitrite, bromide, and total kjeldahl nitrogen (Cations: calcium, potassium, and magnesium are included in TAL)

b Water quality parameters include chloride, total kjeldahl nitrogen, nitrate-nitrogen, sulfates, total phosphorous, hardness, alkalinity, and total suspended solids

Source: E & E, 1992

on the quality of the analytical data. For surface water and sediment samples SW/SE-CSB-6, MS/MSD analyses were completed for TCL, VOCs, Pest/PCBs, and explosives; and a MS/duplicate analysis was completed for TAL metals. A MS/MSD was also performed for water quality and general analytical parameters on samples from that location. For the second round of groundwater sampling at CSB-2, a MS/MSD analysis was completed for TCL BNA, Pest/PCB, and explosives, and a MS/duplicate analysis was completed for TAL Metals.

The MS/MSD results for Shepley's Hill Landfill and Cold Spring Brook Landfill are presented in Tables D-16 through D-40. All results are acceptable with the exception of a few values outside EPA CLP limits indicated on the table. No effect on data usability was determined.

All field and analytical activities were conducted in accordance with the QAPjP, E & E, 1991. The original sampling and analytical requirements are summarized on Table 2-6. The actual field samples collected are summarized on Table 5-16 and the actual field QC samples taken are summarized on Table D-42.

One of the wells, CSB-4, had such a limited yield that a full suite of samples for analysis could not be obtained, and TAL metals analyses, ions, and explosives were not run for this well.

All required QC samples were collected with the exception of additional duplicate samples collected for groundwater. In addition, tripblanks were not taken with the soil samples. As shown on Table 2-6, the soil trip blanks were not originally required. The requirement as indicated in the QAPjP was added based on comments received after the completion of the field work. Overall, the rinsate and trip blanks indicated acceptable field decontamination practices. All compounds detected in the field blanks resulted from laboratory background contamination.

All field and laboratory QC blank results were compared to the sample results and any compounds that are attributable to potential background contamination are identified below. Field duplicate results that indicate potential sample inhomogeneity and hence, estimated analytical results, are also discussed. In addition, all analytical lots were evaluated for laboratory QC parameters and their potential effects on data usability. Specific issues affecting data usability are detailed in the following paragraphs. Analytical results with no laboratory QC issues reported in the analytical case narrative or USATHAMA acceptance letter were considered usable for all purposes.

5.2.6.1 Volatiles

All samples were analyzed within holding times according to USATHAMA certified methods. Methylene chloride and acetone in the samples (including the field duplicates) are attributable to laboratory background contamination. Chloromethane was detected in the trip blanks in the first round, but was not found in the samples.

5.2.6.2 Base Neutral/Acid Extractables (BNAs)

All samples were analyzed within holding times according to USATHAMA certified methods except groundwater samples CSB-2 and CSB-4, which were extracted within holding times but analyzed outside of holding times. Detection limits for these samples should be considered estimated. Low surrogate recoveries were also reported for groundwater from CSB-2. One surrogate was reported low for CSB-8, but data are not affected. One surrogate was also low for the sediments samples, but data are not affected.

No BNA compounds were detected in the rinsate blanks. Bis-2-ethylhexyl phthalate was reported in one water method blank and benzoic acid was reported in most soil blanks; however these compounds were not detected in associated samples.

Several PAH compounds were detected in field duplicate pairs for surface soils at SL-CSB-2 and for sediments at SE-CSB-6 (see Tables D-10 and D-15). All results indicate excellent precision and accuracy with RPDs ranging from 9 to 38 percent for SL-CSB-2 and 21 to 30 percent for SE-CSB-6.

5.2.6.3 Pesticide/PCBs

All samples were analyzed within holding times according to USATHAMA methods except for second round groundwater sample CSB-2, which was re-extracted and re-analyzed beyond holding times. Detection limits for that sample should be considered estimated. Low recoveries of PCBs were also noted for samples SW-CSB-01 to SW-CSB-05, and detection limits for the PCBs for those samples should be considered estimated.

No pesticides were detected in the rinsate samples, but several pesticides including heptachlor, endrin, alpha- and beta-BHC, p,p'-DDT and endosulfan sulfate were detected as unconfirmed hits in several method blank samples. Low levels of these compounds reported in the samples should be considered due to laboratory background. Low level hits of several pesticides were detected in the sample on the first column analyses, but were not confirmed on a second column. These values are reported and flagged, but should be considered suspect. No confirmed pesticides were found in the field duplicate pair SW-CSB-6, but the unconfirmed hit shows 0 percent RPD. For field duplicate SE-CSB-6, the RPD for p,p'-DDD was less than 1 percent. Endrin and p,p'-DDE were detected in the sample but not the duplicate.

5.2.6.4 Explosives

All analytical results were acceptable. No explosives were detected in the blanks or most field duplicates. Field duplicate results for CSB-1 groundwater indicate excellent precision and accuracy for explosives with RPDs ranging from 2.2 to 5.4 percent.

5.2.6.5 Metals

All samples were analyzed within holding times on the first analysis. Several mercury samples had to be reanalyzed at a higher dilution because the initial results exceeded quantitation limits. These were sediment samples SE-CSB-06 to SE-CSB-09 and SW-CSB-06 to SW-CSB-09. Because holding times were exceeded for the second analysis, the analytical results for mercury for these samples should be considered estimated and may be on the low side. Most of these samples exceed levels of concern, despite the need for the repeat analysis, so this factor does not affect the conclusions drawn on the basis of the mapped distribution.

Several metals, including barium, calcium, zinc, copper, and iron were detected in the rinsate blank samples. Several metals, including aluminum, iron, copper, vanadium, and barium were also detected in the laboratory method blanks. Low levels of these metals in the samples should be considered suspect due to potential field or laboratory background contamination.

Field duplicate results indicate excellent precision for most metals for all leachate soil, groundwater, and surface water samples. RPDs ranged from 0 to 21 percent for SL-CSB-2; from 0 to 39 percent for CSB-1; from 6 to 17 percent for CSB-7; and from 1.5 to 9.7 percent for SW-CSB-6. For sediments, RPDs were high for sample SE-CSB-6 but very consistent ranging from 26 to 79 percent for all compounds. The results indicate the variability is due to different amounts of percent moisture determined for the original and duplicate. For SE-CSB-6, the percent moisture was slightly lower in the original sample indicating a potential sampling bias for the sediment samples. Results uncorrected for percent moisture as well as the laboratory duplicates agree very well, indicating no inherent matrix effects. Sampling bias could be low or high, depending on the percent moisture determination.

5.2.6.6 General Analytical Parameters

All other analyses were completed within holding times under USATHAMA methods with acceptable QC parameters. Nitrate was detected in several rinsate samples but not in any laboratory method blanks. Low levels of nitrate in the samples should be considered estimated. Field duplicate results indicate acceptable precision and accuracy for all parameters.

Table S-32

SUMMARY OF ESTIMATED EXCESS CANCER RISKS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions by Chemical[a]
Fishing/fish ingestion	Average	2.1E-04	—	2.4E-04	Fish ingestion - >99% Water ingestion - <1%	Arsenic >99%
Sediment contact	Average	—	3.0E-05	—	Sediment ingestion - >99%	Arsenic - 100%

RC424

[a]For receptor showing greatest risk.

Table S-33

SUMMARY OF ESTIMATED EXCESS CANCER RISKS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions by Chemical[a]
Residential groundwater usage	**Original data** Average	2.8E-03	—	1.6E-03	Water ingestion - 98% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Arsenic - 98% Other chemicals[b] - <1%
	Adjusted data Average	1.8E-03	—	1.1E-03	Water ingestion - 98% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 1%	Arsenic - 99% Other chemicals[b] - <1%
Fishing/fish ingestion	Average	2.1E-04	—	2.4E-04	Fish ingestion - <99% Water ingestion - <1%	Arsenic - >99%
Sediment contact	Average	—	1.2E-04	—	Sediment ingestion - >99%	Arsenic - 100%
Total receptor risks	**Original GW data** Average	3.0E-03	1.2E-04	1.8E-03		
	Adjusted GW data Average	2.0E-03	1.2E-04	1.3E-03		

RC424

[a]For receptor showing greatest risk.
[b]Other chemicals responsible for risks greater than 10^{-6} but less than 1% of the total are beryllium, 1,2-dichloroethane, PCB 1260, 1,1,2,2-tetrachloroethane, and vinyl chloride.

Table S-34

SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor			Risk Contributions Route[a]	Hazard Index By Chemical[a]
		Adult	Adolescent	Child[b]		
Fishing/fish ingestion	Average	1.2	—	8.0	Fish ingestion - >99% Water ingestion - <1%	Arsenic - 6.4 Cadmium - 1.7
Sediment contact	Average	—	0.41	--	Sediment ingestion - >99%	

RC424

[a]For receptor showing greatest risk.
[b]Child risks are assessed using subchronic RfDs

Table S-35

SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL – ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child[b]	Risk Contributions by Exposure Route[a]	Hazard Index by Chemical[a]
Residential groundwater usage	**Original data**					
	Average	12	—	46	Water ingestion – 98% Fruits and vegetables – 1% Dermal contact – <1% Inhalation – <1%	Arsenic – 42 Manganese – 2.3 Cadmium – 1.5
	Adjusted data					
	Average	9.0	—	31	Water ingestion – 98% Fruits and vegetables – 1% Dermal contact – <1% Inhalation – <1%	Arsenic – 28 Cadmium – 1.5 Manganese – 1.7
Fishing/fish ingestion	Average	1.2	—	8.0	Fish ingestion – >99% Water ingestion – <1%	Arsenic – 6.4 Cadmium – 1.7
Sediment contact	Average	—	1.6	—	Sediment ingestion – >99%	Arsenic – 1.5
Total receptor risks	**Original GW data**					
	Average	13	1.6	54		
	Adjusted GW data					
	Average	10	1.6	39		

RC424

[a] For receptor showing greatest risk.
[b] Child risks are assessed using subchronic RfDs.

Table S-36

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH CONTAMINATION IN PLOW SHOP POND FROM SOURCES OTHER THAN SHEPLEY'S HILL LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Fishing/fish ingestion	Average	4.3E-06	—	5.0E-06	Fish ingestion - >99% Water ingestion - <1%	Heptachlor - 79% DDE - 21%
Sediment contact	Average	—	1.8E-07	—	Sediment ingestion - >99%	Beryllium - 53% PAHs[b] - 47%
Non-Cancer Hazard Indices[c]						
Fishing/fish ingestion	Average	1.5	—	10	Fish ingestion - >99% Water ingestion - <1%	Mercury - 10
Sediment contact	Average	—	0.023	—	Sediment ingestion - >99%	

RC424

[a]For receptor showing greatest risk.
[b]Carcinogenic PAHs detected in Plow Shop Pond include benzo(a)anthracene and chrysene.
[c]Child risks are assessed using subchronic RfDs.

Table S-37

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH CONTAMINATION IN PLOW SHOW POND FROM SOURCES OTHER THAN SHEPLEY'S HILL LANDFILL - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Fishing/fish ingestion	Average	4.3E-06	—	5.0E-06	Fish ingestion - >99% Water ingestion - <1%	Heptachlor - 79% DDE - 21%
Sediment contact	Average	—	6.8E-07	—	Sediment ingestion - >99%	Beryllium - 53% PAHs[b] - 47%
Non-Cancer Hazard Indices[c]						
Fishing/fish ingestion	Average	1.5	—	10	Fish ingestion - >99% Water ingestion - <1%	Mercury - 10
Sediment contact	Average	—	0.088	—	Sediment ingestion - >99%	

RC424

[a] For receptor showing greatest risk.
[b] Carcinogenic PAHs detected in Plow Shop Pond include benzo(a)anthracene and chrysene.
[c] Child risks are assessed using subchronic RfDs.

Table S-38

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH GROUNDWATER AT SHL-15 – ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Residential groundwater usage	**Original data** Average	7.5E-03	—	4.4E-03	Ingestion - >99% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Arsenic - 99% Beryllium - 1%
	Adjusted data Average	5.9E-03	—	3.5E-03	Ingestion - >99% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Arsenic - 99% Beryllium - 1%
Non-Cancer Hazard Indices[b]						
Residential groundwater usage	**Original data** Average	35	—	124	Ingestion - 98% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 1%	Arsenic - 115 Manganese - 4.9 Cadmium - 4.5
	Adjusted data Average	29	—	100	Ingestion - 98% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 1%	Arsenic - 92 Cadmium - 4.5 Manganese - 3.9

RC424

[a]For receptor showing greatest risk.
[b]Child risks are assessed using subchronic RfDs.

Table S-39

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH GROUNDWATER AT SHL-7, -8S, -8D, AND -13 - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Residential groundwater usage	**Original data** Average	4.7E-04	—	2.7E-04	Ingestion - >99% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Arsenic - 97% Beryllium - 3%
	Adjusted data Average	4.2E-05	—	2.5E-05	Ingestion - >99% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Arsenic - 79% Beryllium - 21%
Non-Cancer Hazard Indices[b]						
Residential groundwater usage	**Original data** Average	2.6	—	9.2	Ingestion - 98% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 2%	Arsenic - 7.1 Manganese - 1.7
	Adjusted data Average	0.61	—	2.1	Ingestion - 97% Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 2%	Manganese - 1.5 Arsenic - 0.5

RC424

[a]For receptor showing greatest risk.
[b]Child risks are assessed using subchronic RfDs.

6. CONTAMINANT FATE AND TRANSPORT

6.1 SHEPLEY'S HILL LANDFILL

In general terms, all contaminants are capable of moving, to some extent, through all media. The rate at which any individual compound, element, or ion moves within a medium and across media boundaries is a function of the physical, chemical, and biological properties of the media and the contaminant molecule. The smaller, faster-moving, less readily-sorbed, less readily-complexed, and more soluble contaminants tend to have greater fugacity. If contaminants are persistent across media boundaries as well, they rapidly become widespread. Bioconcentrated stable molecules or elements that move through the food chain may also be mobile from one medium to another via the biomass.

Results of migration of contaminants may be observed by repeated sampling, or predicted by extrapolation from general knowledge of contaminant and media properties, and observation of comparable sites.

Prediction of contaminant fate and transport at a particular site is a function of the conceptual model of the site modified by interpretation of the available site-specific contaminant pattern of movement from previous studies.

6.1.1 Fate and Transport of Contaminants In Soils

The soils on Shepley's Hill Landfill showed no evidence of representing a significant chemical hazard (see Section 5.1.1). There is visual evidence that erosion of soils from the ditches around the landfill is transporting soils off the landfill cover and from around the edges of the landfill into Plow Shop Pond and into the wetland north of the landfill. This erosion has created a small sand delta that protrudes approximately 20 feet into Plow Shop Pond at the southeast corner where the main drainage from the south side of the landfill enters the pond and appears to consist of only a few cubic yards of sand. Some sand is being eroded off the north end of the landfill and being carried under the installation boundary fence into the adjoining wetland. The landfill is now closed and capped and being revegetated so that erosion should be reduced.

There was no significant difference between the analyses of particulate samples collected during the air quality survey on and downwind of Shepley's Hill Landfill and those at upwind locations. Transportation of contaminated soils by wind erosion does not appear to be a significant concern.

6.1.2 Fate and Transport of Contaminants In Groundwater

The contaminants apparently originating within the landfill include arsenic, calcium, copper, iron, magnesium, manganese, nickel, sodium, and vanadium. Anions noted as originating within the fill include bromide, chloride, and sulfate.

Organics found in the monitoring wells that apparently originate within the fill include seven contaminants that were detected only once: vinyl chloride; chlorobenzene; 1,1,2,2-tetrachloroethane; trichloroethylene; 1,2-dichloroethane; Tetryl (an explosive); and PCB 1260. Compounds appearing more than once included 1,3-dinitrobenzene (4 times); benzene (3 times); chloroethane (twice); 1,1-dichloroethane (four times); diethylphthalate (twice); alpha-BHC (three times); alpha Chlordane (four times); Heptachlor (five times); chloroform (twice); and 1,3,5-trinitrobenzene (twice).

Downgradient wells obviously impacted by the landfill, at least during one sampling episode, include three wells at the north end of the landfill (SHL-5, SHL-9, and SHL-22), and four wells between the center of the landfill and Plow Shop Pond (SHL-4, SHL-11, SHL-19, and SHL-20). Because of the direction of groundwater flow, contaminants in the first group of wells at the north end of the site will discharge to the wetland north of the landfill and so enter Nonacoicus Creek, or will discharge directly to the creek. Because soils in the wetland are quite high in organic matter, as was shown in Section 1.6.1, both organics compounds and metals may accumulate in the soil before being desorbed and released to the brook. Based on organic compounds and metals noted in groundwater from wells adjoining the wetland, these might include pesticides like alpha-BHC, alpha-chlordane, and Heptachlor, and metals such as iron, manganese, arsenic, copper, and vanadium. However, the pesticides may be an artifact attributable to background contamination. The one sample taken from the wetland was relatively low in organic carbon (2.2 percent), showed only slightly elevated arsenic and barium when compared to background levels in Fort Devens soils, and showed no organics at all. This indicates that no contaminants have yet impacted the sediment within the wetland.

As noted in Section 5.1.3, there is some indication of groundwater discharges having a direct impact on water quality in Plow Shop Pond, with copper, nickel, and zinc all showing a band of elevated levels in pond water parallel to the shoreline adjacent to the landfill.

A clear pattern also exists of high concentrations of arsenic, iron, and manganese in sediments, as well as apparently a pattern of cadmium in sediments in Plow Shop Pond, adjacent to the landfill (see Section 5.1.4). This is interpreted to indicate accumulation of metals in organic-rich sediments (2.95 percent to 23.1 percent) because of contaminated groundwater entering the pond from below.

It is possible that some contaminants could enter the bedrock. If so, they will be in much less volume and move at a much lower rate than leachate in the landfill. This is because:

- o the overburden sands have a high hydraulic conductivity (see Appendix A and B);

- o the bedrock is generally hard and tight with few fractures;
- o lower hydraulic conductivity sediments appear to overlie bedrock in several locations around the landfill, i.e., SHL-24, SHL-22, and SHL-15 (see Appendix A); and
- o vertical gradients within the overburden are slight, and may be upwards or downwards, or both, within the same sand layer (Section 1.6.2).

The combined effect of the location of the source, which lies close to the land surface and therefore is contaminating the aquifer from the top; the contrasting hydraulic conductivities of the overburden and bedrock; and the lower vertical gradients make it extremely improbable that contaminants flowing through the bedrock represent a significant proportion of discharges from the landfill. Additionally, consideration must be given to the effects on the rates of flow and contaminant retardation of fine-grained sediments such as till and silts, which have been noted as resting on top of bedrock in several locations adjacent to the landfill.

No evidence has been found to suggest significant density differences in leachate, or the presence of DNAPLs, which would provide an alternative mechanism for driving contaminants into bedrock.

All contaminants in the groundwater discharging from the landfill will either volatilize into the vadose zone or the atmosphere, sorb onto soil or sediment, biodegrade, or undergo physical/chemical transformation, enter the biosphere, or discharge to Plow Shop Pond or Nonacoicus Brook.

6.1.3 Fate and Transport of Contaminants in Surface Water

All surface run-off from Shepley's Hill Landfill runs into Plow Shop Pond or the wetland north of the landfill. Both of these wetlands drain into Nonacoicus Creek, which discharges to the Nashua River approximately 4,000 feet northwest of the northern end of the landfill.

The pond and the Nonacoicus Creek are slow flowing and provide little aeration. The overflow of the pond is over a two-stage dam which drops approximately 3 feet in elevation. This drop does allow for some aeration and potential loss of volatiles. Adsorption and desorption from organic-rich sediments will retard contaminant migration and allow for biodegradation or uptake of persistent contaminants into the food chain.

Judging from the distinct zoning of contamination in sediments in Plow Shop Pond, as well as the marked variation in surface water quality across the pond, mixing of surface water within the pond is slow, and so is desorption from the sediments.

The degrees of bioconcentration of contaminants into organisms within the pond and the brook has not been investigated as part of the RI.

6.1.4 Fate and Transport of Contaminants in Sediment

At the present time, Plow Shop Pond appears to act as a sediment trap that effectively prevents or strongly reduces sediment movement. This is strikingly evident from the fact that patterns of contaminant concentrations in the sediment of Plow Shop Pond most probably caused by the discharges of a tannery that burned down in 1961 are still distinctly preserved. This implies that the interpretation of the distribution of cadmium, for example, as coming from the landfill, is not invalidated because there is no present indication of unusual levels of cadmium in downgradient wells at the landfill.

The absence of elevated concentrations of metals in the sediment sample from the wetland north of the landfill may imply that elevated levels of metals in the groundwater have been filtered and sorbed out by the swampy, organic-rich soils at lower levels before they reach surface water. Alternatively, the low metals content of SE-SHL-14 is caused by its relatively low organic carbon content of 2.2 percent. It would seem improbable that the low organic carbon content of SE-SHL-14 is the cause of its low metals contents because organic carbon content in the other sediment samples does not correlate with metals concentrations. For example, SE-SHL-08, with a low TOC value of only 2.95 percent shows markedly higher levels of heavy metals than SE-SHL-14.

6.1.5 Fate and Transport of Contaminants in Air

Methane vents have been installed through the cap of Shepley's Hill Landfill and are emitting methane. However, the air quality survey does not show any other volatiles present in the atmosphere above the landfill that are not present in similar concentrations in background areas.

6.2 COLD SPRING BROOK LANDFILL

6.2.1 Fate and Transport of Contaminants in Soil

Surface soils at Cold Spring Brook Landfill are higher in heavy metals than background soils on Fort Devens, and they are also sandy and well- to excessively well-drained. The Cold Spring Brook Landfill surface soils are subject to leaching and erosion, although the latter is minimized by low slopes on top of the landfill, good vegetation cover, and the soils' excellent drainage properties, which enhances infiltration over run-off.

Migration of contaminants from these soils will be primarily by leaching into the groundwater.

The good vegetation cover attracts wildlife, which may result in exposures via ingestion and dermal contact with soils.

The air survey showed no levels of respirable particulate matter above background.

6.2.2 Fate and Transport of Contaminants in Groundwater

By surveying the monitoring wells and the pond elevations, E & E determined that, for the most part, groundwater flows into the Cold Spring Brook Pond. Exceptions occur, however, when the Patton Well is pumping, for it appears to capture flow from the areas of the west end of the landfill near wells CSB-2 and CSB-3. The chemistry of the water captured by the Patton Well is quite distinct from that in the CSB wells and it is evident that the landfill is having no appreciable impact on this well.

If the Patton Well is pumped either at a higher rate or for longer periods, the proportion of water derived from under Cold Spring Brook Landfill will not be affected, since the well will increase its flow from all other directions also, and so dilute the effect of the landfill on the quality of water it captures.

All the remaining monitoring wells monitor groundwater discharge towards and into Cold Spring Brook Pond. Soluble components in the groundwater enter the waters of the pond and discharge to the atmosphere, to Cold Spring Brook, or may be sorbed on sediment or incorporated into the biota. The relatively high concentrations of metals in sediments of the pond suggest that sorption, either after entry into the pond or during entry via the sediments, is capturing the metals that are of most concern at this site.

6.2.3 Fate and Transport of Contaminants in Surface Water

While run-off from the landfill is apparently slight, groundwater from under the fill discharges quickly to Cold Spring Brook Pond. This pond overflows to Cold Spring Brook, although because of the dam at Patton Road, the brook is not perennial and dries up during the summer. Cold Spring Brook joins Bowers Brook approximately one mile downstream, which, in turn, flows into Grove Pond, Plow Shop Pond, Nonacoicus Brook, and the Nashua River.

In Cold Spring Brook Pond, the levels of arsenic, iron, manganese, and sulfate decline from west to east, with the highest levels at the western end adjacent to the landfill. Comparison with the water quality in Cold Spring Brook suggests that it is very similar to the water quality immediately behind the dam and shows little, it any, impact from the landfill.

6.2.4 Fate and Transport of Contaminants in Sediment

Sediment affected by Cold Spring Brook Landfill is effectively captured by Cold Spring Brook Pond.

Contaminants from the landfill (arsenic, lead, manganese, and mercury) are evidently sorbed onto the sediments in proportion to their organic carbon content. The two samples with the highest TOC levels (17 percent at SE-CSB-02 and 10.1 percent in SE-CSB-09) showed the highest metals levels (Figure 6-1). What is noticeable is that while manganese is high (3,000 µg/g) in the sample from immediately adjacent to the landfill (SE-CSB-02), it is only slightly elevated in the sample that was collected adjacent to the dam (450 µg/g). Conversely while mercury and lead are elevated in the sample (SE-CSB-02) taken adjacent to the landfill (0.225 and 174 µg/g, respectively) they are sharply higher (0.724 and 345 µg/g, respectively) in the sample from the east end of the pond (SE-CSB-09), adjacent to the dam.

This strongly suggests that lead and mercury are being mobilized into the pond water and travel down the pond to be sorbed onto sediment at the east end of the pond. Manganese is evidently less mobile than the previous two metals and has not yet begun to concentrate at the east end of the pond. Arsenic falls between lead and manganese in apparent mobility. All metals fall off sharply in the brook sediment, which has only 0.75 percent TOC.

6.2.5 Fate and Transport of Contaminants in Air

There is no evidence of transport of any hazardous substances either as gas or particulates through the air from the landfill.

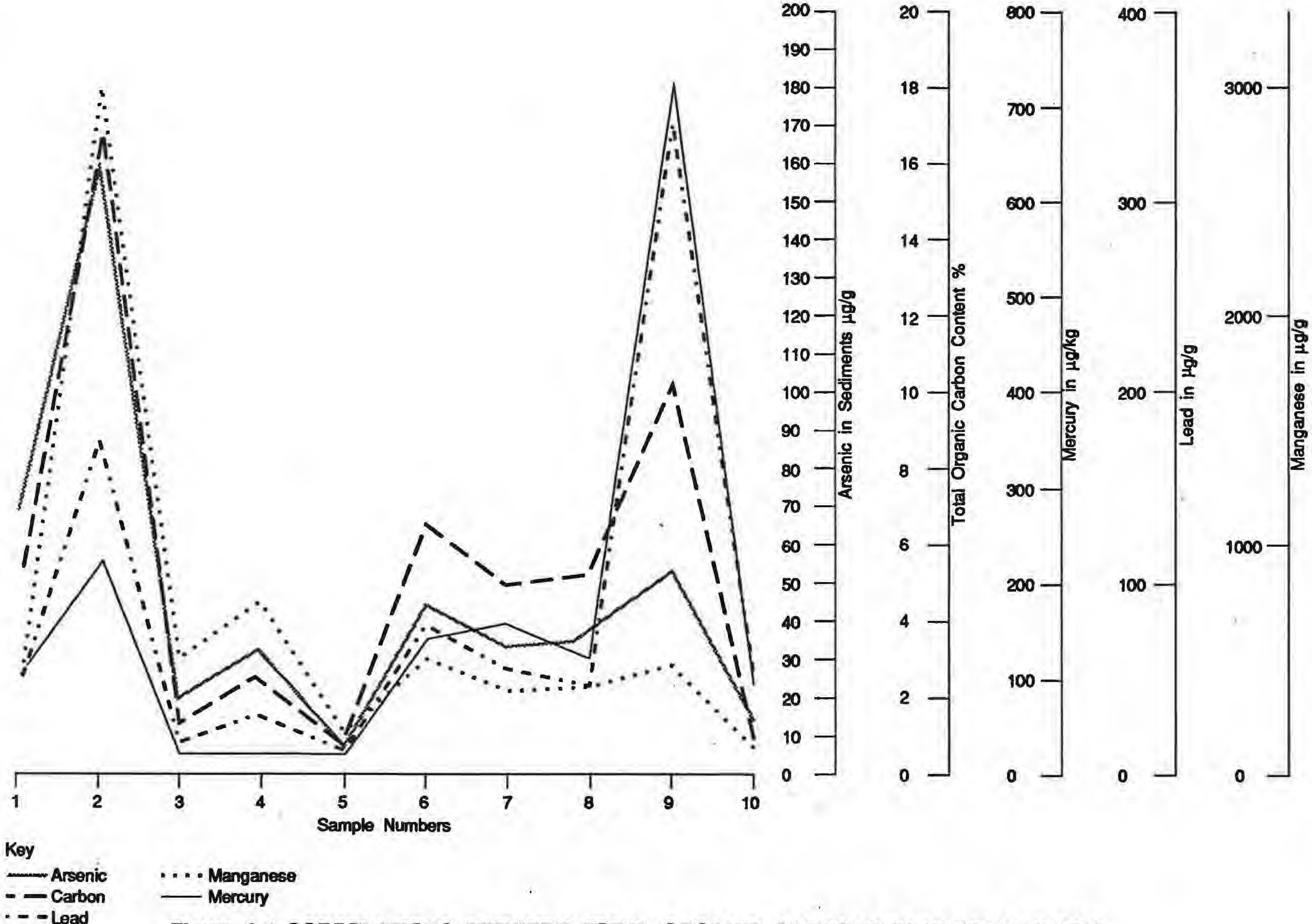


Figure 6-1 CORRELATIONS BETWEEN TOTAL ORGANIC CARBONS IN SEDIMENTS AND HEAVY METALS IN SEDIMENTS IN COLD SPRING BROOK POND

1ARI/Fig.6-1.CDR

7. IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

These studies of Shepley's Hill and Cold Spring Brook Landfills are being conducted as RIs under CERCLA, and therefore it is necessary to identify the Applicable or Relevant and Appropriate Requirements (ARARs) that will apply to these sites.

All RIs must be designed and performed in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan of Section 105 of CERCLA as amended by SARA of 1986, often referred to as the National Contingency Plan (NCP). It directs the investigation for the potential release of oil and hazardous substances, pollutants, and contaminants, and remediation of actual releases.

On-site remedial actions at CERCLA landfill sites comparable to Shepley's Hill and Cold Spring Brook must comply with all ARARs of other environmental statutes. These statutes include those established by EPA and other Federal agencies and those established by the State in which the release occurred, if the State's standards are more stringent than the Federal standards.

Applicable requirements are Federal or State requirements that "specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" (NCP Sec. 300.5). Relevant and appropriate requirements are Federal or State laws that "address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site." (NCP Sec. 300.5)

On-site CERCLA response actions must comply with substantive requirements of other environmental laws but not with administrative requirements. Substantive requirements include cleanup standards or levels of control.

In addition to the legally binding requirements established as ARARs, many Federal and State programs have developed criteria, advisories, guidelines, or proposed standards "to be considered" (TBC). This TBC material may provide useful information or recommend procedures if no ARAR addresses a particular situation, or if existing ARARs do not provide protection. In such situations, TBC criteria or guidelines should be used to set remedial action levels. Their use should be explained and justified in the administrative record for the site.

ARARs are divided into three types:

- o chemical-specific ARARs,
- o location-specific ARARs, and
- o action-specific ARARs.

Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment. If a chemical has more than one such requirement that is ARAR, the most stringent generally should be complied with. There are, at present, only a limited number of chemical-specific requirements.

A site's location is a fundamental determinant of its impact on human health and the environment. Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities based solely on the specific location involved. Some examples of special locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats. An example of a location-specific requirement is the substantive CWA §404 prohibitions of the unrestricted discharge of dredged or fill material into wetlands.

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Because there are usually several alternative actions for any remedial site, very different requirements can come into play. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative must be achieved.

Appendix P lists the Federal location and action-specified ARARs that typically are pertinent to CERCLA municipal landfill sites.

Chemical-specific requirements are usually technology- or risk-based numerical limitations or methodologies that, when applied to site-specific conditions, result in the establishment of acceptable concentrations of a chemical that may be found in or discharged to the ambient environment.

7.1 CHEMICAL-SPECIFIC ARARs

7.1.1 Drinking Water Standards

The Safe Drinking Water Act (SDWA) established health-based primary drinking water standards, which in turn require the promulgation of enforceable Maximum Contaminant Levels (MCLs) (40 CFR 141). Appendix Q provides a listing of the SDWA primary (MCLs) and secondary standards for chemicals as of August 1991. Many MCLs have been proposed or will be effective in the next two years.

Maximum Contaminant Level Goals (MCLGs) are non-enforceable but recommended levels. Goals for all carcinogens are zero on the basis of the EPA policy that there are no threshold levels for carcinogens.

Secondary MCLs are SDWA regulations for taste, odor, and aesthetic effects (such as foaming or color) that are not health-based criteria and are not enforceable.

The Commonwealth of Massachusetts has not only adopted Federal standards but also added a standard for sodium (20 mg/L) to primary drinking-water standards. It also has a policy of non-degradation of groundwater in most instances, which may affect clean-up requirements and effluent limits for discharges to groundwater. Massachusetts Secondary Drinking Water Standards, adopted from analogous Federal standards, are given in Appendix R.

7.1.2 Ambient Water Quality Criteria

Two other types of criteria that may be relevant and appropriate are the ambient water quality criteria (AWQC) for the protection of human health and for the protection of aquatic life. Both sets of criteria were developed under the Clean Water Act (CWA) regulations. The AWQC for the protection of human health include criteria for both the consumption of aquatic organisms as well as for drinking water, and they are not legally enforceable.

The AWQC for the protection of aquatic life are used as guidelines and, like those for human health, are not enforceable.

To protect both surface and subsurface drinking water supplies or potential supplies, Massachusetts has developed surface water quality standards for Class A waters (Appendix R).

7.1.3 Air Quality Standards

Other ARARs that might be applicable are National Ambient Air Quality Standards as developed under the Clean Air Act could be applicable to Fort Devens.

7.2 LOCATION-SPECIFIC ARARs

Applicable or possibly relevant site-specific criteria to be considered at Fort Devens include such conditions as local geologic hazards, hydrologic settings, special natural resource areas, and archaeological and historic resources.

The ARAR Task Group of the Health and Safety Research Division, Oak Ridge National Laboratory (ORNL), has prepared a draft report on the location-specific ARARs for Fort Devens (ORNL 1992). This report identified no site-specific Holocene faulting, but noted that a number of major Holocene earthquakes have caused soil/sediment liquification of susceptible material from the early 1700s to the present. This could result in restrictions on the location of hazardous waste treatment storage or disposal (TSD) facilities at Fort Devens.

No other site-specific geologic hazards such as karst, caves, salt beds, or underground mines were identified at Fort Devens.

Floodplains and wetlands occur both on and immediately adjacent to both RI sites. Any TSD facilities created for the purpose of remediation would be subject to siting requirements excluding their location in wetlands or floodplains under both State and Federal law. In addition, the removal, dredge, fill, or alteration of land subject to flooding is addressed under both State and Federal law. All wetlands, of which there are many on Fort Devens, are subject to restrictions on alteration or use and will have an affect on any potential remedial measures.

Special natural resources in the Fort Devens area include the Oxbow National Wildlife Refuge, the Ayer State Game Area, Lancaster State Forest, and Bolton Flats State Wildlife Management Area. Any remedial actions or activities which might impact such areas will have to consider both the impact and any possible mitigating measures.

A similar consideration would apply to any habitat of a rare, threatened, or endangered species, a number of which have been identified within the Fort Devens area. There are ongoing studies to identify wildlife in the area and to locate the habitats of rare or endangered species. If any such habitats are identified, ARARs could be developed under both the Endangered Species Act (ESA) and the Fish and Wildlife Coordination Act (FWCA). Any activity involving the control of a natural stream or water body with fish or wildlife resources would be subject to ARARs under FWCA, while an action involving the discharge of dredge or fill material into an aquatic ecosystem would be subject to the provisions of the Clean Water Act.

There has not been a complete survey of Fort Devens for archaeological resources (Simon 1992). However, sources at the Massachusetts Historical Commission indicate that there is approximately a 90 percent chance that such resources are present on the installation (Simon 1992). In addition, a historic district has been established around the parade field in the central portion of Fort Devens (Winter 1992). The district includes the post headquarters, residential quarters, and barracks-type buildings constructed in the 1920's and the 1930's (Winter 1992). This district has been nominated to the National Register of Historic Places (Winter 1992; Simon 1992). The State has commented favorably on the nomination and the district will also be included on the comparable State list (Simon 1992).

A survey for archaeological resources and additional historic sites is warranted. If any are located and would be impacted by remedial activities, ARARs would develop under the Archaeological Resources Recovery Act of 1979 (16 USC 470aa-II), 43 CFR 7, 32 CFR 229, the Archaeological and Historic Preservation Act (16 USC 469a-c), 40 CFR 6.301, and 32 CFR 650.181 et seq. In addition, the property in the historic district, or any other property that is eligible for the National Register of Historic Places or the National Historic Landmark

Program, would be subject to ARARs under the National Historic Preservation Act (16 USC 470a-w), Executive ORder 11593, 40 CFR 6.301, 36 CFR 800, and 32 CFR 650.181 et seq. ARARs may also develop under MGL ch. 9 §§ 26-27c, CMR tit. 950 §§ 70-71, MGL ch. 7 § 38A, MGL ch. 38 § 6(b), MGL ch. 30 §§ 61-62, and CMR tit. 301 § 10.

7.3 ACTION-SPECIFIC ARARs

Action-specific requirements will not be identified for most sites until the development of alternatives in the FS.

RCRA has created definitions of "Hazardous Waste" under 40 CFR Section 261. These state that a solid waste is hazardous if it is a "listed" waste produced either by a specific industrial process, or as a general category such as "spent chlorinated solvent" and listed in Section 261. As an alternative, a waste may be hazardous because:

- it is flammable (ignitable),
- it is corrosive (primarily high or low pH),
- it is reactive (primarily cyanide and sulfide wastes), or
- it contains leachable quantities of specific hazardous substances (Toxicity Characteristic Leaching Procedure (TCLP) characterized waste).

Each of the above categories is specifically defined, and each such waste can be characterized by the appropriate test, e.g., closed cup flash test for ignitability.

By far the most comprehensive and the most likely test to cause a waste or contaminated soil to be classifiable as a "hazardous waste" is the TCLP. This procedures subjects a specified quantity of a solid to leaching by a specified quantity of water at a specific pH and temperature for 24 hours. The extract from this procedure, which is obtained by filtering off the remaining solid, has to be below certain concentrations (see Appendix R) if it is not to "fail" the test and be classified as hazardous waste (and a waste banned from land disposal without further treatment).

Alternatively, if the waste is water with less than five percent solids by weight, it can be filtered without extraction and the filtrate analyzed. Again, if it "fails" the test, it is hazardous and cannot be disposed of without further treatment.

Under CERCLA and RCRA, hazardous waste generally cannot be left in place. It must be treated, stored, or disposed of in a properly permitted facility, unless it can be demonstrated not to be "capable of posing a substantial present or potential hazard to human health or the environment when remedial measures have been implemented in its present location." The above quote is an alternative definition of a hazardous waste that relies on its effects rather than its characteristics (40 CFR 261.11).

7.3.1 Hazardous Waste

If the feasibility study concludes that an identified hazardous waste is present and should be treated, stored, or disposed of on-site, then RCRA standards for a treatment, storage, or disposal (TSD) facility would apply.

The Commonwealth of Massachusetts designates other wastes as hazardous under State regulations. These are cited in Appendix R, Table R-5. Note that M002 (Massachusetts Waste Number) is the clean-up standard for PCB-contaminated soil in a controlled industrial site as promulgated under the Toxic Substances Control Act (TSCA) regulations. In less controlled situations, the TSCA regulations might require clean-up standards as low as 10 ppm. State of Massachusetts M003 waste, the constituents, and the treatment standards required are listed in Appendix R, Table R-6.

7.4 GENERAL APPLICABILITY TO FEDERAL FACILITIES

All the above-mentioned laws and regulations now apply to Federal Facilities as specifically ordered by the Federal Facilities provisions of the Superfund Amendments and Reauthorization Act of 1986 (Section 120), reauthorizing CERCLA. These state that the same guidelines, rules, criteria, and regulations apply to Federal Facilities as apply to non-Federal facilities.

8. HUMAN HEALTH RISK ASSESSMENT

8.1 SHEPLEY'S HILL LANDFILL

8.1.1 Introduction

8.1.1.1 Overview

Shepley's Hill Landfill has served as the general disposal area for Fort Devens since the installation was established in 1917. Over the years, the base has been used mainly for training and for equipment preparation and demobilization. The base facilities include weapons ranges, an airfield, administrative buildings, some light industrial operations, and housing for military personnel and their dependents. The main waste-producing industrial operations are photographic processing and maintenance of vehicles, aircraft, and small engines.

The types of waste disposed of in the landfill have included incinerator ash from the burning of household debris, household refuse, military refuse, and construction debris. Background information indicates that at one time the landfill operated as an open burning site, and there are reports that flammable liquids were disposed of in the southern portion of the landfill. Most of the landfill has been closed, covered with a cap, including a PVC liner, and revegetated. The remaining portion at the southeast corner of the landfill is undergoing final closure.

The landfill is approximately 90 acres in size and is located in the northeast corner of the main cantonment area of the base. The landfill and adjoining areas are shown in Figure 8-1. Several of the base's light industrial activities occupy areas along the south side of the landfill. Shepley's Hill, a wooded area, borders the west side of the landfill; a small wetland is located on the north side; and Plow Shop Pond and the Boston and Maine railroad right-of-way border the east side of the landfill. The Town of Ayer is located north and east of the landfill, the closest part being about 0.25 mile to the north. The surface contours of the landfill slope gently toward the northeast. Both surface runoff and groundwater from the landfill area flow generally northeastward toward Plow Shop Pond.

Elevated concentrations of a number of metals were found in groundwater downgradient from the landfill, in the sediment, and, to a much lesser extent, in the surface water in Plow Shop Pond. Low levels of a number of volatile organic compounds (VOCs), pesticides, PCBs, and several explosives also were detected occasionally, mainly in the groundwater. No contamination was detected in surface soils or in the air.

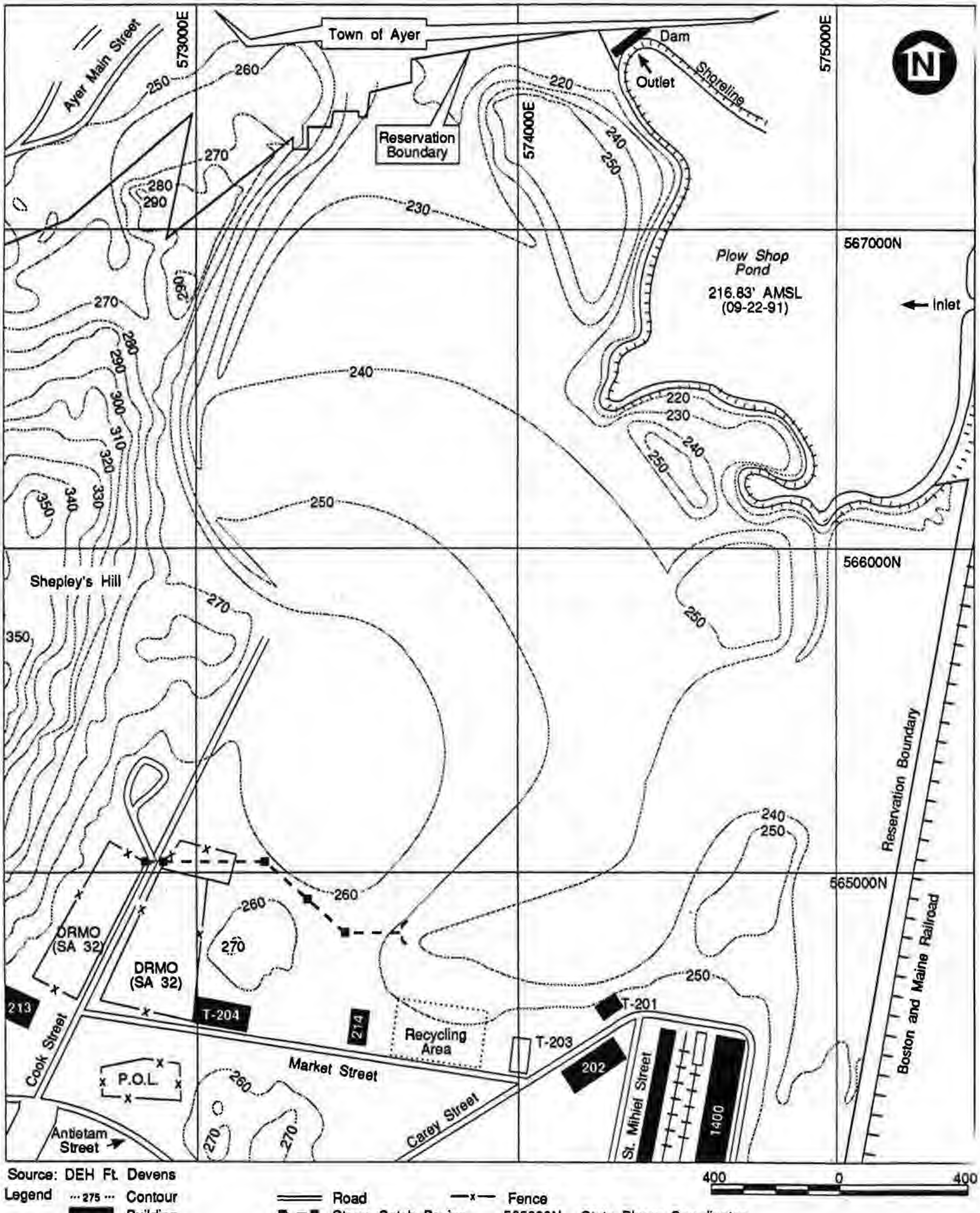


Figure 8-1 SHEPLEY'S HILL LANDFILL AREA

8.1.1.2 Site Background

Detailed descriptions of the site, its history and setting, the nature of previous investigations, and the nature and extent of contamination are provided in previous sections of this report.

8.1.1.3 Conceptual Site Model

A conceptual site model has been prepared and is presented in Figure 8-2. As shown in the figure, under current site conditions there appear to be three main exposure pathways:

- Direct contact (dermal exposure and incidental ingestion) with contaminated sediments along the shore of Plow Shop Pond;
- Direct contact (dermal exposure and incidental ingestion) with surface water in the pond while swimming; and
- Ingestion of surface water while fishing in Plow Shop Pond and consumption of contaminated fish caught from the pond.

These pathways would also apply to future site conditions if the site were converted to residential use. In addition, future exposures could potentially occur through use of groundwater as a source of potable water for domestic supply purposes.

There are two primary groups of potential receptors under existing site conditions: adolescent site visitors who might play along the edge of the pond or swim in the pond, and fishermen and their families who might eat contaminated fish caught from the pond. The groundwater is not presently used for drinking water supply purposes downgradient from the landfill, so there are no receptors currently exposed to groundwater contaminants.

Fort Devens is scheduled to be closed in the near future. After closure, parts of the base including areas around the landfill might be converted to residential use. If this happens and wells are installed to supply these new residences with drinking water, the future residents could be exposed to the groundwater contaminants. Adolescent residents living in these homes also may play along the shore of the pond and swim in the pond and potentially contact contaminated sediments and surface water in that area.

8.1.1.4 Organization of the Human Health Risk Assessment Section

This risk assessment has been prepared and organized in accordance with EPA's Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (RAGS-HHEM) (USEPA 1989c), with the Massachusetts Guidance for Disposal Site Risk Characterization and

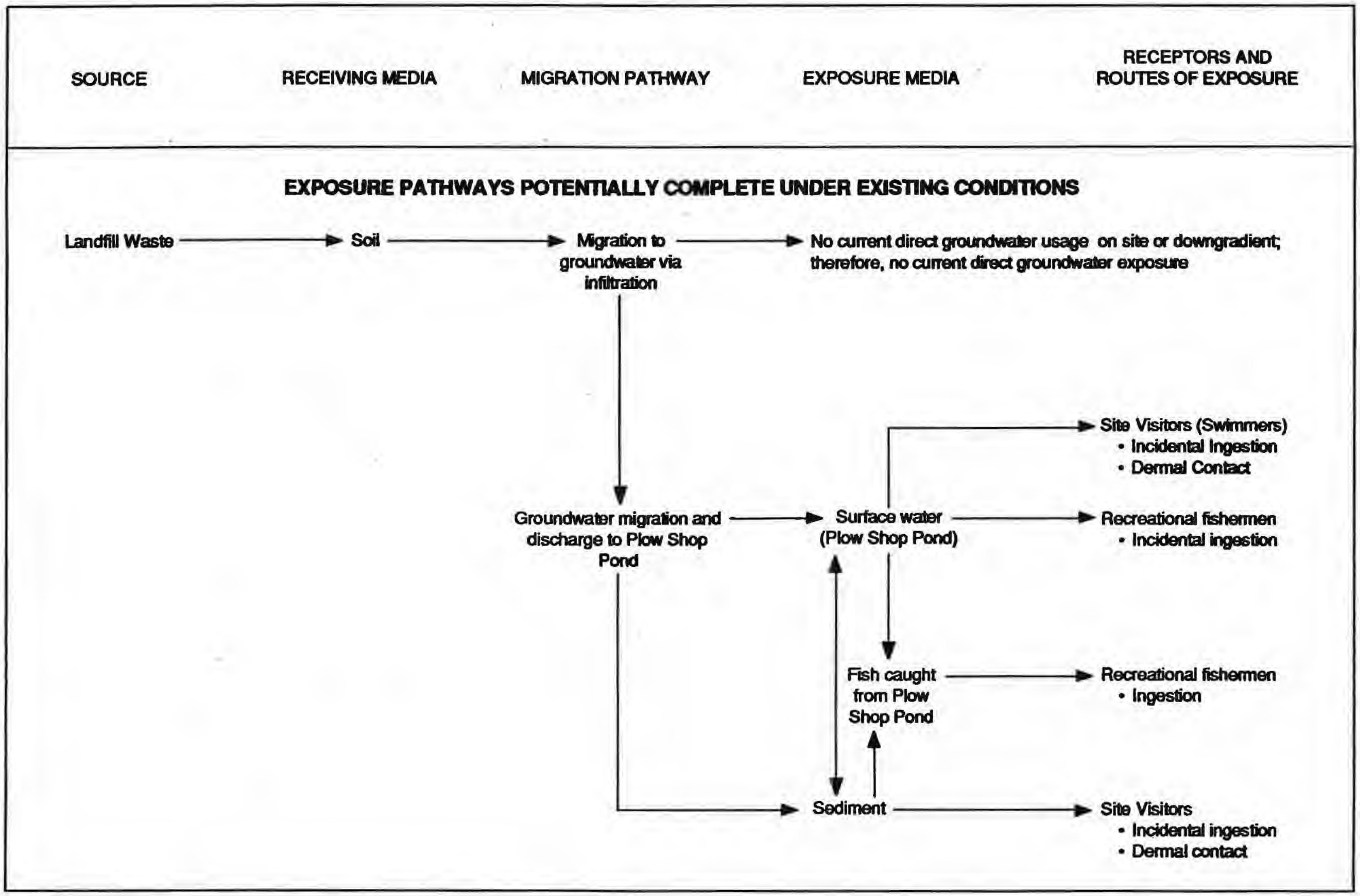


Figure 8-2 CONCEPTUAL SITE MODEL FOR SHEPLEY'S HILL LANDFILL

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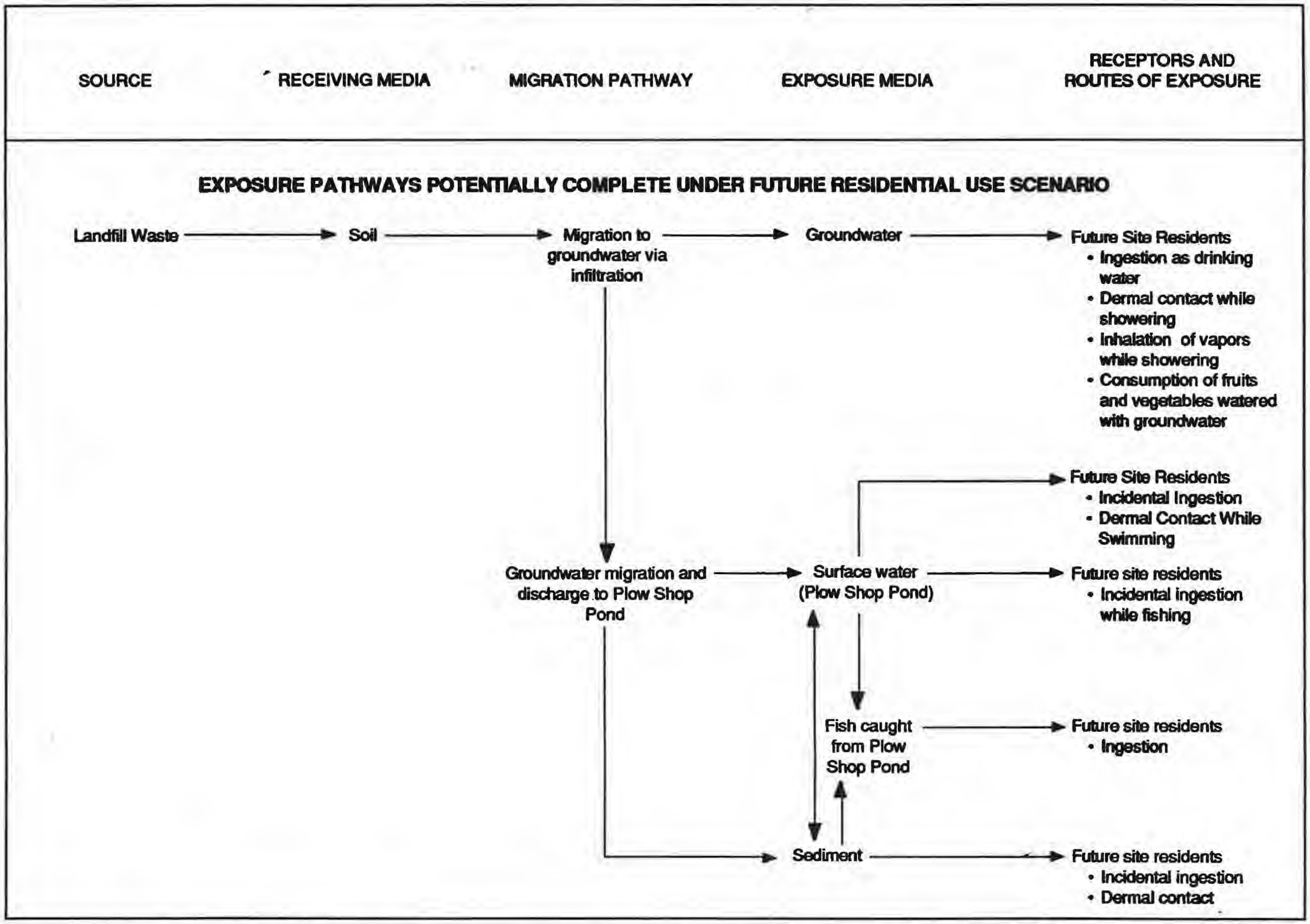

Figure 8-2 (Cont.) CONCEPTUAL SITE MODEL FOR SHEPLEY'S HILL LANDFILL

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Related Phase II Activities (MDEP 1989a), and with other related EPA Guidelines listed in the Work Plan (E & E 1991a).

The remainder of the risk assessment is organized as follows:

- o In Section 8.1.2, E & E reviews the site characterization data available, including the sampling plan, sampling and analytical methods, and data limitations, and identifies the substances potentially of concern at the site.
- o In Section 8.1.3, E & E assesses the potential exposure of receptors to the substances of concern. The potential exposure pathways are reviewed and exposure estimates derived, taking into consideration the site setting and various site characteristics.
- o In Section 8.1.4, E & E provides toxicity assessments for the chemicals of potential concern at the site. Toxicity assessment methodologies are reviewed and a brief discussion of the toxicological properties of each chemical is provided, along with tables summarizing the quantitative indices of toxicity for the chemicals of potential concern.
- o In Section 8.1.5, E & E integrates the exposure and toxicity assessments from Section 8.1.3 and 8.1.4 into an overall risk assessment. The main risks associated with the site are identified, along with the pathways and chemicals giving rise to those risks.

8.1.2 Identification of Chemicals of Potential Concern

8.1.2.1 Data Collection

The objective of the RI is to characterize the nature and extent of contamination associated with the Shepley's Hill Landfill area of contamination and to assess the site topography, geology, hydrogeology, climate, and demographics in order to identify and evaluate potential migration and exposure pathways. The investigative activities carried out to achieve this objective is described in Section 2 of the report and the results of the RI are described in Sections 3 and 5.

General Considerations

The Shepley's Hill Landfill area of contamination (AOCs) has served as a sanitary landfill for Fort Devens since the base was established in 1917. In the past, open burning was conducted in the area. Until recently, the landfill operated as a sanitary landfill and received household refuse, military refuse and construction debris. There are several other potential areas of contamination near the landfill that might also be sources of environmental contamination, including the POL area, the DRMO yard. Building 202 and the transfer station for the landfill. Plow Shop Pond, which is used by local residents for fishing, borders the northeastern boundary of the landfill, and there is a wetland just north of the landfill. Both of these areas could be affected by contaminants from the landfill. The Army has been conducting an ongoing groundwater monitoring program for the landfill that has detected contaminants downgradient from the landfill. The geology and hydrogeology of the area is complex, and the proximity of other potential source areas have made it difficult to install monitoring wells in locations that would provide reliable information on the background water quality in the immediate vicinity of the landfill.

With these considerations in mind, the following program was implemented to characterize the nature and extent of contamination associated with the landfill. To better characterize groundwater movement and the quality of the water entering and leaving the landfill, monitoring wells were installed around the perimeter of the landfill to supplement the existing well network used in the Army's monitoring program . Monitoring well locations were selected based on hydrogeological considerations and the locations of other nearby potential source areas. Two rounds of groundwater samples were collected.

The landfill has been capped, covered with clean fill, and revegetated except for the remaining active area. Because the existing surface soil consists of clean fill, surface soil contamination was considered unlikely and surface soil samples were not collected. However, three surface soil/sediment samples were collected from leachate seep areas identified by the site geologist. Surface water and sediment samples were collected from locations throughout Plow Shop Pond and in Nonacoicus Brook immediately downstream from Plow Shop Pond to characterize any contamination from the landfill that may have affected these areas.

Finally, an air quality survey that included VOCs and respirable size particulate matter (PM_{10}) was conducted to investigate potential air emissions from the landfill.

Sampling locations for each medium were selected in a directed or purposive manner, taking into consideration the physical characteristics of the landfill and the surrounding area, and the potential contaminant migration patterns that might exist. Neither systematic nor random sampling--employing a grid to select sampling locations--was used because of the complex site conditions.

Twenty background soil samples, 16 surface and four subsurface, were collected from locations throughout Fort Devens that did not appear to be affected by any known or suspected sources of contamination. These samples were analyzed for metals to determine the normal range of metals concentrations in soils at the base.

Sampling, analytical, and QA/QC methods are USATHAMA methods that were approved by the EPA and are described in Sections 2 and 4 of this report, in the Field Sampling Plan (FSP) (E & E 1991a), and the Quality Assurance Project Plan (QAPjP) (E & E 1991b).

8.1.2.2 Data Evaluation

Data Validation

Analysis of laboratory samples was performed by the Arthur D. Little Laboratory located in Cambridge, Massachusetts ADL's Laboratory is certified by USATHAMA; the laboratory uses (ADL) USATHAMA methods approved by the EPA. E & E reviewed and validated the data as described in the QAPjP (E & E 1991b). Only data approved for use by this process were used in the risk assessment.

Quantitation Limits

The quantitation limits used in the analytical work for Shepley's Hill Landfill were the standard certified reporting limits (CRLs) for the USATHAMA methods employed. The CRLs are tabulated in the QAPjP (E & E 1991b) and were approved by the EPA. The adequacy of these limits were evaluated in accordance with EPA risk assessment guidance recommendations (USEPA 1989c) by estimating the cancer risk and/or hazard index for the COPCs, assuming that each chemical was present in water, soil or sediment at its CRL.

For water, the cancer risks and hazard indices were calculated using the standard default residential drinking water exposure assumptions and the equations for target risks and target hazard indices given in RAGS-HHEM Part B (USEPA 1991h) for residential water usage. Both inhalation and ingestion exposure were considered for the VOC's whereas only ingestion exposure was considered for inorganics, pesticides, and explosives. Although additional exposure by dermal absorption is possible, it is considered a minor pathway and is not included in the drinking water calculations.

To calculate the cancer risks and hazard indices for soil and sediment, the standard default residential soil exposure assumptions and the corresponding target risk and target hazard index equations in RAGS-HHEM Part B (USEPA 1991h) were used in the calculations. Only incidental ingestion of soil is considered in these calculations.

The CRLs for water and soil/sediment are shown in Table 8-1 along with the corresponding cancer risks and hazard indices. None of the COPCs have hazard indices greater than 1 at their CRLs for either medium. Arsenic, beryllium, benzene, chloroform, 1,2-dichloroethane, 1,1,2,2-tetrachloroethane, vinyl chloride, and PCB-1260 have estimated cancer risks greater than 10^{-6} at their CRLs for water and the carcinogenic PAHs had estimated risks greater than 10^{-6} at their CRLs for soils/sediments. This indicates that the CRLs for arsenic, beryllium, benzene, chloroform, 1,2-dichloroethane, 1,1,2,2-tetrachloroethane, vinyl chloride, and PCB-1260 in water and for PAHs in soils/sediments were not entirely adequate for risk assessment

Table 8-1

CANCER RISKS AND HAZARD INDICES CORRESPONDING TO CRL CONCENTRATIONS OF THE CHEMICALS OF POTENTIAL CONCERN

Chemical	Water CRL	Water Cancer Risk	Water Hazard Index	Soil/Sediment CRL	Soil/Sediment Cancer Risk	Soil/Sediment Hazard Index
Inorganics	(µg/L)	a	a	(mg/kg)	e	e
Aluminum	81.5	--	--	15	--	--
Arsenic	3.09	6.3 E-5[b]	2.9E-1	0.219	7.3E-7	2.7E-3
Barium	1.52	--	6.2E-4	2.27	--	1.1E-4
Beryllium	0.341	1.7 E-5[b]	1.9E-4	0.078	--	7.8E-5
Cadmium	2.67	--	1.5E-1	0.424	--	3.1E-3
Chromium	4.47	--	2.6E-2	3.9	--	2.9E-3
Copper	4.29	--	2.6E-2	1.95	--	1.9E-4
Iron	24.6	--	--	1.89	--	--
Lead	4.74	--	--	0.536	--	--
Manganese	6.88	--	2.0E-3	0.839	--	3.1E-5
Nickel	8.76	--	1.3E-2	2.46	--	4.5E-4
Vanadium	4.00	--	1.6E-2	1.34	--	7.0E-4
Zinc	19.4	--	2.8E-3	7.96	--	1.5E-4
Volatile Organics	(µg/L)	c	c	(µg/kg)	e	e
Benzene	2.4	3.9E-6[b]	--	2.9	1.3E-10	--
Chloroethane	5.0	--	6.5E-5	27.0	--	9.9E-9
Chloroform	0.83	3.0E-6[b]	1.1E-2	2.3	2.2E-11	8.4E-7
1,1-Dichloroethane	1.1	--	1.4E-3	1.7	--	6.2E-8
1,2-Dichloroethane	7.6	3.9E-5[b]	--	3.1	4.4E-10	--
Methylene Chloride	5.4	8.6E-7	3.1E-3	5.7	6.7E-11	3.5E-7
1,1,2,2-Tetrachloroethane	4.7	5.2E-5[b]	--	1.6	5.0E-10	--
Vinyl Chloride	2.9	1.0E-4[b]	--	15.0	4.5E-8	--

RC424

Key at end of table.

Chemical	Water			Soil/Sediment		
	CRL	Cancer Risk	Hazard Index	CRL	Cancer Risk	Hazard Index
Semivolatile Organics	(µg/L)	[d]	[d]	(µg/kg)	[e]	[e]
Acenaphthylene	19	--	--	460	--	--
Anthracene	20	--	--	540	--	6.6E-6
Benzo(a)anthracene	14	--	--	300	2.7E-6[b]	--
Benzo(a)pyrene	10	--	--	380	3.4E-6[b]	--
Benzo(b)fluoranthene	23	--	--	360	3.3E-6[b]	--
Benzo(g,h,i)perylene	7.1	--	--	240	--	--
Benzo(k)fluoranthene	21	--	--	800	7.2E-6[b]	--
Chrysene	15	--	--	450	4.1E-6[b]	--
Fluoranthene	20	--	--	520	--	4.7 E-5
Indeno(1,2,3-cd)pyrene	7.2	--	--	210	3.8E-6	--
Phenanthrene	22	--	--	410	--	--
Pyrene	17	--	--	420	--	5.1 E-5
Pesticides/PCBs	(µg/L)	[a]	[a]	(µg/kg)	[e]	[e]
Chlordane	0.00201	3.1E-8	9.2 E-4	1.84	3.7E-9	1.1 E-4
4,4'-DDD	0.0201	8.0E-8	--	10.1	5.4E-9	--
4,4'-DDE	0.088	3.5E-7	--	3.99	2.1E-9	--
Dieldrin	0.0218	4.1E-6[b]	1.2E-2	5.19	1.3E-7	3.8E-4
Heptachlor	0.00841	4.4E-7	4.6 E-4	1.15	8.1E-9	8.4 E-6
α-Hexachlorocyclohexane	0.00561	4.1E-7	--	5.05	5.0E-8	--
PCB-1260	0.0754	6.8E-6[b]	--	53.8	6.5E-7	--
Explosives	(µg/L)	[a]	[a]	(µg/kg)	[e]	[e]
1,3-Dinitrobenzene	0.270	--	7.4 E-2	304	--	1.1 E-2
Tetryl	0.191	--	--	1,040	--	--
1,3,5-Trinitrobenzene	0.388	--	9.1 E-2	352	--	2.5 E-2

RC424

Key:

[a] Calculated using standard default exposure assumptions for residential drinking water usage - ingestion exposure water (USEPA 1991h).
[b] Exceeds reference value of 10^{-6}.
[c] Calculated using standard default exposure assumptions for residential drinking water usage - ingestion and inhalation exposure (USEPA 1991h).
[d] No semivolatile organics were selected as COPCs for groundwater or surface water.
[e] Calculated using standard default exposure assumptions for residential soil exposure - incidental ingestion exposure only (USEPA 1991h).

Source: Ecology and Environment, Inc., 1992

purposes. Significant risks could exist but be overlooked if these chemicals were present at concentrations below, but approaching their CRLs for water.

It should be noted that, except for arsenic and 1,2-dichloroethane, the USATHAMA methods' CRLs for the chemicals with risks at CRLs greater than 10^{-6} are lower than the contract required quantitation limits (CRQLs) for the corresponding EPA contract laboratory program (CLP) routine analytical services (RAS) methods. In every case the risks at CRQLs for these chemicals would also be greater than 10^{-6}.

Data Qualifiers

The USATHAMA/IRDMIS analytical methodologies and data system use a somewhat different set of data qualifiers than EPA's CLP. QA/QC of the data for Shepley's Hill Landfill was discussed in Section 5.1.6 of this report. All of the data that were retained after the QA/QC review was used in the risk assessment. Most of the hits for acetone, methylene chloride, and phthalates were attributed to laboratory or sampling contamination and were discounted. A number of samples fell outside of normal QC limits, such as holding times and spike recoveries. Some of the values are described as "estimated" or "suspect" because of these discrepancies. Guidance on data usability for risk assessment recommends that estimated values be included in the risk assessment because, even though these data may not be as reliable as data meeting all QA criteria, they still represent the best available estimate of the analyte's concentration in that sample. Therefore, as long as a sample result was retained after the QA/QC review, it was included in the database for the risk assessment.

LT-flagged values (indicating that the chemical was not detected at the specified value) were evaluated on a case-by-case basis. If there was no reason to believe the substance was present in a sample, the LT value was regarded as zero. If there was reason to believe it might be present, one-half of the quantitation limit (QL) for that substance was substituted for the LT value. The presence of the chemical in a nearby sample or, if the chemical is a known degradation product of another compound, the presence of the parent compound was considered evidence that the substance might be present.

8.1.2.3 Selection of Chemicals of Potential Concern - General Approach and Selection Criteria

Several factors complicated the identification and selection of the COPCs for the Shepley's Hill Landfill and Cold Spring Brook Landfill sites. These factors include the following:

- o Complicated and heterogeneous geological and hydrogeological settings made it difficult to site true upgradient and downgradient wells;

- o The apparent presence of suspended sediment in most of the groundwater samples, which made interpretation of the metals results difficult; and

- o The presence of other source areas that appear to have contributed contamination to the AOCs under consideration.

This section describes how the usual COPC selection process was implemented and the ways the complicating factors described above were addressed.

Data Usability

The usability of the data for risk assessment purposes was determined using established EPA guidelines (USEPA 1992b). For example, sample values that did not exceed five times the blank values (10 times for common laboratory contaminants) were not included in the risk assessment.

A number of pesticides were detected in many of the samples at concentrations slightly above their detection limits; however, many of these hits were not confirmed by second column analysis. Because unconfirmed hits such as these are often analytical artifacts, or noise, they were not included in the quantitative risk assessment.

The analytical results are reviewed in detail and the confirmed hits summarized in Section 5 of this report.

Comparison With Natural Background Concentrations

Many metals and anions are naturally present in water, soils, and sediments. The metals concentrations in the soils and sediments were compared to the upper tolerance limits of the concentrations found in the 20 background soil samples from Fort Devens (see Figure 5-1 for background soil sample locations.) The upper tolerance limit is the statistic recommended for comparison of individual investigative sample results to the distribution of concentrations found in natural background populations (USEPA 1989i). The geometric means, upper tolerance limits, and maximum observed concentrations of metals in background soils from Fort Devens are given in Table 8-2.

As noted earlier, the geological/hydrogeological setting of the landfill has made it very difficult to locate true upgradient monitoring wells. The groundwater flow pattern in the landfill area is shown in Figure 8-3. Figure 8-3 also shows the area in which the groundwater could potentially be affected by the landfill based on the evident groundwater flow patterns. As shown, groundwater under the landfill flows generally toward the northeast, making the west side of the landfill the upgradient edge. Unfortunately, efforts to get a reliable indication of the background quality of water entering the landfill from upgradient have been unsuccessful. Boring 14 and SHL-16 were dry holes, SHL-1 did not provide enough water to sample and analyze, and SHL-15

Table 8-2

BACKGROUND CONCENTRATIONS OF METALS IN SOILS AT FORT DEVENS, MA

Chemical	Geometric Mean (mg/kg)	Upper Tolerance Limit[a] (mg/kg)	Maximum Value Detected (mg/kg)
Aluminum	9,195	30,290	24,000
Arsenic	14.1	66.3	99.0
Barium	21.5	91.4	67.2
Beryllium	0.151	1.015	0.672
Cadmium	0.410	5.46	4.48
Calcium	682	3,460	2,800
Chromium	13.4	89.4	56.5
Copper	4.99	50.7	30.2
Iron	9,687	40,500	>50,000
Lead	19.6	275	326
Magnesium	2,285	15,174	11,000
Manganese	166	589	460
Mercury	0.0535	0.886	0.412
Nickel	3.41	53.1	27.0
Potassium	859	4,000	2,400
Silver	0.053	0.260	0.582
Sodium	72.3	571	680
Vanadium	13.9	64.3	46.6
Zinc	20.5	105	130

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[a]The upper tolerance limit is defined as the upper 95% confidence limit for the upper 95th percentile of a population and is the statistic recommended for use in comparing investigative samples to a background population (USEPA 1989i).

Source: Ecology and Environment, Inc., 1992

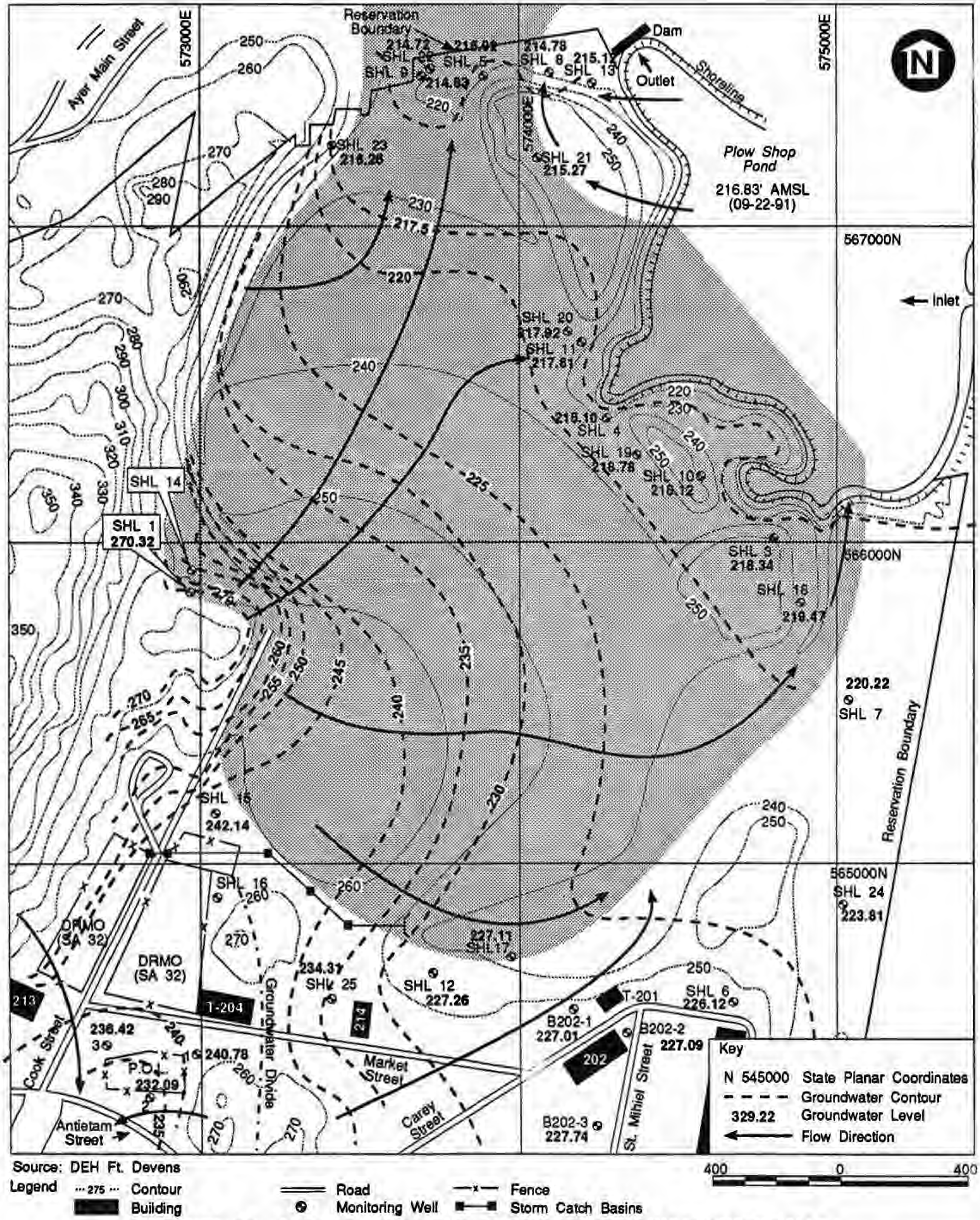

Figure 8-3 AREA IN WHICH THE GROUNDWATER COULD POTENTIALLY BE AFFECTED BY THE SHEPLEY'S HILL LANDFILL

SHL11.CDR

appears to be contaminated. Due to the lack of information from true upgradient wells, an effort was made to identify wells across gradient but close to the landfill that would give an indication of background groundwater quality. Based on this information and the analytical data for the groundwater samples, the wells in the vicinity of the landfill were divided into three groups: wells potentially under the influence of the landfill, apparent background wells, and wells outside the zone of influence but apparently receiving contaminants from some other source. (The DRMO and transfer area are two possible sources of contamination near the landfill.) The groupings are shown in Table 8-3. Wells SHL-6, SHL-23, SHL-24, and SHL-25 appear to provide an indication of background water quality in the landfill area. The chemical concentrations found in these wells were regarded as background levels and were used in evaluating concentrations found in wells within the influence of the landfill.

Plow Shop Pond and Nonacoicus Brook are adjacent to the eastern side of the landfill and receive surface runoff and groundwater discharge from the landfill. The main surface water inlet to the pond is through a culvert (under the railroad right-of-way on the east side of the pond) that connects Plow Shop Pond to Grove pond. Thus most of the surface water entering Plow Shop Pond comes from Grove Pond. The principal outlet from Plow Shop Pond is located at the end of the northwestern arm of the pond, where it discharges over a dam to Nonacoicus Brook. Historically the main outlet was located at the end of the northeastern arm, where the pond discharged to a different branch of Nonacoicus Brook. The outlet was changed by the relative height of dams installed at both possible pond outlets.

Surface water and sediment samples were collected throughout Plow Shop Pond. In designing the sampling program, it was expected that samples from the central and eastern parts of the pond away from the landfill, including one location (SW/SED-SHL-12) near the inlet culvert, would serve as background samples. However, the analytical results indicated that Plow Shop Pond evidently receives contaminants from the east side of the pond, including the inlet from Grove pond, as well as from the landfill. As a result, none of the samples appears to provide reliable information on the natural background surface water and sediment quality upstream from the part of the pond potentially affected by the landfill.

A background air sampling location was identified for the air quality survey based on the meteorological data collected at the site and historical data from Moore Airfield. The background air quality samples were collected at the Fort Devens Elementary School, west of the landfill, which was identified as the prevailing upwind direction.

Spatial Distribution

The spatial distribution of chemicals detected in environmental media with respect to the source area under investigation, as well as other potential sources, was considered in assessing whether a chemical

Table 8-3

CLASSIFICATION OF MONITORING WELLS AROUND SHEPLEY'S HILL LANDFILL

Wells Within the Landfill's Zone of Influence	Wells Outside the Landfill's Zone of Influence	
	Background Wells	Wells Receiving Contaminants From Another Source
SHL-3	SHL-6	SHL-7
SHL-4	SHL-23	SHL-8
SHL-5	SHL-24	SHL-13
SHL-9	SHL-25	SHL-15
SHL-10		
SHL-11		
SHL-12		
SHL-17		
SHL-18		
SHL-19		
SHL-20		
SHL-21		
SHL-22		

RC424

Source: Ecology and Environment, Inc., 1992

originated from the study area or from other potential sources. Chemicals that were present at elevated concentrations but did not appear to be site related were excluded from the quantitative risk assessment for the Shepley's Hill AOC. For example, many of the elevated metals concentrations found in the Plow Shop Pond sediments appear to have entered from Grove Pond or the railroad right-of-way rather than from Shepley's Hill Landfill. One potential source of these metals may have been the tannery that was located on the east side of Grove Pond. The tannery burned down in 1961 and was reportedly bulldozed into the pond. For completeness, non-site-related chemicals have been assessed separatly in this report and are provided for use in a future base-wide or area-wide (Plow Shop Pond, for example) risk assessment.

Suspended Sediment

Many of the unfiltered groundwater samples collected from monitoring wells at Shepley's Hill Landfill contained substantial amounts of suspended sediment as judged by their markedly elevated aluminum and iron concentrations. Aluminum is quite insoluble under typical groundwater conditions; therefore, its presence in groundwater samples is usually indicative of suspended sediment. Since the soil minerals comprising these suspended sediments contain a variety of metals, these samples artificially exhibit elevated concentrations of many metals. Metals associated with suspended soil minerals are generally not mobile in the groundwater and would not pose a health risk unless the water from these monitoring wells was used directly as a drinking water source. Water supply wells that might be installed in this area in the future typically would be developed until any suspended sediment was eliminated.

Regional EPA guidance indicates that risk estimates for water that could be used as a drinking water source should be based on data for unfiltered and untreated water. However, the water obtained from the Shepley's Hill monitoring wells is not and never will be used for drinking water, and any groundwater drawn from this area by possible future water supply wells would not contain the sediment present in the monitoring well samples. The very low aluminum concentrations found in the Patton well near the Cold Spring Brook Landfill illustrate this point. Therefore, use of the raw metals data from the monitoring well samples could substantially overestimate the potential risks posed by metals contamination in the groundwater and/or the areal extent of the actual contamination.

To address this problem, a method was developed that uses the aluminum content of the samples to estimate the contribution of suspended soil minerals to the concentrations of other metals found in the groundwater. The method is described in Appendix K. The metals concentrations can then be adjusted to remove the portions of the concentrations attributable to suspended sediments.

In light of the regional EPA guidance on the use of data for unfiltered samples in risk assessments, the adjusted metals concentrations were not used in the selection of COPCs. However, exposure and risk estimates were derived using both adjusted and unadjusted metals to provide a measure of the uncertainty introduced into the risk estimates by the presence of suspended sediment in the samples.

8.1.2.4 Summary of Analytical Results and Chemicals of Potential Concern

Groundwater

Detailed analytical results for the groundwater at Shepley's Hill Landfill are discussed in Section 5 of this report and presented in Tables 5-4 and 5-5. See Tables 8-4 and 8-5 for a summary of these results. The results for the wells that appear to reflect background groundwater quality are compared to those for the wells within the landfill's zone of influence.

Well SHL-15, which is also included in these tables, appears to be upgradient from the landfill and outside of its zone of influence; however, substantial contamination was found in this well. SHL-15 is close to both the DRMO area and the transfer station for the landfill; however, considering the groundwater flow pattern shown in Figure 8-3, the contamination cannot be firmly linked to those areas either. Since SHL-15 appears to be an orphan, a separate risk estimate was prepared for the groundwater contamination found at this location to facilitate a future base- or area-wide risk assessment.

The presence of suspended sediment in most of the groundwater samples makes it very difficult to interpret the metals results. This is illustrated by the range of metals concentrations in the four wells that appear to reflect background groundwater quality in the area. Wells SHL-6, -24, and -25 were relatively free of suspended sediment as evidenced by their low aluminum concentrations. However, well SHL-23 contained a large amount of sediment, particularly in its Round 1 sample (see Table 8-4). The results for well SHL-23 illustrate the effect suspended sediment can have on many of the TAL metals. The Round 2 sample from SHL-23 had much less sediment and correspondingly lower metals concentrations (see Table 5-5). When the results for both samples from SHL-23 were adjusted to remove the effect of suspended sediment using the method described in Appendix K, virtually all of the elevated metals concentrations found in this well proved to be attributable to suspended sediment (see Table 8-6).

Sampling and analyses of the POL wells were originally included in the RI for Shepley's Hill Landfill because it was thought that they might be upgradient from the landfill. However, the hydrogeological investigation showed that they are actually on the opposite side of a groundwater divide from the landfill and are therefore unrelated to the landfill. The POL area is adjacent to the DRMO area, which is another AOC that will be the subject of an RI and risk assessment. The

Table 8-4

SUMMARY OF RI GROUNDWATER RESULTS FOR SHEPLEY'S HILL LANDFILL INORGANIC CHEMICALS

Chemical	Background Wells				Wells Within Landfill's Zone of Influence[b]			Well SHL-15		
		Range for Wells SHL-6, -24, -25		Well SHL-23		Range			Range	
	Detection Frequency	Minimum	Maximum	Maximum	Detection Frequency	Minimum	Maximum	Detection Frequency	Minimum	Maximum
Metals (µg/L)										
Aluminum	7/8	90.5	1,650	47,000	22/26	304	94,000	2/2	7,600	29,000
Arsenic[a]	8/8	4.29	17	140	26/26	3.41	710	2/2	130	580
Barium[a]	8/8	5.51	19.4	210	26/26	12.7	710	2/2	71	240
Beryllium[a]	1/8	—	—	1.26	11/26	0.351	3.90	2/2	1.24	3.16
Cadmium[a]	0/8	—	—	—	4/26	3.14	150	1/2	—	44.7
Calcium	8/8	12,000	22,000	14,000	26/26	6,800	99,000	2/2	9,300	34,000
Chromium[a]	6/8	5.66	20.2	67.6	24/26	5.59	240	1/2	—	28.8
Cobalt	0/8	—	—	—	1/26	—	27.7	0/2	—	—
Copper[a]	6/8	5.98	9.46	90.8	25/26	4.74	250	2/2	41.6	71.5
Iron	8/8	366	4,300	55,000	26/26	458	51,000	2/2	14,000	48,000
Lead[a]	3/8	—	9.5	78	21/26	8.90	62.0	2/2	26.2	240
Magnesium	8/8	1,300	3,900	18,000	26/26	1,200	48,000	2/2	2,600	7,600

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Key at end of table.

Table 8-4 (Cont.)

	Background Wells				Wells Within Landfill's Zone of Influence[b]			Well SHL-15		
		Range for Wells SHL-6, -24, -25		Well SHL-23		Range			Range	
Chemical	Detection Frequency	Minimum	Maximum	Maximum	Detection Frequency	Minimum	Maximum	Detection Frequency	Minimum	Maximum
Manganese[a]	8/8	8.61	320	1,700	26/26	83.9	7,600	2/2	770	9,100
Nickel[a]	4/8	12.2	12.6	37.2	15/26	9.81	290	1/2	—	10.3
Potassium	8/8	1,900	9,900	8,800	26/26	1,040	35,000	2/2	2,850	9,100
Silver	0/8	—	—	—	1/26	—	0.667	0/2	—	—
Sodium	6/8	18,000	26,000	2,230	12/26	1,670	30,000	1/2	—	2,870
Vanadium[a]	2/8	—	—	44.8	16/26	5.99	160	2/2	17.5	75.0
Zinc[a]	7/8	23	127	155	24/26	26.0	570	2/2	64.5	380
Anions (µg/L)										
Bromide[a]	0/8	—	—	—	9/26	84.8	517	2/2	125	199
Chloride	8/8	4,900	4,900	1,690	26/26	843	100,000	2/2	5,700	21,000
Fluoride	0/8	—	—	—	1/26	—	116	0/2	—	—
Nitrate	8/8	1,100	3,400	8,400	19/26	29.1	2,300	2/2	184	2,600
Nitrite	0/8	—	—	—	0/26	—	—	1/2	—	83.5
Sulfate	8/8	17,000	29,000	3,040	26/26	225	27,000	2/2	13,000	39,000

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Key:

[a]Selected as COPC.
[b]These include SHL-3, -4, -5, -9, -10, -11, -12, -17, -18, -19, -20, -21, -22.

Source: Ecology and Environment, Inc., 1992

Table 8-5

SUMMARY OF RI GROUNDWATER RESULTS FOR SHEPLEY'S HILL LANDFILL ORGANIC COMPOUNDS (μg/L)

	Background wells		Wells Within Landfill's Zone of Influence			Well SHL-15	
				Range			
Chemical	Detection Frequency	Maximum	Detection Frequency	Minimum	Maximum	Detection Frequency	Maximum
Acetone	0/8	—	1/26		5.8	0/2	—
Alpha-hexachlorocyclohexane[a]	0/8	—	2/26	0.018	.046	1/2	0.073
Alpha-chlordane[a]	0/8	—	2/26	0.004	0.009	0/2	—
Benzene[a]	0/8	—	3/26	1.18	2.06	0/2	—
Chlorobenzene	0/8	—	1/26		1.94	0/2	—
Chloroethane[a]	0/8	—	2/26	2.18	7.78	0/2	—
Chloroform[a]	0/8	—	2/26	.734	5.3	0/2	—
1,1-Dichloroethane[a]	0/8	—	4/26	1.2	4.6	0/2	—
1,2-Dichloroethane[a]	0/8	—	1/26		14	0/2	—
Dieldrin[a]	0/8	—	0/26		—	1/2	0.032
Diethyl Phthalate	0/8	—	1/26		32	0/2	—
1,3-Dinitrobenzene[a]	0/8	—	4/26	0.169	1.49	0/2	—

RC424

Table 8-5 (Cont.)

Chemical	Background Wells Detection Frequency	Background Wells Maximum	Wells Within Landfill's Zone of Influence Detection Frequency	Wells Within Landfill's Zone of Influence Range Minimum - Maximum	Well SHL-15 Detection Frequency	Well SHL-15 Maximum
Heptachlor[a]	0/8	—	2/26	0.014 - 0.017	1/2	0.016
Methylene Chloride[a]	0/8	—	1/26	118	0/2	—
PCB 1260[a]	0/8	—	1/26	2.07	0/2	—
1,1,2,2-Tetrachloroethane[a]	0/8	—	1/26	9.0	0/2	—
Tetryl[a]	0/8	—	2/26	0.612 - 0.864	0/2	—
Trichloroethene	1/8	0.564	0/26	—	0/2	—
1,3,5-Trinitrobenzene[a]	0/8	—	2/26	0.649 - 1.35	0/2	—
Vinyl Chloride[a]	0/8	—	1/26	3.4	0/2	—

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Key:

[a]Selected as COPC.

Source: Ecology and Environment, Inc., 1992

Table 8-6

CONCENTRATIONS OF METALS IN GROUNDWATER ADJUSTED TO REMOVE THE EFFECT OF SUSPENDED SEDIMENT AOC 5 - SHEPLEY'S HILL LANDFILL ($\mu g/L$)

	Group 1 Wells				Group 2 Wells		
Chemical	SHL-19	SHL-4	SHL-11	SHL-20	SHL-21	SHL-5	SHL-9
Arsenic	303.486[a,c] 670.785[b,c]	217.768[c] 94.819[c]	295.487[c] 277.768[c]	97.273 84.808	0.069 0.931	<3.090 <3.090	26.876[c] 2.582
Barium	25.409 1.270	93.704 <1.520	101.495 163.704	40.609 56.853	2.773 <1.520	<1.520 <1.520	12.272 <1.520
Beryllium	<0.341 0.079	<0.341 <0.341	<0.341 0.196	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341
Cadmium	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 2.593	<2.670 <2.670	<2.670 10.438	0.444 <2.670
Chromium	3.047 <4.470	2.945 <4.470	5.453 8.045	6.763 5.486	<4.470 <4.470	<4.470 3.997	1.289 4.341
Copper	31.225 <4.290	18.225 1.185	1.702 24.125	<4.290 2.429	14.723[c] <4.290	13.278 <4.290	30.875[c] 32.052
Iron	40768.396[c] <24.600	37897.863[c] 24917.179[c]	43540.368[c] 38897.863[c]	15888.644 34158.527	<24.600 875.298	<24.600 1350.635	5772.064[c] <24.600
Lead	6.572[c] 42.524[c]	16.539 <4.740	0.104 10.539	<4.740 <4.740	6.917[c] <4.740	<4.740 <4.740	6.254 8.538
Manganese	2823.392[c] 285.577	2643.132[c] 1501.424	4388.816[c] 7043.132[c]	4692.783 6052.954	353.099[c] 144.845	196.932 <6.880	269.173 <6.880
Nickel	3.551 <8.760	<8.760 <8.760	<8.760 0.909	<8.760 <8.760	<8.760 <8.760	<8.760 <8.760	3.798 <8.760
Vanadium	<4.000 <4.000	0.697 <4.000	3.935 9.397	<4.000 <4.000	<4.000 <4.000	<4.000 <4.000	5.163 <4.000
Zinc	59.521 <4.000	<19.400 <4.000	1.882 <4.000	194.185 133.394	12.932 36.062	<4.000 <4.000	137.168[c] 58.202

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Key at end of table.

Table 8-6 (Cont.)

	Group 2 Wells (Cont.)	Group 3 Wells					Group 4 Wells
Chemical	SHL-22	SHL-12	SHL-17	SHL-18	SHL-3	SHL-10	SHL-15
Arsenic	22.808[a] 20.808[b]	7.868 100.606	10.000 <3.090	4.418 20.931	8.734 13.753	2.582 22.204	473.753[c] 91.550[c]
Barium	76.853 63.853	<1.520 364.130	<1.520 <1.520	<1.520 <1.520	<1.520 35.513	11.561 <1.520	75.513 0.438
Beryllium	<0.341 <0.341	<0.341 0.639	<0.341 <0.341	<0.341 <0.341	0.016 <0.341	<0.341 <0.341	1.816 0.750
Cadmium	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 14.289
Chromium	10.786 6.486	13.298 176.029	<4.470 <4.470	<4.470 <4.470	<4.470 36.661	<4.470 1.670	<4.470 <4.470
Copper	<4.290 <4.290	0.660 175.097[c]	<4.290 <4.290	<4.290 <4.290	0.540 67.699[c]	<4.290 <4.290	<4.290 48.300[c]
Iron	16158.527 17158.527	8454.029 <24.600	<24.600 <24.600	632.605 2075.298	804.524 14900.408	<24.600 3102.396	12900.408 3139.893
Lead	<4.740 <4.740	6.301 77.659	<4.740 <4.740	<4.740 <4.740	1.671 <4.740	<4.740 <4.740	190.911[c] 7.077
Manganese	5152.954 6052.954	<6.880 3317.430	<6.880 <6.880	<6.880 <6.880	4.958 1905.807	<6.880 <6.880	7605.807[c] 266.314
Nickel	4.130 <8.760	17.007 267.421[c]	<8.760 <8.760	<8.760 <8.760	3.603 67.874[c]	<8.760 9.895	<8.760 44.000
Vanadium	<4.000 <4.000	6.501 97.087	<4.000 <4.000	<4.000 <4.000	<4.000 12.454	<4.000 <4.000	<4.000 63.305
Zinc	<19.400 <19.400	11.655 435.367[c]	37.682 <19.400	<19.400 <19.400	120.024[c] 145.708	<19.400 <19.400	283.708[c] <19.400

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Key at end of table.

Table 8-6 (Cont.)

	Group 5 Wells				Group 6 Wells		
Chemical	SHL-23	SHL-25	SHL-6	SHL-24	SHL-13	SHL-8D	SHL-8S
Arsenic	<3.090[a] <3.090[b]	5.497 <3.090	<3.090 <3.090	7.513[a] 9.968[b,c]	0.212 <3.090	<3.090 <3.090	3.423 <3.090
Barium	<1.520 <1.520	<1.520 <1.520	1.581 <1.520	9.009 8.210	10.938 4.088	10.050 12.409	9.309 2.419
Beryllium	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341	<0.341 <0.341
Cadmium	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670	<2.670 <2.670
Chromium	20.803 1.559	<4.470 <4.470	<4.470 9.868	5.633 14.610	<4.470 1.996	<4.470 <4.470	<4.470 <4.470
Copper	36.573 <4.290	<4.290 <4.290	1.401 <4.290	5.351 3.037	<4.290 <4.290	10.142[c] 7.201	12.271 <4.290
Iron	1420.440 <24.600	<24.600 <24.600	11.902 1450.574	254.644 152.991	<24.600 4765.751	<24.600 10.644	<24.600 <24.600
Lead	9.037 <4.740	<4.740 <4.740	<4.740 2.975	<4.740 <4.740	<4.740 <4.740	6.864[c] <4.740	5.538 <4.740
Manganese	<6.880 <6.880	<6.880 <6.880	114.196 174.274	14.783 6.004	<6.880 <6.880	2080.797[c] 1992.783	1992.783 1892.783
Nickel	16.163 <8.760	<8.760 <8.760	<8.760 <8.760	<8.760 1.482	<8.760 <8.760	<8.760 <8.760	<8.760 <8.760
Vanadium	5.231 <4.000	<4.000 <4.000	<4.000 <4.000	<4.000 <4.000	<4.000 2.412	<4.000 <4.000	<4.000 <4.000
Zinc	44.501 <19.400	<19.400 <19.400	92.565[c] <19.400	32.285 4.403	<19.400 <19.400	168.113[c] 90.185	143.185 <19.400

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Key at end of table.

Table 8-6 (Cont.)

Chemical	Group 6 Wells (Cont.) SHL-7
Arsenic	<3.090 <3.090
Barium	<1.520 <1.520
Beryllium	<0.341 <0.341
Cadmium	<2.670 <2.670
Chromium	<4.470 <4.470
Copper	2.000 4.499
Iron	<24.600 3675.298
Lead	<4.740 <4.740
Manganese	1706.989[c] 2294.845[c]
Nickel	3.580 3.296
Vanadium	<4.000 <4.000
Zinc	4.742 5.162

RC424

Note: Wells were grouped by location to aid in identifying patterns of contamination. Groups 1, 2, and 3 are inside the landfill's zone of influence; Groups 4, 5 and 6 are not.

Group 1 - Near northeastern part of landfill and southwestern arm of plow shop pond.

Group 2 - North end of landfill.

Group 3 - South and southeast sides of landfill.

Group 4 - SHL-15 alone.

Group 5 - Apparent background wells.

Group 6 - Wells outside the landfill but apparently receiving contamination from some other source.

[a] Round 1.
[b] Round 2.
[c] These values exceed their upper prediction limits and cannot be attributed entirely to suspended sediment (see Appendix K).

Source: Ecology and Environment, Inc., 1992

groundwater contamination found in the POL wells will be considered in the risk assessment for the DRMO AOC.

Because of the suspended sediment, meaningful comparisons between the metals concentrations in wells within the landfill's zone of influence and the concentrations in the background wells cannot be made using the unadjusted data. Consequently, only metals that were not detected or detected only once or twice could be eliminated as COPCs based on detection frequencies and unadjusted metals concentrations. Metals eliminated on this basis included cobalt, mercury, and silver.

Several other metals were eliminated as COPCs because they are commonly found in groundwater at comparable concentrations. They are essential nutrients generally regarded as having low toxicities and there are no quantitative toxicological indices (reference doses and slope factors) available to use in assessing them. Metals in this group included calcium, iron, magnesium, potassium, and sodium. The maximum concentrations of aluminum, calcium, iron, and magnesium in wells within the landfill's zone of influence were higher than in the background wells. The range of concentrations of potassium and sodium in the background wells and the wells within the landfill's zone of influence were similar. Aluminum also exhibits relatively low toxicity and lacks quantitative toxicological indices, and was eliminated for this reason. The remaining metals, arsenic, barium, beryllium, cadmium, chromium, copper, lead, manganese, nickel, vanadium, and zinc were selected as COPCs.

The anions generally had similar concentrations in the background wells and the wells within the zone of influence. A notable exception was bromide, which was not detected in the background wells but was detected in nine of 26 samples from wells inside the zone of influence. The occurrences of bromide seem to coincide with wells exhibiting elevated metals concentrations. No quantitative toxicological indices are available for bromide, so it could not be included in the quantitative risk assessment; however, it will be considered qualitatively.

Trichloroethene was the only organic chemical with a confirmed hit in a background well. All other confirmed organic hits were in wells inside the zone of influence or in SHL-15. All of the organic chemicals with confirmed hits in wells within the zone of influence or in SHL-15 were selected as COPCs except acetone, chlorobenzene, and diethylphthalate. Each of these chemicals was detected only once at a concentration well below that associated with adverse health effects and none are carcinogens.

Seep Area Soils/Sediments

No COPCs were selected for the surface soil/sediment samples collected from the three seep areas identified on the landfill (see Table 5-3). The metals concentrations found were all within the range of concentrations found in the background soil samples except for the calcium concentration in SEL-SHL-03. This sample was above the observed background range but below the upper tolerance limit for calcium. Acetone and methylene chloride were the only organics detected and the occurrences of these chemicals were attributed to sampling or laboratory contamination.

Plow Shop Pond/Nonacoicus Brook Sediments

The analytical results for the Plow Shop Pond/Nonacoicus Brook sediments are presented in Table 5-8 of this report and are summarized in Table 8-7. All of the metals detected in the sediment exceeded the upper tolerance limit for local soils except aluminum and zinc, which were excluded as COPCs for this reason. The spatial distribution of the remaining metals in the pond sediments are shown in Figures 5-3 through 5-12 in Section 5 of this report. The highest concentrations of arsenic, iron, and manganese (see Figures 5-3 through 5-5) are found on the west side of the pond, particularly in the southwestern arm of the pond near wells SHL-4, -11, and -19, which also had elevated levels of these metals. Thus, the elevated sediment concentrations of these metals clearly appear to be related to the landfill. The findings for barium and cadmium (see Figures 5-6 and 5-7) are slightly more ambiguous but may also be related to the landfill. Conversely, chromium, copper, lead, mercury, and nickel are highest in sediments on the east side of the pond (See Figures 5-8 through 5-12). These metals may have entered Plow Shop Pond either via the culvert from Grove Pond or may be associated with the railroad right-of-way.

One potential source of the latter group of metals may have been the tannery that was located on the east side of Grove Pond from 1944 until it burned down in 1961. The debris remaining after the fire was reportedly bulldozed into Grove Pond.

The spatial distribution of the metals in Plow Shop Pond sediment indicates fairly clearly that only arsenic, barium, cadmium, iron, and manganese appear to be related to the landfill. The other metals appear to have come from some other source. None of the metals exceeded its upper tolerance limit in samples SE-SHL-14 and -15 taken from the wetland between the landfill and Nonacoicus Creek. On the bases of this information, arsenic, barium, cadmium, and manganese were selected as COPCs for sediment. Iron was not selected because it is an essential nutrient with low toxicity and because there are no quantitative toxicological indices available for use in evaluating it. The other metals were not selected as COPCs because they did not appear to be site related, however they were evaluated separately in the quantitative risk assessment for completeness and to facilitate a future base- or area-wide risk assessment.

Low levels of both 4,4'-DDE and heptachlor were confirmed in SE-SHL-2. These hits were not obviously site related, but both chemicals are carcinogens so they were also evaluated separately in the quantitative assessment. Several PAH compounds were found in samples SE-SHL-9, -11, and -12 along the railroad right-of-way on the eastern

Table 8-7

**SUMMARY OF RI SEDIMENT RESULTS FOR
AOC 5 - SHEPLEY'S HILL LANDFILL - PLOW SHOP POND**

Chemical	Detection Frequency	Range of Detected Concentrations (µg/g) Min		Max	Upper Tolerance Limit for Local Soil Concentrations	Exceedence Frequency	Apparent Principal Source
Inorganics							
Aluminum	14/15	963	-	24,000	30,300	6/15	RR/Grove Pond
Arsenic[a]	15/15	17	-	3,200	66	13/15	Shepley's Hill Landfill
Barium[a]	15/15	9.68	-	310	91	11/15	Shepley's Hill Landfill
Beryllium	8/15	0.4	-	2.72	1.0	8/15	RR/Grove Pond
Cadmium[a]	12/15	4.38	-	60.2	5.5	12/15	Shepley's Hill Landfill
Chromium	13/15	11.8	-	10,000	89	12/15	RR/Grove Pond
Copper	11/15	4.74	-	132	51	8/15	RR/Grove Pond
Iron	14/15	1,400	-	330,000	40	10/15	Shepley's Hill Landfill
Lead	15/15	7.76	-	632	275	8/15	RR/Grove Pond
Manganese[a]	12/15	84	-	8,800	590	8/15	Shepley's Hill Landfill
Mercury	14/15	0.099	-	130	0.88	13/15	RR/Grove Pond
Nickel	10/15	6.35	-	79.3	53	6/15	RR/Grove Pond
Vanadium	11/15	5.14	-	166	64	6/15	RR/Grove Pond
Zinc	3/15	20.5	-	42.8	105	2/15	—

RC424

Key at end of table.

Table 8-7 (Cont.)

Chemical	Detection Frequency	Range of Detected Concentrations (µg/g) Min	Max	Upper Tolerance Limit for Local Soil Concentrations	Exceedence Frequency	Apparent Principal Source
Organics						
Acetone	9/15	0.058	0.543	—	—	—
2-Butanone	5/15	0.023	0.129	—	—	—
4,4'-DDE	1/15		0.172	—	—	—
Heptachlor	1[b]/15	—	0.020	—	—	—
PAHs	3/15	3.53	12.8	—	—	RR/Grove Pond

RC424

Key:

[a]Selected as COPC.
[b]Confirmed by second column analysis.
[c]Suspected laboratory contaminant.

Source: Ecology and Environment, Inc., 1992

side of the pond. PAHs are formed whenever organic matter is burned. The greatest number and highest concentrations of PAHs were found in sample SE-SHL-12, taken from near the culvert inlet from Grove Pond. The spatial distribution of the PAHs suggests that the most likely source of these chemicals may have been the tannery fire debris reportedly bulldozed into Grove Pond. Another possible source could be creosote used in treating railroad ties. Whatever the source of PAHs, their spatial distribution indicates that they are probably unrelated to the landfill. Therefore they were not selected as COPCs for the landfill but separate assessments of these chemicals have been provided for completeness.

Acetone and 2-butanone were also detected at low levels in a number of sediment samples. Acetone and 2-butanone were not found in the groundwater near the pond or in the surface water from the pond, and their spatial distribution in the sediment shows no particular relationship to the landfill. Acetone and 2-butanone were not selected as COPCs because both were found only in low concentrations, both exhibit relatively low noncarcinogenic toxicity, neither appears to be site related, and neither is a carcinogen.

Surface Water

The analytical results for surface water samples from Plow Shop Pond and Nonacoicus Brook are presented in Table 5-7 of this report and are summarized here in Table 8-8. The metals concentrations in the surface water are generally low and may reflect the concentrations typically found in the area. However, with the presence of contaminated sediment throughout the pond and historical information indicating that Grove Pond may have been the source of some of the contaminants, none of the surface water samples can confidently be regarded as representing background water quality. In the absence of reliable background samples, the chemical concentrations found were compared to Ambient Water Quality Criteria (AWQC) for human health based on water and fish consumption. No AWQC has been established for zinc, so its secondary drinking water MCL was used as a reference point. Of the metals detected in the surface waters, the highest concentrations of barium, chromium, copper, silver, and zinc were at least 10 times lower than their AWQCs (or MCL in the case of zinc). These metals were excluded as surface water COPCs because they are unlikely to contribute significantly to any site-related risks.

Arsenic, iron, manganese, and nickel exceeded their AWQCs. The AWQCs for iron and manganese appear to be based on their secondary drinking water MCLs, which in turn are based on aesthetic considerations (taste, odor, and appearance) rather than health effects. Iron is an essential nutrient with relatively low toxicity. In addition, no toxicological indices are available for use in assessing iron. Iron was excluded as a COPC for these reasons. The spatial distribution of the higher concentrations of nickel in the surface water suggests that they are probably not related to the landfill. Nickel exhibits a band of higher concentrations extending from SW-SHL-1 on the south side of the

Table 8-8

SUMMARY OF RI SURFACE WATER RESULTS FOR AOC 5 - SHEPLEY'S HILL LANDFILL-PLOW SHOP POND AND NONACOICUS BROOK

Chemical	Detection Frequency	Range of Detected Concentrations (μg/L) Minimum	Maximum	Benchmark Health Risk Value (MCLs)	Ambient Water[a] Quality Criteria, Human Health
Inorganics					
Arsenic[e]	15/15	2.99 -	6.96	50	2.2×10^{-3}
Barium	15/15	3.35 -	15.2	1,000	1,000
Chromium	1/15		4.9	100	50[d]
Copper	13/15	4.59 -	48.7	1,300	1,300
Iron	15/15	214 -	1,100	300[c]	300
Manganese[e]	15/15	7.81 -	500	50[c]	50[c]
Nickel[e]	8/15	10.2 -	44.2	100	13.4
Silver	2/15	0.564 -	3.6	—	91
Zinc	5/15	21.5 -	58.1	5,000[c]	—
Organics					
Chloroform[e]	6[b]/14	0.996 -	1.410	100	0.19
Endrin	1/15		0.008	0.2	0.76

RC424

[a] Based on water and fish consumption, USEPA Clean Water Act.
[b] Suspected laboratory contaminant.
[c] Secondary MCL based on aesthetic considerations.
[d] Hexavalent chromium.
[e] Selected as COPC.

Source: Ecology and Environment, Inc., 1992

pond, across the pond to its present outlet from the northwestern arm to Nonacoicus Creek. However, the band skips samples SW-SHL-5 and -6, which are closest to the pond's western shore and to the landfill. Copper and zinc exhibit a similar pattern to that of nickel but remain well below their respective criteria.

A discussion of the copper, nickel, and zinc results appears in Section 5.1 of the report. That section raises the possibility that the band of higher concentrations may have resulted from upwelling of groundwater from the landfill into the pond. However, examination of the data indicates that the concentrations of copper, nickel, and zinc in the surface water band are higher than those in monitoring wells adjacent to the pond, which rules out that potential connection to the landfill. While it is unlikely that the nickel in the surface water could be related to the landfill, it was included in the risk assessment for completeness and to facilitate a future base- or area-wide risk assessment.

The concentrations of arsenic in the surface water only varied by about a factor of 2 across the entire pond. However, the majority of the higher concentrations were found on the western side of the pond, with two of the three highest concentrations occurring in samples SW-SHL-5 and -6 closest to the landfill and to the areas where arsenic contamination was found in the groundwater and pond sediment. Most of the higher arsenic concentrations appear to be related to the landfill, therefore arsenic was selected as a COPC.

Endrin was detected only once at a concentration close to its detection limit and nearly 100 times lower than its AWQC. The single hit was not considered significant and endrin was not selected as a COPC. Chloroform was detected at nearly identical concentrations in samples SW-SHL-1 through -6, which suggests some type of sampling or laboratory contamination. This could not be firmly established from the QC data, however. Samples 1 through 6 are from the western side of the pond near the landfill but chloroform was not found in the groundwater near the pond or in the pond sediments. While it appears unlikely that the chloroform found in the surface water is related to the landfill, chloroform is a carcinogen and will also be included in the risk assessment for completeness.

Air

The results of the air quality survey are presented in Appendix G of this report and shown in Tables 6-1 and 6-2 in Appendix G. No chemicals were found in ambient air samples at concentrations significantly different from background concentrations; therefore, no COPCs were selected for air.

Methane generation can sometimes be a problem at municipal landfills. However, soil gas was not investigated as part of the RI at Shepley's Hill Landfill. Therefore there is no basis upon which to assess potential contaminant migration by this pathway in the risk assessment.

Summary of Chemicals of Potential Concern

The chemicals selected as being of potential concern in environmental media potentially affected by Shepley's Hill Landfill are summarized in Table 8-9.

Most metals can exist in the environment in more than one oxidation state. The analytical methods used in this investigation do not distinguish between the various forms. Generally, this is not an issue when assessing risks associated with most metals, since a single toxicity value is used for each metal regardless of the oxidation state. However, the two major forms of chromium, hexavalent (Cr [VI]) and trivalent (Cr [III]), have different potential adverse health effects and different toxicological indices. Therefore, for the risk assessment, some assumptions must be made regarding the form of chromium present in each environmental medium of concern at Shepley's Hill Landfill.

The two forms of chromium are interconvertible under natural conditions in aquatic environments. Cr(VI) is much more soluble than Cr(III). If environmental conditions favor Cr(VI), then chromium will accumulate as soluble forms in water, however, if conditions favor Cr(III), then accumulation will occur in the sediments (Callahan et al. 1979). Because little chromium was detected in the surface water in Plow Shop Pond despite the very high concentrations found in the sediment, and given the fact that Cr(III) is the form that would have been used at a tannery (which is the probable source of chromium contamination in the pond), the chromium found in the sediment is assumed to be Cr(III) for this risk assessment. Chromium detected in groundwater is assumed to be the more soluble Cr(VI).

8.1.3 Exposure Assessment

8.1.3.1 Exposure Setting

The physical setting of the site including geology, hydrogeology, climate, and current land uses are discussed in Section 1.3.

Potentially Exposed Populations

Chemicals of potential concern have been found in groundwater in the landfill's zone of influence and in surface water and sediment in Plow Shop Pond adjacent to the landfill. No COPCs were found in soil or ambient air. The potentially exposed populations are therefore the groups that might come in contact with contaminants in the surface water or sediment in Plow Shop Pond or the groundwater affected by the landfill. These would include fishermen who could be exposed to the water in Plow Shop Pond while fishing; the fishermen and their families and friends who might eat contaminated fish caught in the pond; visitors

Table 8-9

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN FOR SHEPLEY'S HILL LANDFILL[a]

Chemical	Groundwater	Surface Water	Sediment
Inorganics			
Arsenic	X	X	X
Barium	X		X
Beryllium	X		o
Cadmium	X		X
Chromium	X		o
Copper	X		o
Iron			
Lead	*		*
Manganese	X	X	X
Nickel	X	o	o
Vanadium	X		o
Zinc	X		
Bromide	*		
Volatile Organics			
Benzene	X		
Chloroethane	X		
Chloroform	X	o	
1,1-Dichloroethane	X		
1,2-Dichloroethane	X		
Methylene chloride	X		
1,1,2,2-Tetrachloroethane	X		
Vinyl chloride	X		

RC424

Key at end of Table.

Table 8-9 (Cont.)

Chemical	Groundwater	Surface Water	Sediment
Semivolatile Organics			
Benzo(a)Anthracene			o
Chrysene			o
Fluoranthene			o
Naphthalene			o
Phenanthrene			o
Pyrene			o
Pesticides/PCBs			
Alpha-hexachlorocyclohexane	X		
Alpha-chlordane	X		
4,4'-DDE			X
Dieldrin			
Heptachlor	X		X
PCB-1260	X		
Explosives			
1,3-Dinitrobenzene	X		
Tetryl	X		
1,3,5-Trinitrobenzene	X		

RC424

Key:

X Chemical selected as a COPC.
* Chemical selected as a COPC but will be evaluated qualitatively because reference doses (RFDs) and slope factors (SFs) have not been established.
o Chemical does not appear to be site-related but will be included in the risk assessment to facilitate completion of an area or basewide risk assessment.
[a] No COPCs were identified in seep area soils/sediments or air.

Source: Ecology and Environment, Inc., 1992

to the pond (most likely adolescents playing) who might come in contact with contaminated sediment and surface water while wading or swimming; and possible future users of the affected groundwater (there are no known current users). All of these groups would probably consist of individuals living or working on or near the base either now or in the future.

There are a number of housing areas on the base. The closest are located about 0.5 to 0.75 mile west and southwest of the landfill and nearly a mile from Plow Shop Pond. The Base Elementary School is located about 0.5 mile southwest of the landfill and 0.8 mile southwest of the pond. Parts of the Town of Ayer are located within 0.25 mile north and east of the landfill and Plow Shop Pond. There are administrative, light industrial, and some support services (snack bar, gymnasium, etc.) on the base located closer to the landfill than the base housing areas. However, there is nothing about any of these activities that would be especially likely to bring workers or visitors to these areas into contact with site-derived contaminants.

Since Fort Devens is slated for closure, additional areas of the base, including areas around the landfill, could be converted to residential use in the future; and private wells might be installed to provide the new homes with drinking water. This is probably unlikely since the base has an existing water supply system, however it cannot be ruled out. Individuals living in these homes might be exposed to landfill-related groundwater contaminants.

8.1.3.2 Potential Exposure Pathways

A schematic depiction of the potential pathways is shown in Figure 8-2, the conceptual site model.

Sources and Receiving Media

The Shepley's Hill Landfill was formerly operated as an open burning site. It received primarily household debris. Flammable liquids reportedly were also disposed of in the landfill. Currently the landfill receives about 6,500 tons/year of household refuse, military refuse, and construction debris.

The landfill is unlined and until recently was uncapped, allowing precipitation to infiltrate through buried waste to groundwater. Contaminants that have been detected in groundwater within the landfill's zone of influence include metals, VOCs, pesticides, and explosives.

Contaminant Fate and Transport

The fate and transport of contaminants in the environment are influenced by a variety of site- and chemical-specific factors. Environmental fate and transport processes for the COPCs at the

Shepley's Hill Landfill site, which are discussed in Section 6, are summarized briefly in this section.

Metals are persistent in the environment, but their chemical and physical forms can change depending on environmental conditions. Metals in soils and sediment may be in a metallic form, sorbed or chelated by organic matter or oxides, sorbed on exchange sites of soil colloids, or dissolved in soil water. Most metals are immobile at usual soil pH ranges and become significantly leachable only if acidic solutions percolate through the soils. At the normal range of soil pH values, metals usually do not leach at an appreciable rate. Other environmental factors that influence metal mobility include soil clay content, organic content, oxidation-reduction potential, carbonate content, and groundwater chemistry.

Speciation of metals is also an important factor in their mobility. If the metals are present as oxides or hydroxides, they will remain relatively immobile in soils and sediments. If they are present as soluble salts, the most likely reaction that may occur is the hydrolysis of metals to either oxides or hydroxides, or the precipitation of low solubility sulfates or carbonates. At the Shepley's Hill Landfill site, elevated levels of metals have been detected in site groundwater, which discharges to Plow Shop Pond. Elevated concentrations of several of the metals present in groundwater have been found in the pond sediments adjacent to the landfill. Some metals, such as arsenic and cadmium, can bioconcentrate in aquatic organisms.

The VOCs, which have moderate to high vapor pressures, high water solubility, and little tendency for adsorption by soil and sediments, are highly mobile in the environment. At the surface, VOCs can volatilize to the atmosphere; in the subsurface, they can migrate downward with infiltrating precipitation, eventually reaching groundwater. Most organic contaminants undergo biotransformation or biodegradation in soil or groundwater when environmental conditions are favorable. Chlorinated methanes (chloroform, methylene chloride) and chlorinated ethenes (vinyl chloride) undergo sequential reductive dehalogenation under anoxic conditions (Smith and Dragun 1984).

The pesticides, which have low water solubilities and a tendency to adsorb to soils, are relatively immobile in the subsurface. Some pesticides are persistent in the environment and may bioaccumulate in aquatic environments.

The contaminants associated with explosives (tetryl, dinitrobenzene, trinitrobenzene) are fairly soluble and readily leach to groundwater. These chemicals undergo biotransformation when environmental conditions are favorable.

Complete Exposure Pathways

As shown in Figure 8-2, the following exposure pathways are potentially complete under existing site conditions:

- o Incidental ingestion of surface water while fishing in Plow Shop Pond and consumption of fish caught in Plow Shop Pond by recreational fisherman and their families;

- o Direct contact (dermal contact and incidental ingestion) with contaminated pond sediments along the landfill shoreline by site visitors; and

- o Direct contact (dermal contact and incidental ingestion) with surface water by site visitors swimming in Plow Shop Pond.

If land surrounding the landfill is converted to residential use without prior remediation, the same exposure pathways would exist for future residents. In addition, if the groundwater is used as a potable water source by future site residents, four routes of exposure associated with groundwater usage could potentially be complete:

- o Ingestion of contaminated groundwater as drinking water;

- o Dermal contact with contaminated groundwater while bathing or showering, or through other household water uses;

- o Inhalation of contaminant vapors while bathing or showering, or through other household water uses; and

- o Consumption of homegrown fruits and vegetables watered with groundwater.

The potentially complete exposure pathways and receptors are summarized in Table 8-10. The pathways selected for quantitative evaluation are identified along with a reason for their selection or exclusion.

Most of the pathways will be included in the quantitative evaluation. The exception is exposure to surface water by site visitors who swim in Plow Shop Pond. Although swimming has been reported near the outlet of Plow Shop Pond, the frequency of this occurring is probably very low. Access to the pond is impeded by some of the adjacent land uses (the base to the south and west, a wetland to the northwest, and industrial and commercial facilities to the north) and the edges of the pond tend to be shallow and abundantly vegetated, making it relatively undesirable for swimming. Additionally, the concentrations of site-related COPCs in the surface water are low, well below the concentrations found in pond sediment. The potential risks to site visitors from exposure to surface water are probably far less than the risks posed by their exposure to pond sediment. Exposure to COPCs in sediment at the shoreline is being assessed using pond bottom sediment data, which also addresses exposures to sediment contaminants that might occur while wading in the pond.

Table 8-10

POTENTIAL HUMAN EXPOSURE PATHWAYS
SHEPLEY'S HILL LANDFILL

Potentially Exposed Population	Exposure Pathway	Pathway Selected for Evaluation?	Rationale
CURRENT LAND USE			
Fishermen and their families	Consumption of contaminated fish caught from Plow Shop Pond.	Yes (1A)	Arsenic and cadmium in in sediment can bioaccumulate in fish.
	Incidental ingestion of surface water while fishing.	Yes (1B)	Low levels of COPCs in surface water.
Site visitors (mainly adolescents)	Dermal contact and incidental ingestion of shoreline pond sediments	Yes (2A and 2B)	Probable low exposure rate but substantial COPCs concentrations are present in the sediments.
	Dermal contact and incidental ingestion of pond water while swimming	No	Concentrations of COPCs in surface water much lower than those in sediments. Probable exposure rate is also lower.

RC424

RC424

Table 8-10 (Cont.)

Potentially Exposed Population	Exposure Pathway	Pathway Selected for Evaluation?	Rationale
FUTURE RESIDENTIAL USE			
Residents	Consumption of groundwater as drinking water; dermal contact with and inhalation of groundwater organics while showering or bathing.	Yes (3A, 3B, and 3C)	Presence of COPCs in groundwater; use of groundwater for domestic supply is possible.
Residents	Consumption of home-grown produce watered with groundwater.	Yes (3D)	Accumulation of some COPCs in produce is possible.
Residents (mainly adolescents)	Dermal contact and incidental ingestion of shoreline pond sediments.	Yes (4A and 4B)	Substantial COPCs concentration present in the sediment.
	Dermal contact and incidental ingestion of pond water while swimming	No	Concentrations of COPCs in surface water are <u>much</u> lower than those in sediments. Probable exposure rate is also lower.
Residents	Consumption of contaminated fish caught from Plow Shop Pond.	Yes (1A)	Arsenic and cadmium in sediment can bioaccumulate in fish.
	Incidental ingestion of surface water while fishing.	Yes (1B)	Low levels of COPCs detected in surface water.

RC424

Source: Ecology and Environment, Inc., 1992

8.1.3.3 Quantification of Exposure

This section describes how the quantitative exposure estimates were obtained. The first part describes how the exposure point contaminant concentrations used in the exposure assessment calculations were selected or derived, and the second part describes the exposure estimation calculations for each receptor and route of exposure.

Exposure Media Concentrations

The exposure media of concern at this site are groundwater, pond water, pond sediment, and fish from the pond. For each of these media, the average chemical concentration and the maximum observed concentrations from the relevant RI data were used as estimates of exposure point concentrations for the average exposure and reasonable maximum exposure (RME) cases. For calculating averages, non-detects were regarded as one-half the quantitation limit if there was reason to believe the chemical might be present. Otherwise they were regarded as zero.

As discussed in Section 8.1.2.3, most of the groundwater samples contained suspended sediments (soil minerals), which resulted in artificially high concentrations of many metals in these samples due to the natural metals content of the entrained soil minerals. Since metals associated with suspended sediments found in monitoring well samples are unlikely to pose a health risk, a method was devised for estimating the contribution of suspended sediment to the observed metals concentrations. The observed values were then adjusted by deducting the estimated sediment contribution (see Appendix K). The adjusted concentrations for each sample is given in Table 8-6.

The estimated contribution of the sediment was obtained from the regression equation for each of the metals concentrations versus the aluminum concentration. Because of the natural variability in both metals concentrations, some of the actual sample values fell above or below the regression line, as can be seen in the scatterplots in Appendix K. Thus, when the estimated sediment contributions taken from the regression line are deducted from the observed metals concentrations, some of the adjusted concentration values are positive and some are negative. The positive values were incorporated directly into Table 8-6; however, because negative concentration values are meaningless, they were simply reported in the table as less than the metal's CRL.

Some samples had adjusted metals concentrations that fell farther above the regression line (above the upper prediction limit - see Appendix K) than would be expected based just on sample variability. These metals concentrations are not entirely attributable to suspended sediment and are regarded as reflecting actual groundwater contamination. Values in this category are identified in Table 8-6 with a superscript "c."

In Table 8-6, the wells are arranged in groups according to their location around the landfill to make patterns of contamination more apparent. The first three groups are located within the landfill's zone of influence. The first group of wells are those near the northeastern part of the landfill and the southwestern arm of Plow Shop Pond. The second group is located at the north end of the landfill, the third group is along the south and southeast side of the landfill, and well SHL-15 is alone in the fourth group. The fifth group consists of the apparent background wells and the sixth group includes wells outside the landfill's zone of influence, but which evidently received contamination from some other source(s). The water concentrations corresponding to 10^{-4} and 10^{-6} risk levels for carcinogens and a hazard index of 1 for noncarcinogens, using standard default drinking water exposure assumptions (consumption of two liters per day by a 70 kg individual 350 days per year over 30 years, (USEPA 1991h)) and the toxicity indices listed in Tables 8-23 and 8-24 (in Section 8.2.4), are given in Table 8-11 to show which contaminants and which groundwater areas might pose the greatest threat to human health.

Groundwater exposures were evaluated for three sets of wells. The first is composed of all monitoring wells within the landfill's zone of influence (Groups 1, 2, and 3 described above). The second includes only well SHL-15, which is outside the landfill's zone of influence, but which appears to be contaminated from another source. The third set is composed of the remaining contaminated wells that fall outside the landfill's zone of influence (Group 6 described above); these were evaluated to provide information for a future base-wide risk assessment. Groundwater exposure point concentrations were determined first using the original groundwater data from the RI, and then using adjusted data with metals concentrations reduced by the amount attributable to suspended sediment in the groundwater. (The adjusted groundwater data are presented in Table 8-6.)

The groundwater exposure point concentrations were used to evaluate drinking water ingestion and dermal absorption while showering. Vapor concentrations used for evaluating contaminant inhalation during showering were calculated from the water concentrations using a shower volatilization model developed by Foster and Chrostowski (1986). The model is presented in Appendix L.

The groundwater exposure point concentrations of inorganic contaminants in groundwater were also used to estimate the intake of these contaminants in homegrown fruits and vegetables. The procedure, which uses transfer coefficients to estimate concentrations in plant tissue from concentrations in soil pore water, is described in detail in Appendix M. Organic contaminants in homegrown fruits and vegetables were not assessed because suitable water-to-plant transfer coefficients were not available. However, these contaminants are not expected to accumulate in plants, and their levels in the groundwater are minor compared with those of the inorganics.

Table 8-11

CHEMICAL CONCENTRATIONS IN WATER CORRESPONDING TO DESIGNATED RISK LEVELS

	Risk-Based Concentrations[a] (µg/L)		
Chemical	Cancer Risk = 10^{-6}	Cancer Risk = 10^{-4}	Hazard Index = 1
Inorganics			
Arsenic	0.049	4.9	11
Barium	NA	NA	2,400
Beryllium	0.020	2.0	180
Cadmium	NA	NA	18
Chromium	NA	NA	170
Copper	NA	NA	1,300
Iron	NA	NA	NA
Lead	NA	NA	15[b]
Manganese	NA	NA	3,400
Nickel	NA	NA	670
Vanadium	NA	NA	250
Zinc	NA	NA	6,900
Bromide	NA	NA	NA
Volatile Organics			
Benzene	0.62	62	NA
Chloroethane	NA	NA	76,000
Chloroform	0.28	28	75
1,1-Dichloroethane	NA	NA	790
1,2-Dichloroethane	0.19	19	NA
Methylene chloride	6.3	630	1,700
1,1,2,2-Tetrachloroethane	0.09	9	NA
Vinyl chloride	0.029	2.9	NA

RC424

Key at end of table.

Table 8-11 (Cont.)

Chemical	Risk-Based Concentrations[a] ($\mu g/L$) Cancer Risk = 10^{-6}	Cancer Risk = 10^{-4}	Hazard Index = 1
Pesticides/PCBs			
Alpha-hexachloro-cyclohexane	0.014	1.4	NA
Alpha-chlordane	0.065	6.5	2.2
4,4'-DDE	0.25	25	NA
Heptachlor	0.019	1.9	18
PCB-1260	0.011	11	NA
Explosives			
1,3-Dinotrobenzene	NA	NA	3.6
Tetryl	NA	NA	NA
1,3,5-Trinitrobenzene	NA	NA	4.3

RC424

[a]Using standard default drinking water exposure assumptions (EPA 1991h).
[b]Safe Drinking Water Act Action Level for avoidance of most adverse effects in children.

Key:

NA = Not applicable.

Source: Ecology and Environment, Inc., 1992

The data from all surface water samples from Plow Shop Pond were used to estimate average and maximum surface water exposure point concentrations. For sediment exposures, only the sediment samples collected from the pond near the shoreline were used to estimate the exposure concentrations. The contaminant concentrations in these sediments are most likely to be representative of concentrations that may be present at the shoreline where direct contact exposure might occur. Exposure point concentrations of site-related COPCs in sediment were estimated using data from along the west shoreline where the highest concentrations of these chemicals were found. Exposure point concentrations for chemicals evaluated but not related to the site, which generally showed the highest concentrations on the opposite side of the pond, were estimated using sediment data from along the eastern shoreline of the pond.

A chemical's concentration in fish is a function of its concentrations in the surface water and sediment, and its tendency to bioaccumulate. Contaminant concentrations in the sediment in Plow Shop Pond were so much higher than in surface water, it was assumed that the sediments would be the main source of contaminants in fish tissue. The estimated contaminant concentrations in fish muscle, or the filet, was used to estimate exposure of fish eaters to site contaminants. The fish muscle concentration was estimated by multiplying the average or maximum observed sediment concentration in the pond by a bioaccumulation factor obtained by comparing the concentrations for COPCs reported in the literature for fish tissues with sediment concentrations reported for the same locations.

The relationship between contaminant concentrations in sediment and fish is complex, depending on a variety of factors that can affect a metal's bioavailability. As a result, there is a wide range of sediment-to-fish concentration ratios reported in the literature for some chemicals, such as cadmium. For other chemicals, little or no information is available. Efforts were made to base the bioaccumulation factors used on studies in which the conditions were similar to those in Plow Shop Pond, particularly with respect to sediment concentrations. Further discussion of the selection of bioaccumulation factors and specific references can be found in Section 9, the ecological assessment.

The two site-related chemicals of greatest concern in the sediment are arsenic and cadmium. Both of these chemicals are toxic to fish; therefore, their uptake by fish may be self limiting. Fish that have accumulated large body burdens of these metals may die and not be available for consumption by fishermen.

The bioaccumulation factors used in the human health risk assessment for arsenic and cadmium were 0.002 and 0.03, respectively. Bioaccumulation factors used for copper and mercury, which were not site related but were evaluated for completeness, were 0.19 and 0.11, respectively. Some of these values differ from values used in the ecological assessment because they pertain to concentration in the filet rather than the whole fish. Since these values are based on actual sediments and tissue concentrations found in the environment, they automatically include any concurrent uptake of these metals from the water column. Suitable sediment and tissue data could not be located for other metals in Plow Shop Pond sediment.

Concentrations of pesticides in fish from sediment were derived using an equilibrium partitioning approach, also described in Section 9. The resulting bioaccumulation factors for DDE and heptachlor were 1.4 and 1.8, respectively. No bioaccumulation factors were derived for the PAHs because they are metabolized by aquatic organisms and do not significantly bioaccumulate.

Arsenic, chloroform, manganese, and nickel exceeded AWQCs in the surface water. Uptake of arsenic from surface water by fish is included in the sediment bioaccumulation factor. Fish bioconcentration factors for chloroform (3.75 l/kg) and nickel (106 l/kg) were obtained from ambient water quality criteria documents (USEPA 1980a; 1986d). No information was located for manganese. The exposure point concentrations used to estimate receptor exposures are included in the detailed exposure and risk estimate tables in Appendix N.

Exposure Estimation Methods

As explained previously, three exposure scenarios were selected for the quantitative risk assessment: a fishing scenario and a site visitor scenario under current land uses, and a future residential scenario. The exposure estimates for these scenarios are described in this section and combine the following:

- o Estimates of exposure media (surface water, sediment, and groundwater) contaminant concentrations developed in the previous two sections;

- o Estimates of contact rate and the frequency and duration of exposure that receptor populations are likely to experience; and

- o Estimates of various physiological parameters (e.g., breathing rate, body weight, and average life expectancy).

The equations used to estimate the exposure for each pathway and route of exposure are provided in Tables 8-12 through 8-21. The parameter values used to evaluate the equations along with the rationale for their selection and a reference source are also provided.

Two cases were evaluated for each exposure route and receptor to satisfy EPA Region I requirements. In accordance with EPA Region I Guidance (USEPA 1989e), the RME case uses the highest observed contaminant concentrations, and the average case uses the average contaminant concentration in the exposure media along with the standard default exposure factors given in EPA's Supplemental Risk Assessment

Table 8-12

AOC 5: SHEPLEY'S HILL LANDFILL
CURRENT AND FUTURE EXPOSURE:
PATHWAY 1A - INGESTION OF CONTAMINATED FISH
(FISHERMEN AND THEIR FAMILIES)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW/S \times BAF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CW/S = Contaminant Concentration in Water or Sediment (mg/L or mg/kg)
BAF = Bioaccumulation Factor (L/kg or kg/kg)
IR = Ingestion Rate (kg/day) Average Daily Fish Consumption
FI = Fraction of Fish Consumption from Contaminated Source (Unitless)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adult/Child	Average	Average concentration in pond sediment or water
		RME	Maximum observed concentration in pond sediment or water
BAF	Adult/Child	Average/RME	Chemical-specific
IR	Adult/Child	Average/RME	0.054 kg/day (USEPA 1991b)
FI	Adult/Child	Average/RME	0.5 (assumed)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989b)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-13

**AOC 5: SHEPLEY'S HILL LANDFILL
CURRENT AND FUTURE EXPOSURE:
PATHWAY 1B - INGESTION OF SURFACE WATER WHILE FISHING
(FISHERMEN AND THEIR FAMILIES)**

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CW = Contaminant Concentration in surface water (mg/L)
IR = Ingestion Rate (kg/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average RME	Average concentration in pond water Maximum observed concentration in pond water
IR	Adult/Child	Average/RME	0.01 L/day (professional judgement)
EF	Adult/Child	Average/RME	50 days/year (professional judgement)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-14

AOC 5 - SHEPLEY'S HILL LANDFILL
CURRENT EXPOSURE:
PATHWAY 2A - DIRECT DERMAL CONTACT WITH CHEMICALS IN SEDIMENT
(SITE VISITORS)

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times ABS \times CF \times SA \times AF \times EF \times ED}{BW \times AT}$$

where:
CS = Chemical Concentration in Sediment (mg/kg)
ABS = Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
SA = Skin Surface Area Available for Contact (cm^2/event)
AF = Soil-to-Skin Adherence Factor (mg/cm^2)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentrations in shoreline sediments
		RME	Maximum observed concentration in shoreline sediment
ABS	Adolescent	Average/RME	Negligible for metals (EPA 1989e)
SA	Adolescent	Average/RME	3500 cm^2 (hands, one-half arms and one-half legs; surface area; USEPA 1989f)
AF	Adolescent	Average/RME	0.5 mg/cm^2 (Lepow 1975)
EF	Adolescent	Average/RME	26 days/year (professional judgement)
ED	Adolescent	Average/RME	10 years (entire duration of age group 6-16)
BW	Adolescent	Average/RME	42 kg (median body weight for age group 6-16; USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year); and 70-year lifetime for carcinogenic effects (i.e. 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure

Source: Ecology and Environment, Inc. 1992.

Table 8-15

AOC 5 - SHEPLEY'S HILL LANDFILL
CURRENT EXPOSURE:
PATHWAY 2B - INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT
(SITE VISITORS)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times RAF \times CF \times EF \times ED}{BW \times AT}$$

where:
- CS = Chemical Concentration in Sediment (mg/kg)
- IR = Ingestion Rate (mg soil)
- RAF = Relative Absorption Factor (unitless)
- CF = Conversion Factor (10^{-6} kg/mg)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in shoreline sediment
		RME	Maximum observed concentration in shoreline sediment
IR	Adolescent	Average/RME	100 mg/day (USEPA 1991b)
RAF	Adolescent	Average/RME	1.0 for metals and PAHs (USEPA 1989e)
EF	Adolescent	Average/RME	26 days/year (professional judgment)
ED	Adolescent	Average/RME	10 years (entire duration of age group 6-16)
BW	Adolescent	Average/RME	42 kg (median body weight for age group 6-16; USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogens (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effect (i.e., 70 years x 365 days/year.

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-16

AOC 5 - SHEPLEY'S HILL LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 3A - INGESTION OF CHEMICALS IN DRINKING WATER
(ADULT AND CHILD RESIDENTS)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CW = Chemical Concentration in Water (mg/L)
IR = Ingestion Rate (L/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentration in groundwater
	Adult/Child	RME	Maximum observed concentration in groundwater
IR	Adult	Average/RME	2.0 L/day (90th percentile; USEPA 1991b)
	Child	Average/RME	0.50 l/day (90th percentile intake; USEPA 1989f)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1991b)
	Child	Average/RME	5 years (entire period of life in age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1989b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-17

AOC 5 - SHEPLEY'S HILL LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 3B - DERMAL CONTACT WITH CHEMICALS DURING SHOWERING
(ADULT AND CHILD RESIDENTS)

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times PC \times SA \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW = Chemical Concentration in Water (mg/liter)
PC = Chemical-Specific Dermal Permeability Constant (cm/hr)
SA = Skin Surface area Available for Contact (cm^2)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1,000 cm^3)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentrations in groundwater
	Adult/Child	RME	Maximum detected concentrations in groundwater
PC	Adult/Child	Average/RME	Chemical-specific values used
SA	Adult	Average/RME	1.94 m^2 (total body SA for adults; MDEP, 1989a; USEPA, 1989f)
	Child	Average/RME	0.72 m^2 (average total body SA, 3- to 6-year old child; USEPA 1989f)
ET	Adult/Child	Average/RME	0.2 hour/day (12 minutes; 90th percentile; USEPA 1989f)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1991)
	Child	Average/RME	5 years (entire period of life in age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year.)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-18

AOC 5 - SHEPLEY'S HILL LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 3C - INHALATION OF AIRBORNE (VAPOR PHASE) CHEMICALS DURING SHOWERING
(ADULT AND CHILD RESIDENTS)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA = Chemical Concentration in Air (mg/m^3)
IR = Inhalation Rate (m^3/hour)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CA	Adult/Child	Average/RME	Value modeled from water concentration
IR	Adult/Child	Average/RME	0.6 m^3/hr (all age groups, USEPA 1989f)
ET	Adult/Child	Average/RME	0.2 hour/day (12 minutes; 90th percentile; USEPA 1989f)
EF	Adult/Child	Average/RME	350 days/year
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1989f)
	Child	Average/RME	5 years (entire duration of 1-6 year age group)
BW	Adult	Average/RME	70 kg (USEPA 1989f)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effect (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure

Source: Ecology and Environment, Inc. 1992.

Table 8-19

AOC 5 - SHEPLEY'S HILL LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 3D - INGESTION OF CHEMICALS IN
HOMEGROWN FRUITS AND VEGETABLES IRRIGATED WITH GROUNDWATER
(ADULT AND CHILD RESIDENTS)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times (UFF \times IRF + UFV \times IRV) \times EF \times ED}{BW \times AT}$$

where:

CW = Chemical Concentration in Water (mg/L)
UFF = Uptake Factor for Fruit (L/g)
IRF = Ingestion Rate for Fruit (g/day)
UFV = Uptake Factor for Vegetables (L/g)
IRV = Ingestion Rate for vegetables (g/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentration in groundwater
	Adult/Child	RME	Maximum observed concentration in groundwater
UFF	Adult/Child	Average/RME	Chemical-specific value - see Appendix M
IRF	Adult/Child	Average/RME	42 g/day (USEPA 1991b)
UFV	Adult/Child	Average/RME	Chemical-specific value - see Appendix M
IRV	Adult/Child	Average/RME	80 g/day (USEPA 1991b)
EF	Adult/Child	Average/RME	350 days/year
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1991b)
	Child	Average/RME	5 years (entire period of life in age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-20

AOC 5 - SHEPLEY'S HILL LANDFILL
FUTURE EXPOSURE:
PATHWAY 4A - DIRECT DERMAL CONTACT WITH CHEMICALS IN SEDIMENT
(ADOLESCENT RESIDENTS 6-16 YEARS OLD)

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times ABS \times CF \times SA \times AF \times EF \times ED}{BW \times AT}$$

where:
- CS = Chemical Concentration in Sediment (mg/kg)
- ABS = Absorption Factor (unitless)
- CF = Conversion Factor (10^{-6} kg/mg)
- SA = Skin Surface Area Available for Contact (cm^2/event)
- AF = Soil-to-Skin Adherence Factor (mg/cm^2)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in shoreline sediment
	Adolescent	RME	Maximum observed concentrations in sediments
ABS	Adolescent	Average	Negligible for metals; 0.05 for PAHs (EPA 1989e)
SA	Adolescent	Average	3,500 cm^2 (area of hands, one-half arms, and one-half legs; USEPA 1989f)
AF	Adolescent	Average/RME	0.5 mg/cm^2 (Lepow 1975)
EF	Adolescent	Average/RME	100 days/year (professional judgment)
ED	Adolescent	Average/RME	10 years (entire duration of 6-16 year old age group)
BW	Adolescent	Average/RME	42 kg (median body weight for age group, USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year).

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-21

AOC 5 - SHEPLEY'S HILL LANDFILL
FUTURE EXPOSURE:
PATHWAY 4B - INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT
(ADOLESCENT RESIDENTS 6-16 YEARS OLD)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times RAF \times CF \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Sediment (mg/kg)
IR = Ingestion Rate (mg soil)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in shoreline sediment
		RME	Maximum observed concentrations in sediments
IR	Adolescent	Average/RME	100 mg/day (USEPA 1991b)
RAF	Adolescent	Average/RME	1.0 for metals and PAHs (USEPA 1989e)
EF	Adolescent	Average/RME	100 days/year (professional judgment)
ED	Adolescent	Average/RME	10 years (entire duration of 6-16 year old age group)
BW	Adolescent	Average/RME	42 kg (median body weight for age group, USEPA 1989f).
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year).

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Guidance for Superfund (USEPA 1991b). Exposure factors not specified in these guidances are taken from the EPA Exposure Factors Handbook (USEPA 1989f), when possible, or are based on professional judgment.

A third exposure case was evaluated to comply with Massachusetts Department of Environmental Protection (MDEP) risk assessment guidelines. This case uses the average contaminant concentration measured or estimated in each exposure medium along with the default exposure assumptions from Appendix B of Massachusetts Guidance for Disposal Site Risk Characterization and Related Phase II Activities (MDEP 1989a). Exposure equations and parameters for this case are presented in Appendix S.

Two groups of receptors (adults, and children one to six years old) are considered for most of the pathways involving residential exposure. The child receptor was used to evaluate potential risks from subchronic exposures of this potentially sensitive age group, which might otherwise be "diluted" and be overlooked if only a 30-year exposure was considered. The only exception is residents potentially exposed to shoreline sediments, who were assumed to be adolescents from six to 16 years old. The site visitors potentially exposed to shoreline sediments were also assumed to be adolescents in this age range. The individuals fishing and consuming fish caught in Plow Shop Pond were assumed to include adults and children one to six years old.

Acute exposures were not evaluated quantitatively for several reasons. First, the metals, which are the principal contaminants at this site, tend to accumulate in the body, and their most serious adverse effects are usually associated with repeated or chronic exposure. Second, a number of the contaminants are carcinogens, and cancer risks are estimated and expressed as excess lifetime risks. Third, the exposure frequencies postulated are high enough, either in the current or future exposure scenarios, that estimates of potential risks would not be unduly diluted by long averaging times relative to the frequency of exposure. Finally, none of the COPCs are known to produce serious acute toxic effects out of proportion to their chronic or subchronic effects.

For Pathway 1A, ingestion of contaminated fish by fishermen and their families, all of the parameters will be described and discussed in the text; for subsequent pathways, only the key parameters for that pathway and parameters not previously mentioned will be described.

Scenario 1: Exposures of Recreational Fisherman and Their Families.

Pathway 1A – Ingestion of Contaminated Fish by Fisherman and Their Families.

The contaminant concentrations in sediment (CS) and surface water (CW) are the average or the maximum concentrations detected. The bioaccumulation factor (BAF) is a measure of the uptake of the COPCs by fish directly from surface water and sediment and through the aquatic food chain. BAFs were determined as described earlier in this section.

Two key variables specific to the fish ingestion pathways are the fish ingestion rate (IR) and the fraction of fish ingested (FI). The IR is an estimate of the daily fish consumption rate. The IR value from EPA for the RME case (equivalent to about two 7-ounce portions per week) is 0.054 kg/day. The FI is the estimated proportion of total fish consumption that comes from Plow Shop Pond. Since the pond is a small source, the FI is unlikely to exceed half of the total fish eaten per year (see Table 8-12).

The exposure frequency is 350 days per year for both the average and RME case. This represents year-round exposure allowing for two weeks of the year spent away from the area. The exposure duration (ED) is the total number of years during which exposure could occur. The values used are self explanatory. The body weights (BW) used for both exposure cases are the average body weights for the age groups indicated (adult males, or children one to six years old).

Averaging time (AT) is the period over which the estimated exposure is averaged. For noncarcinogens, the averaging time is equal to the exposure duration, while for carcinogens it is taken as the standard life expectancy of 70 years because the carcinogenic potency slope factors (described in Section 8.1.4) are based on lifetime exposure.

Pathway 1B-Ingestion of Surface Water While Fishing

The IR is the key variable for the inadvertent ingestion of surface water pathway. This value (0.01 l/day) is an estimation of the amount of surface water a fisherman might ingest through hand-to-mouth contact. The exposure frequency (EF) is 50 days, or roughly once per week (see Table 8-13).

Scenario 2: Exposure of Site Visitors

Pathway 2A - Direct Dermal Contact with Chemicals in Sediment

The most likely site visitors were judged to be adolescent trespassers. Several parameters are specific to this pathway. The absorption factor (ABS) is a chemical-specific value which describes the fraction that is likely to be absorbed through the skin relative to the absorption in the laboratory study from which the toxicological index was derived. Default relative absorption factors for dermal contact with soils, from Region I guidance (EPA 1989e), were used. The skin area (SA) that might come into contact with the sediment was assumed to be equivalent to that of the hands, one-half of the arms, and one-half of the legs. The soil-to-skin adherence factor (AF) is an estimate of the amount of sediment that might adhere to the skin and serve as a source of exposure.

Potential exposure frequency (EF) was assumed to be 26 days a year. The western shoreline of Plow Shop Pond, where exposure to contaminated sediments could occur, is at least 3/8 mile from the nearest existing residential areas and there is nothing about the area that would be expected to be especially attractive to adolescents. Therefore, exposure was assumed to occur an average of once a week during the warmer half of the year. The ED, the total number of years during which exposure might occur, was 10 years, or the entire duration of the six- to 16-year-old age period (see Table 8-14).

Pathway 2B - Incidental Ingestion of Chemicals in Sediment

The key parameter is the IR, an estimate of the sediment a site visitor might ingest through hand-to-mouth contact. A relative absorption factor (RAF) is included to account for the differing bioavailability between the contaminant in soil or sediment and in the administered medium (e.g., food, water) that is the basis for the toxicological index. Default values from Region I guidance (EPA 1989e) were used (see Table 8-15).

Scenario 3: Future Residential Exposure

The pathways that are potentially complete under current land use conditions would also exist under a future residential scenario; however, the frequency of exposure could be greater for the future on-site resident. In addition, the future resident could potentially be exposed to site-derived contaminants by using the groundwater for domestic purposes.

The equations and parameters used to estimate the potential future residential exposures for each route of exposure are given in tables as follows:

- o Groundwater usage - Pathways 3A, 3B, 3C, and 3D (Tables 8-16 to 8-19).
- o Recreational fishing - Pathways 1A and 1B (Tables 8-12 and 8-13). The equations and parameters are identical to those used for Scenario 1.
- o Direct contact with sediment - Pathways 4A and 4B (Tables 8-20 and 8-21). The equations are identical to those used in Scenario 2. The EF value was increased to reflect on-site residents' greater potential for exposure. Although adults and small children are also potential receptors, the maximally exposed receptor is the adolescent who would be expected to play in the vicinity of the pond.

The recreational fishing and sediment contact pathways have already been discussed. The groundwater usage pathways are described below.

Pathway 3A – Ingestion of Chemicals in Drinking Water

For tap water consumption, the key variable is the IR. The value used is the EPA 90th percentile intake value (see Table 8-16).

Pathway 3B – Dermal Contact with Chemicals While Showering

The permeability constant (PC) is a measure of the COPCs transfer through skin from water. Chemical specific permeability constant (Kp) values recommended by EPA's Dermal Exposure Assessment document (USEPA 1992a) were used. The values used for SA are average total body areas for the two age groups (see Table 8-17).

Pathway 3C – Inhalation of Airborne Chemicals During Showering

The values for inhalation rate and exposure time are the values recommended in the Exposure Factors Handbook (USEPA 1989f) for evaluating this exposure route (Table 8-18).

Pathway 3D – Consumption of Homegrown Fruits and Vegetables Irrigated with Groundwater

The uptake factors for fruits and vegetables (UFF and UFV) are transfer factors relating the contaminant concentrations in the water used to irrigate the homegrown fruits and vegetables to the concentrations in the plant tissue. These factors were derived from information in Baes et al. (1984) and the Exposure Factors Handbook (EPA 1989), and are described in detail in Appendix M. The intake rates for fruits and vegetables (IRF and IRV) are 42 and 80 g/day, respectively, which are the standard default values for this pathway (see Table 8-19).

Information on the values of the transfer factors was available only for individual chemical elements (Baes et al. 1984). Therefore, this pathway could be evaluated only for metals, which are the predominant COPCs at the site. Obtaining reliable transfer factors for organic chemicals is difficult because many organics can be transformed or biodegraded by the plants. In addition, VOCs can be rapidly lost from the plant tissue through evapotranspiration.

The exposure estimates from the equations described above are expressed as chronic daily intakes (CDIs), subchronic daily intakes (SDIs), or lifetime average daily intakes (LADIs) for each complete pathway and exposure case in the risk estimation tables referenced in Appendix N. CDIs and SDIs are used to estimate non-carcinogenic risks. CDIs are calculated for exposure durations greater than 7 years (adults and adolescents in this risk assessment) while SDIs are calculated for exposure durations less than 7 years (children). LADIs are used to estimate excess lifetime cancer risks. The exposure estimates are combined with toxicity estimates for each chemical discussed in Section 8.1.4 to obtain risk estimates. The exposure estimates can be found in the detailed exposure and risk assessment table in Appendix N.

8.1.3.4 Uncertainty in the Exposure Assessment

A number of factors will cause the exposure levels estimated in this section to differ from the exposures that potential receptor populations may actually experience. This section will identify these factors, discuss the potential effects of the factors on the exposure estimates and, where possible and appropriate, estimate the degree of confidence that should be placed in the various assumptions and parameter estimates that have gone into the exposure estimates.

Environmental Sampling

Samples collected during the RI were intended to characterize the nature and extent of contamination at the site. Accordingly, most were collected from locations selected in a purposeful or directed manner to accomplish this goal. Samples collected in this manner provide considerable information about the site but are not statistically representative of the contamination that may be present on the site as a whole. In order to gather statistically representative data, the sampling locations need to be selected in a random or systematic fashion, usually using a grid system.

While the data are not statistically representative, there is no reason to believe that they are not typical of the Shepley's Hill Landfill site area. Development of the source media concentrations used to estimate exposures was discussed previously. In most cases, moderate-sized data sets were used as the basis for the source concentrations.

Analytical Result Limitations

One aspect of the analytical data that could marginally reduce the level of confidence in the estimates of contaminant concentrations in environmental media is the inclusion of estimated results that may not have the same precision and accuracy as data meeting all of the standard QA criteria. This is a very minor concern.

Another aspect is the use of analytical detection limits that could allow potentially hazardous concentrations of some chemicals to go undetected. The estimated cancer risks that would result if arsenic, beryllium, PCBs, and all of the VOCs were present in drinking water at their detection limits exceeded EPA's benchmark risk level of 10^{-6}. This source of uncertainty reduces the level of confidence that can be placed in the upper limit of the risk associated with environmental media in which these contaminants could be present at or close to the detection limit.

Exposure Point Concentration Estimates

Measured values were not available for the contaminant concentrations potentially present in shoreline sediments or in fish in Plow Shop Pond, therefore these exposure point concentrations had to be estimated from concentration values that were available. The extrapolation and estimation techniques used are described in Section 8.1.3.3. Uncertainties in these processes probably lead to overestimation of the actual exposures involved.

Exposure Estimation Calculations

The primary uncertainty regarding the exposure estimation calculations is associated with the selection of appropriate parameter values. The values used and a brief rationale for their selection are provided in Tables 8-12 through 8-21, which describe the exposure calculations for the various pathways. Individual parameter values were selected so that the overall pathway exposure estimates would approximate average and RMEs.

Steady State Assumption

The exposure calculations used in this risk assessment assume that the concentrations of COPCs in the source media are at steady state and remain constant for the duration of the exposure periods, which range from six years to 30 years.

The steady state assumption appears to be appropriate for inorganics in the sediment. The inorganic COPCs neither evaporate nor degrade; therefore, the inorganic contaminant concentrations in the sediment will probably change little over the six- to 30-year exposure periods of interest. The concentrations of contaminants in groundwater could increase or decrease over the next six to 30 years. There are many site-specific environmental factors that will have an effect on groundwater contaminant levels. However, because information needed to reliably estimate future concentrations of COPCs is not readily available, the steady state assumption was used.

Exposure Assessment Uncertainty Summary

Overall, the exposure estimates obtained are probably highly to moderately reliable for COPCs at the Shepley's Hill Landfill site. Several of the factors adding uncertainty to the estimates tend to result in overestimation of the exposure. These include:

- o The directed nature of the sampling program;
- o The use of maximum observed values for source concentrations;
- o The use of estimated and extrapolated values for some exposure point concentrations;
- o The use of many 90th-percentile values in the exposure estimation calculations; and

- o The use of the steady state assumption for source concentration estimates.

Two factors could lead to underestimation of the exposures:

- o The use of sample quantitation limits that could result in missing low concentrations of some contaminants that might pose significant risks; and
- o Evaluation of the fruits and vegetable pathway for metals only. The effect of this factor is probably very minor.

The cumulative effect of all of the exposure uncertainties most likely is to overestimate rather than underestimate the true potential exposure.

8.1.4 Toxicity Assessment

8.1.4.1 Introduction

The purpose of the toxicity assessment is to compile toxicity data for the COPCs at the site and to provide an estimate of the relationship between the extent of exposure to a contaminant and the likelihood and/or severity of adverse effects. The toxicity assessment will be accomplished in two steps: hazard identification and dose-response assessment.

Hazard identification is a qualitative description of the potential toxic properties of the COPCs at the site. Brief health effects summaries for the COPCs are presented in Section 8.1.4.2.

The dose response evaluation is a process that results in a quantitative estimate or index of toxicity for each COPC at the site. For carcinogens, the index is the slope factor (SF) and for non-carcinogens, it is the reference dose (RfD). Practices and procedures used to develop quantitative indices of toxicity and to incorporate toxicological information into the risk estimation process and the quantitative indices of toxicity are presented in Section 8.1.4.3. Uncertainties in the toxicity assessment process are discussed in Section 8.1.4.4

8.1.4.2 Health Effects Summaries

The health effects summaries describe the potential toxic properties of most of the COPCs at Shepley's Hill Landfill. For carcinogens, the weight-of-evidence category is also included. In most cases, the information in the summaries is drawn from the Public Health Statement in the ATSDR's toxicological profile for the chemical (ATSDR 1991). Exposure concentrations that may be associated with adverse effects, or minimal risk levels (MRLs), are included in some of the summaries. MRLs, as used in ATSDR toxicological profiles, are estimates of exposure levels posing minimum risk to humans. Exposures to concentrations below the MRL are not expected to result in adverse noncarcinogenic health effects. MRLs include adjustments to reflect human variability and, where appropriate, the uncertainty of extrapolating from laboratory animal data to humans. The MRLs were developed using generic exposure assumptions appropriate for the general population; therefore, they may differ somewhat from exposure and risk estimates in this assessment that utilize site-specific exposure assumptions.

Arsenic

Arsenic is a naturally occurring element and is usually found combined with one or more elements, such as oxygen or sulfur. This element is widely distributed in the environment from natural sources, but higher concentrations have been found to occur in association with chemical waste, smelting of copper and other metals, fossil fuel combustion, and pesticide use. The primary use of arsenic is as a wood preservative, but it is also used to make insect and weed killers and pharmaceuticals.

All people are exposed to low levels of arsenic because it is naturally occurring and low levels are present in food, water, soil, and air. Workers in several industries (nonferrous smelting, wood preservation, arsenical pharmaceutical production, and production and application of arsenical pesticides) may be exposed to significantly higher levels. Since ancient times, arsenic has been recognized as a human poison. Large oral doses can kill. Chronic arsenic overexposure may cause many health effects including body weight changes, changes in the blood, and liver and kidney damage. The critical or most sensitive effects, based on chronic oral exposure to humans, are hyperpigmentation, keratosis, and possible vascular complications.

Arsenic is considered a Group A human carcinogen by EPA. Epidemiologic studies and case reports have found evidence that arsenic exposure is associated with increased risk of cancer of the skin, lungs, bladder and kidneys. In workers exposed by the inhalation pathway, increased risk of lung cancer is the major carcinogenic effect. If humans are exposed by the oral route, the major carcinogenic effect is an increased risk of skin cancer.

There are no MRLs available for arsenic.

Barium

Barium is a naturally occurring element that makes up 0.05 percent of the earth's crust. Barium compounds are used commercially in the metallurgic, paint, glass, ceramic, and electronics industries and for medicinal purposes.

Background levels of barium in the environment are very low. Barium can enter the body by inhaling air or ingesting food or water containing barium or its compounds. Little is known about the human health effects of barium. Most of the reported data comes from short-term exposure to large amounts of barium. Ingestion of barium can cause many effects including: breathing difficulty; increased blood pressure; changes in heart rhythm, blood, and nerve reflexes; stomach irritation; swelling of the brain; and damage to the liver, kidney, heart, and spleen.

The critical or most sensitive effect from oral exposures, seen in animal studies, is a significant increase in blood pressure. Other long-term effects are changes in function and chemistry of the heart and reduced life span. Adverse effects associated with inhalation of barium dusts have not been well characterized. Smaller litter size and increased miscarriage have been reported as the critical effect from inhalation of barium.

There is no reliable information to determine whether barium can cause cancer in animals or people.

There are no MRLs available for barium.

Benzene

Benzene, in the environment, is from both natural processes and human activity. Today, most benzene is produced from petroleum sources. Benzene has a long history of industrial use, most notably as a solvent and as a starting material for the synthesis of other chemicals.

Benzene evaporates easily, and exposure of the general public to benzene occurs mainly by breathing contaminated air. The major sources of benzene in air are gasoline and automobile exhaust, tobacco smoke, and industrial emissions. It has been estimated that 50 percent of the exposure to benzene in the United States is due to tobacco smoke. Household products including glues, paints, furniture wax, and detergents can also be a source of exposure.

Benzene is readily absorbed by inhalation and ingestion, but is absorbed to a lesser extent through the skin. Most of what is known about the human health effects of benzene exposure is based on studies of workers, who were usually exposed for long periods to high concentrations of benzene.

Benzene is toxic to blood-forming organs and to the immune system. Excessive exposure (inhalation of concentrations of 10 to 100 ppm) can result in anemia, a weakened immune system, and headaches. Occupational exposure to benzene may be associated with spontaneous abortions and miscarriages (supported by limited animal data), and certain developmental abnormalities such as low birth weight, delayed bone formation, and bone marrow toxicity. Benzene is classified as a Group A human carcinogen based on numerous studies documenting excess leukemia mortality among occupationally exposed workers.

An MRL has been established for benzene based on animal studies of immunological effects. The acute inhalation MRL is .002 ppm in air.

Beryllium

Pure beryllium is a hard gray metal. In nature it occurs as a chemical component of certain rocks. The minerals bertrandite and beryl are mined commercially for recovery of beryllium.

Most beryllium ore mined is processed into pure metal, alloys, or beryllium oxide. Beryllium metal and alloys are used in electronics, aircraft and space craft structures, X-ray machines, nuclear weapons, and nuclear reactors. Beryllium oxide is used in the manufacture of specialty ceramics.

Beryllium is released into the air by natural sources such as volcanic dust, however the major emission source to the environment is the burning of fossil fuels. Beryllium compounds are naturally present in soils, but deposition of atmospheric beryllium and disposal of beryllium-containing wastes can increase the levels in localized areas. The general population is exposed to low levels of beryllium in air, food, and water. Beryllium occurs naturally in tobacco and can be inhaled in cigarette smoke.

Industrial workers have the highest exposure to beryllium in the mining, milling, and processing of beryllium to alloys or beryllium oxide. In general, the primary route of exposure to beryllium is inhalation, since relatively little beryllium is absorbed from the gastrointestinal (GI) tract or through the skin.

The respiratory tract is the major target of inhalation exposure to beryllium. Short-term exposure can produce lung inflammation and pneumonia-like symptoms. Long-term exposure can cause berylliosis, an immune reaction characterized by noncancerous growths on the lungs. Similar growths can appear on the skin of sensitive individuals exposed by dermal contact.

Epidemiological studies have found that an increased risk of lung cancer may result from exposure to beryllium in industrial settings. In addition, laboratory studies have shown that breathing beryllium causes lung cancer in animals. However, it is not clear what cancer risk, if any, is associated with ingestion of beryllium.

EPA has classified beryllium as a Group B2-probable human carcinogen based on the limited human evidence and the animal data. The International Agency for Research on Cancer (IARC), has concluded there is sufficient evidence that beryllium is an animal carcinogen, but limited human evidence. Considering both the animal and human studies together, IARC concludes beryllium should be suspected of being a human carcinogen.

No MRLs are available for beryllium.

Bromide

There is little toxicological information on bromide.

Cadmium

Cadmium is a naturally occurring element present in trace amounts in the earth's crust. Cadmium has several industrial applications but it is used mostly in metal plating and the manufacture of pigments, batteries, and plastics.

Humans are exposed to small quantities of cadmium because it is widely distributed in air, water, soil, and food. Cadmium can enter the body by absorption from the stomach or intestines after ingestion of food or water containing cadmium, or by absorption from the lungs after inhalation of cadmium-containing dust, mists, or fumes. Food and cigarette smoke are probably the largest sources of cadmium for the general public. Very little cadmium enters the body through the skin.

Cadmium can cause a number of adverse health effects. Ingestion of high doses causes severe irritation to the stomach, leading to vomiting and diarrhea, while inhalation can lead to severe irritation of the lungs and may cause death. People have committed suicide by drinking water containing high levels of cadmium. There is very strong evidence that the kidney is the main target organ of cadmium toxicity following chronic exposure. Long-term ingestion of cadmium has caused kidney damage and fragile bones in humans. Long-term human exposure by the inhalation route may cause kidney damage and lung disease such as emphysema. The most sensitive or critical effect of cadmium exposure is significant proteinuria, indicative of abnormal kidney function.

Long-term inhalation of air containing cadmium by workers is associated with an increased risk of lung cancer. Laboratory rats that breathe cadmium have increased cancer rates. Studies of humans or animals have not demonstrated increased cancer rates from eating or drinking cadmium. EPA classifies cadmium as a Group B1, probable human inhalation carcinogen based on occupational studies.

A chronic MRL of 0.0002 mg/m^3 in air has been derived from human studies. A chronic MRL of 0.0002 mg/kg/day for ingested cadmium has been derived from human studies of one year or longer duration.

Chlordane/Heptachlor

Chlordane and heptachlor are man-made pesticides. Chlordane was registered for use in the United States until 1988, when carcinogenicity concerns lead to its ban. Commercial chlordane is a mixture composed primarily of cis-chlordane, trans-chlordane, and heptachlor. Similarly, technical-grade heptachlor contains chlordane. Commercial chlordane is a mixture composed of more than 50 different compounds. It is a white, crystalline, solid possessing a mild, pungent odor. Heptachlor and chlordane were wide-spectrum pesticides used on more than 20 types of crops and in household applications to eliminate termites.

Both chlordane and heptachlor persist in the environment. In the environment, heptachlor is converted to heptachlor epoxide, which is more persistent than the parent compound, by chemical and microbial reactions.

Since chlordane and heptachlor were used on food crops and in homes, there are residual levels in soils, ambient air, and indoor air in many parts of the United States. Groundwater levels of chlordane have been found to range from 0.02 to 830 ppb, while in soil, levels up to 57 ppm have been detected.

Chlordane and heptachlor can be absorbed by the body through dermal contact, inhalation of particulates in ambient air, and ingestion of contaminated soils. They may remain stored for months or years in the blood plasma or the body fat of the liver, spleen, brain, and kidneys.

Little data are available on the adverse health effects of chlordane and heptachlor exposure in humans. Symptoms associated with human overexposure to chlordane and heptachlor include headache, dizziness, lack of coordination, irritability, weakness, and convulsions. In humans, an acute oral lethal dose of chlordane was estimated by the World Health Organization (WHO) (1984) to be between 25 and 50 mg/kg.

Experimental studies exploring the health effects on animals exposed to levels of chlordane between 5 and 1,000 ppm showed an association between exposure and immunologic dysfunction, reproductive dysfunction, nervous system damage, liver damage, convulsions, liver cancer, and death. The lethal dose of chlordane in rats is estimated to be between 85 and 560 mg/kg.

Some occupational epidemiology research supports an increased cancer risk with human exposure to chlordane. Chronic oral treatment with chlordane and heptachlor has resulted in significant increases in hepatocellular carcinomas in mice. The EPA has classified chlordane and heptachlor as Group B2-probable human carcinogens. Chlordane has an MRL of 0.0005 mg/m3 in air and 0.02 ppm for long-term oral exposure. MRLs are not available for heptachlor.

Chloroethane

Chloroethane, which is also called ethyl chloride, is a man-made chemical used in manufacturing some pharmaceuticals and commercial chemicals, in the production of the gasoline additive tetraethyl lead, and as a solvent and refrigerant. At room temperature and pressure, chloroethane is a colorless gas.

Most chloroethane released to the environment ends up in the atmosphere. Small amounts of chloroethane can enter the groundwater by infiltrating through the soil. Chloroethane is most likely to enter the body through the lungs after inhalation of chloroethane vapor, although it may also be absorbed from the digestive tract after ingestion of water containing chloroethane.

Brief exposure to high levels of chloroethane vapor can produce temporary feelings of intoxication and, at still higher levels, it can cause loss of muscle coordination and unconsciousness.

The health effects resulting from long-term human or animal exposure to chloroethane are not known. EPA has chosen retarded gestational development as the critical or most sensitive effect.

It is not known whether chloroethane produces cancer in humans; however, there is evidence that long-term exposure to high levels of chloroethane vapor can produce cancer in animals. EPA has not made a carcinogenicity determination for chloroethane.

Various MRLs have been derived for noncarcinogenic effects of chloroethane depending on exposure conditions. The MRL for short-term exposure is 1,300 ppm in air, based on human health effects. The MRL for long-term exposure is 76 ppm in air based on effects in animals.

Chloroform

Chloroform, also know as trichloromethane, is a colorless liquid with a pleasant, non-irritating odor and a slightly sweet taste. Chloroform is used primarily to synthesize other chemicals. Most chloroform found in the environment comes from chemical manufacturing plants, pulp and paper mills, chlorinated drinking water supplies, and chlorination of waste water from sewage treatment plants. Chloroform is highly soluble in water, and it readily evaporates into air where it is ultimately degraded by indirect photochemical reactions. The most likely source of exposure to chloroform is through drinking water and/or breathing air containing chloroform contamination. It can also be absorbed through the skin. Inside the body, chloroform can be transported throughout the body, concentrating mainly in fat tissue, brain, liver, and kidney.

In humans, chloroform has been found to adversely affect the central nervous system (CNS), liver, kidneys, digestive system, heart, and circulatory system after exposure through inhalation or ingestion. CNS effects associated with human exposure to chloroform include dizziness, vertigo, headache, and in some cases death. When used as a anesthetic in the past, chloroform caused irregular heartbeat and low blood pressure. Anesthetic use was discontinued because of liver and kidney damage. Long-term exposure to low concentrations of chloroform also causes liver and kidney damage in humans.

In long-term animal studies, chloroform-induced liver and kidney damage has also been noted. Reproductive effects in mice associated with chloroform inhalation exposure include decreased ability to maintain pregnancy and an increase in birth defects. It is not known if chloroform can cause similar reproductive effects in humans.

Although it is unknown whether long term exposure contributes to the development of cancer in humans, liver and kidney tumors have been associated with oral exposure in mice and rats. Chloroform is classified as a Group B2-probable human carcinogen by EPA based on animal studies.

MRLs have been calculated for chloroform based on health effects in animals and humans. The inhalation MRL for chloroform is 0.009 ppm. The acute oral MRL for chloroform is 0.2 mg/kg/day, and the chronic MRL for chloroform is 0.01 mg/kg/day.

Chromium

Chromium is a naturally occurring element used industrially in the manufacture of steel and other alloys. Its compounds are used in refractory brick for the metallurgical industry, and in metal plating (chromium VI), the manufacture of pigments (both chromium III and chromium VI), leather tanning (chromium III), and other processes. Exposure to chromium can result from inhalation of air containing chromium-bearing particles and ingestion of contaminated water or food. Chromium is considered an essential nutrient that helps to maintain normal glucose, cholesterol, and fat metabolism. The minimum daily requirement of chromium for optimal health has not been established, but ingestion of 20 to 500 µg/day has been estimated to be safe and adequate.

The two major forms of chromium found in the environment differ in their potential adverse health effects. Chromium VI is an irritant, and short-term, high-level exposure can result in adverse effects at the site of contact, causing ulcers of the skin, irritation and perforation of the nasal mucosa, and irritation of the gastrointestinal tract. Minor to severe damage to the mucous membranes of the respiratory tract and to the skin have resulted from occupational exposure to as little as 0.1 mg/m^3 chromium VI compounds. Chromium VI may also cause adverse effects in the kidney and liver, and long-term occupational exposure to low levels of chromium VI compounds has been associated with lung cancer in humans.

The second form, chromium III (chromium 3^+), does not result in these effects and is the form thought to be an essential nutrient. The only effect observed in toxicological studies of chromium III was a decrease in liver and spleen weights in rats.

Because chromium VI is much more water soluble than chromium III, chromium VI toxicity values have been used for chromium in the quantitative risk assessment of groundwater. For chromium accumulated in pond sediment, toxicity values for chromium III have been used in the quantitative risk assessment.

An MRL for inhalation of chromium (VI) of 0.00002 mg/m^3 was derived from noncarcinogenic health effects in humans.

Copper

Copper is a naturally occurring element that is used to make electrical wiring and some water pipes and is a component of alloys such as bronze and brass. Copper compounds are used in gardening supplies to prevent plant disease, in water treatment and in wood, leather, and fabric preservatives.

Copper may enter the body by breathing air, drinking water, or eating food containing copper, and by skin contact with soil, water, and other copper-containing substances. Copper is an essential element at low-dose levels but may induce toxic effects at high-dose levels. The National Academy of Sciences has recommended 2 to 3 mg/day of copper as a safe and adequate daily intake. Long-term overexposure to copper dust can irritate the nose, mouth, and eyes and cause headaches, dizziness, nausea, and diarrhea. Ingestion of high concentrations of copper can cause vomiting, diarrhea, stomach cramps, and nausea. Liver and kidney damage and possibly death may occur if exposure continues.

Very young children are particularly sensitive to liver damage from overexposure to ingested copper. In general, the seriousness of health effects of copper increase as the level and duration of exposure increases. Copper is not known to cause cancer or birth defects.

DDT/DDE/DDD

DDT is a manmade chemical that has been used extensively throughout the world as a broad-spectrum insecticide. Technical grade DDT typically contains 80 percent to 90 percent 4,4'-DDT as well as other components including DDD and DDE. Although the agricultural use of DDT in the United States was banned by the EPA in 1972, it is presently widely distributed in the environment as a result of its extensive past use and its high stability and persistence.

Absorption of DDT has been demonstrated following oral, inhalation, and dermal exposure. The primary route of exposure, however, is the oral route.

The major adverse effects of DDT appear to involve the nervous system, the liver, and reproduction and development of off-spring. In humans, doses of up to 6 mg/kg usually produce no general illness, but headaches, excessive perspiration, and nausea have been reported. Vomiting, due to nervous system effects rather than gastrointestinal irritation, appears at doses of about 10 mg/kg, and convulsions appear at about 16 mg/kg.

At lower doses (250 mg), noted effects are limited to prickling sensations on the tongue and mouth. Intermediate doses (750 mg) were reported to produce sensitivity of the lower part of the face, uncertain gait, cold moist skin, and hypersensitivity to contact. A dose of 1,500 mg produced prickling of the mouth and nose, disturbance of equilibrium, dizziness, confusion, tremors, malaise, headache, fatigue, and severe vomiting. All of the human volunteers orally exposed to DDT at doses of 250 to 1,500 mg recovered within 24 hours.

Although there is insufficient evidence to classify DDT, DDE, or DDD as carcinogens based on human studies, they have been found to be carcinogenic in a number of animal studies, primarily producing liver tumors. EPA classifies DDT, DDE, and DDD as Group-B2 probable human carcinogens.

An oral MRL of 0.0178 ppm DDT has been derived from noncarcinogenic effects in animals.

1,1-Dichloroethane (1,1-DCA)

1,1-DCA is a man-made liquid chemical that is used industrially as a solvent and in the manufacture of other chemicals. When 1,1-DCA is released to surface water or surface soil, the chemical will evaporate into air. Although its water solubility is low, 1,1-DCA can migrate from soil into groundwater. Some 1,1-DCA found in the environment is a breakdown product of 1,1,1-trichloroethane. Human exposure to 1,1-DCA can result from breathing contaminated air or eating or drinking contaminated food or water.

Relatively little information is available on the health effects of 1,1-DCA in humans or animals. 1,1-DCA was once used as a surgical anesthetic gas, although this use was discontinued when it was discovered that irregular heartbeats were induced at anesthetic doses. Exposure to high levels of 1,1-DCA in air has caused death in animals, and long-term exposure to high levels of 1,1-DCA has caused kidney damage in laboratory animals. In addition, exposure of pregnant rats to 1,1-DCA in air resulted in delayed development in the offspring. There is no evidence of similar harmful health effects in humans.

One laboratory study suggests 1,1-DCA may increase the risk of cancer in rats and mice but the results are inconclusive. There is no evidence that 1,1-DCA is carcinogenic in humans. In light of the results of animal studies, the EPA has classified 1,1-DCA as a Group C-possible human carcinogen.

No MRLs for adverse effects for the oral or inhalation routes of exposure have been calculated.

1,2-Dichloroethane (1,2-DCA)

1,2-DCA is a manmade liquid chemical used primarily in the synthesis of other solvents--particularly those that remove grease, glue, and dirt. In the past, 1,2-DCA was also found in commercial and household cleaning agents. When released to surface soil or surface water, 1,2-DCA evaporates readily into air, where it is broken down by sunlight. In the subsurface, 1,2-DCA migrates in soil gas and in groundwater. In soil, groundwater, and surface water 1,2-DCA does not break down rapidly.

Humans are exposed to 1,2-DCA primarily by breathing air containing its vapors or by drinking contaminated water. 1,2-DCA can also enter the body through the skin.

The lungs, heart, liver, and kidneys are the organs primarily affected in both humans and animals exposed to 1,2-DCA. Short-term exposure to 1,2-DCA in air may result in an increased susceptibility to infection and liver, kidney, and/or blood disorders. Effects seen in animals after long-term exposure to 1,2-DCA include liver, kidney, and/or heart disease, and death.

1,2-DCA has caused increased numbers of tumors in laboratory animals when administered in high doses in the diet or on the skin, and is classified as a Group B2-probable human carcinogen.

A short-term exposure MRL of 0.025 ppm in air or 0.026 ppm in water has been derived based on animal studies. The long-term MRL of 0.021 ppm in air or 0.5 ppm in food was also derived from animal studies. The MRLs were derived based on potential noncarcinogenic effects and does not consider the presence, absence, or level of risk of cancer.

Dieldrin

Dieldrin is a man-made chemical that was used extensively as an agricultural pesticide for over 20 years until its use was suspended by the United States Department of Agriculture (USDA) in 1970. Use of dieldrin to control termites continued until 1987, when the manufacturer voluntarily canceled the registration.

Although not used for several years, dieldrin persists in the environment and can be found tightly bound to soils and sediment. Dieldrin is also present as the breakdown product of the related pesticide aldrin.

Plants can take up dieldrin from soil and fish and livestock can accumulate high concentrations through the food chain. In animals, dieldrin concentrates in fat.

Dieldrin can be absorbed into the body through skin contact, ingestion, and inhalation. The most likely route of human exposure to dieldrin is through eating contaminated food. Foods most likely to be contaminated include fish, shellfish, root crops, meat, and dairy products.

Human poisoning from dieldrin is characterized by major voluntary muscle convulsions or kidney damage that can be fatal. Other effects include malaise, uncoordination, headache, dizziness, and gastrointestinal disturbances.

Animal studies show effects of dieldrin on the nervous system and kidneys similar to the effects in humans. In addition, dieldrin exposure has resulted in increases in liver enzymes and liver weight, decreased immune response, and high mortality in nursing rat pups. Liver damage is the critical or most sensitive effect in animals according to EPA. It is unknown whether humans exposed to dieldrin have similar health effects.

Dieldrin is a carcinogen in mice, with the liver being the site of increased tumor incidence. However, there is insufficient evidence to classify dieldrin as a human carcinogen.

Dieldrin is classified as a Group B2-probable human carcinogen by EPA.

MRLs for oral exposure to dieldrin have been derived from animal data on non-carcinogenic health effects. An MRL of 7 x 10^{-5} mg/kg/day has been calculated for short-term exposure, and an MRL of 5 x 10^{-5} mg/kg/day has been calculated for long-term exposure to dieldrin.

1,3-Dinitrobenzene (DNB)

DNB is a man-made solid chemical that occurs as an impurity in TNT (trinitrotoluene) and related explosives. DNB is found in soils where open burning or open detonation of ordnance has occurred as well as in the wastewater of munitions factories. When released to surface soil in the environment, most DNB migrates to deeper soils and groundwater. In general, DNB persists in the environment, although some microorganisms can biodegrade DNB.

Most of what is known about the health effects of DNB comes from occupational studies of workers during World War I and World War II, when DNB was used in explosives manufacture. The primary effect on workers exposed by inhalation and dermal contact is a reversible blood disorder (methemoglobinemia).

Laboratory animals exposed to DNB have shown enlarged spleens as the critical or most sensitive health effects. There is limited evidence from one study that DNB exposure may decrease the litter size of treated rats. It is not known if DNB causes reproductive effects in humans.

There are no data regarding the carcinogenicity of DNB in humans or animals. No MRLs are available.

Hexachlorocyclohexane

Hexachlorocyclohexane (HCH) is a man-made chemical that occurs in eight forms or isomers. The isomers alpha (α), beta (β), gamma (γ), and delta (δ) are all solids that were used primarily as pesticides. The γ isomer, also called lindane, was the active component in pesticide formulations. Commercial lindane contains a mixture of the isomers. The HCH insecticides were used on fruit, vegetable, and forest crops. Lindane is also used as a human medicine for head and body lice and scabies (Kwell). Since the late 1970s, HCH has not been used as a pesticide in the United States, and manufacture of lindane stopped. Lindane is still imported for use in consumer products including dog dips, shampoos, lotions, sprays, and creams.

Although no longer used as a pesticide, former widespread use of HCH pesticides has left α, β, γ, and δ isomers in the air, water and soil. In general lindane is degraded poorly in the environment, but does biodegrade slowly in soil and aerated water.

Human exposure can occur through contact with contaminated air, water, or food. HCH is found in meat and milk as well as fruit and vegetables. In the body, HCH is absorbed rapidly from the digestive tract. In addition, lindane can absorb through the skin when used in lotions, creams, and shampoos.

Data on human exposure comes primarily from occupational studies. HCH can cause lung irritation, heart disorders, and blood disorders. Accidental and suicidal poisonings have caused death in some cases.

Long-term exposure to high doses has caused convulsions, kidney disease, liver disease, and death in laboratory animals. HCH was removed from use as an insecticide because long-term exposure to the α, β, and γ isomers caused liver cancer in mice. EPA has classified α and γ HCH as Group B2-probable human carcinogens based on animal data.

The MRL for short-term exposure to HCH in food and drink is 0.3 ppm. The long-term MRL is 0.02 ppm.

Lead

Lead is a naturally occurring metal that is used in the manufacture of storage batteries and the production of ammunition and miscellaneous metal products (e.g., sheet lead, solder, and pipes). Other uses for lead are in the manufacturing of lead compounds including gasoline additives and pigments.

Lead can enter the body via ingestion and inhalation. Although it may also enter the body through the skin, dermal absorption of inorganic lead compounds is less significant than absorption through other routes. Children appear to be the segment of the population at greatest risk from toxic effects of lead. Children absorb about 50 percent of ingested lead while adults absorb only 5 percent to 15 percent. Initially, lead travels in the blood to the soft tissues (heart, liver, kidney, brain, etc.), then it gradually redistributes to the bones and teeth where it tends to remain. Children retain a larger fraction of the absorbed lead, about 57 percent, in the blood and soft tissue compartments whereas in adults roughly 95 percent of the total body burden of lead is found in bones and teeth.

The most serious effects associated with markedly elevated blood lead levels include neurotoxic effects such as irreversible brain damage. Health effects are the same for inhaled and ingested lead. At blood lead levels of 40 to 100 micrograms per deciliter (μg/dl) children have exhibited nerve damage, permanent mental retardation, colic, anemia, brain damage, and death. Chronic kidney disease is also evident at these levels. For most adults, such damage does not occur until blood lead levels exceed 100 to 120 μg/dl. At these levels, damage to the male reproductive system; miscarriages; anemia; severe digestive system symptoms; decreased reaction time; weakness in fingers, wrists, or ankles; and some increased risk of heart and circulatory system disease may be exhibited.

None of the epidemiology studies conducted to explore the relationship between lead exposure and increased cancer risk in humans found any relationship. However, animal studies have shown increased kidney cancer and CNS cancer in rats and mice orally exposed to lead. The EPA has classified lead as a Group B2-probable human carcinogen.

MRLs are not available for lead because no thresholds have been demonstrated for the most sensitive effects in children.

Manganese

Manganese is a naturally occurring element used in the steel industry, metallurgical processing, and as a component of dry cell batteries. Manganese is an essential element for humans and is a cofactor for a number of enzymatic reactions. A WHO committee concluded that an intake of 2 to 3 mg/day was inadequate for adults.

Following inhalation of manganese dust, absorption into the bloodstream occurs only if particles are sufficiently small to be able to penetrate deeply into the lungs. Long-term inhalation of manganese dust may result in a neurological disorder characterized by irritability, difficulty in walking, and speech disturbances. Short-term inhalation exposure has been associated with respiratory disease.

There are few reports of negative health effects in humans exposed to manganese in drinking water or food. Laboratory studies of animals exposed to manganese in water or food have demonstrated adverse health effects including changes in brain chemical levels, low birth weights in rats when mothers were exposed during pregnancy, slower than usual testes development, decreased body weight gain, and weakness and muscle rigidity in monkeys.

There are no human carcinogenicity data for manganese exposure. The data from some animal studies have shown increases in tumors in a small number of animals at high doses of manganese, but the data are inadequate to judge whether manganese can cause cancer.

An MRL of 2 $\mu g/m^3$ has been derived for manganese in air based on long-term human exposure data.

Mercury

Mercury is a naturally occurring element that exists in three oxidation states--metalic mercury (Hg°), mercurous mercury (Hg_2^{++}), and mercuric mercury (Hg^{++})--and a variety of chemical forms. The most important with respect to human exposure are compounds of methyl mercury, mercuric mercury, and elemental mercury vapor.

Uptake of inorganic mercury and methyl mercury compounds is primarily through ingestion, with the major source of human exposure to methyl mercury being through the consumption of fish and shellfish. Mercury can also readily enter the body through inhalation of mercury vapor.

All forms of mercury, once absorbed, are distributed to tissues throughout the body via the bloodstream. The critical, or most sensitive, effect of inorganic mercury is kidney damage and CNS damage. Long-term exposure to all forms of mercury can permanently damage the brain, kidneys, and developing fetus. The form of mercury and route of exposure determine which health effects will be most severe. Mercury vapor and methyl mercury readily cross the blood-brain and placental barriers.

Prenatal life is very sensitive to methyl mercury poisoning, with effects in infants ranging from slowed mental and coordination development to a severe form of cerebral palsy. To date, these effects have been found to be irreversible. Depending upon the form, the level of mercury taken in, and the duration of exposure, effects on the adult nervous system can range from reversible feeling of burning, or pins and needles, and feeling "out-of-sorts" to irreversible brain damage leading to permanent tremors and shakiness, and constriction of the visual field.

Mercury has not been found to be carcinogenic in animals or humans. A long-term MRL of 0.000032 ppm for metallic mercury in air has been estimated based on effects in humans. A long-term MRL of 0.063 ppm inorganic mercury in food has been estimated based on animal studies.

Methylene Chloride (Dichloromethane, MC)

MC is a man-made liquid chemical that is widely used as an industrial solvent and as a paint stripper. Because MC evaporates easily, most MC released into the environment will end up in the air. Small amounts of MC may be found in some drinking water. Absorption into the body occurs readily following exposure by breathing vapors or accidental ingestion. Occupational worker exposure to MC in air has resulted in drowsiness, fatigue, lack of appetite, and light-headedness. Other effects include impaired reaction time and coordination, numbness or tingling of fingers and toes, and intoxication. The critical, or most sensitive, effect of MC exposure is liver damage observed in rats treated with MC.

Chronic exposure of laboratory animals to high concentrations of MC by inhalation resulted in an increased incidence of liver and lung cancer in mice and rats. MC has not been shown to cause cancer in occupationally exposed humans. Based on results from animal studies, MC is classified as a Group B2-probable human carcinogen.

MRLs for noncarcinogenic effects by inhalation are 0.4 ppm for short-term exposure and 0.03 ppm for intermediate exposure.

Nickel

Nickel is a naturally occurring metal found in small quantities in the earth's crust. Nickel is used industrially in making various steels and alloys and in electroplating. Exposure to nickel and nickel compounds may occur through inhalation of dust and particles, ingestion of food and drinking water containing nickel, and by absorption through the skin. Very small amounts of nickel have been shown to be essential nutrients for some species of animals and may be essential to humans.

Inhalation exposure to high levels of nickel and nickel compounds may have adverse effects on the lungs. Exposure by oral and inhalation routes can also affect the immune system, kidneys, and blood. Inhalation of nickel at concentrations greater than 0.001 mg/m^3 in air may cause immune system depression, lung irritation, and pulmonary disease. Death may result at concentrations greater than 0.1 mg/m^3.

Inhalation of nickel refinery dust has caused cancer of the lung, nasal cavity, and voice box in humans. Nickel refinery dust and nickel subsulfide have been classified as Group A-human carcinogens. It is not known if other nickel compounds are carcinogenic.

MRLs have been derived for long-term exposure by inhalation, and short- and long-term exposure by ingestion. The MRL for long-term inhalation exposure is 0.001 mg/m^3. The MRL for ingestion is 0.125 and 0.015 for short- and long-term exposure, respectively.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular, or cluster arrangements. PAHs are formed during the incomplete burning of fossil fuel, garbage, or any organic matter. PAHs produced by burning may be carried into the air on dust particles and distributed into water and soil. In general, PAHs do not evaporate easily and do not dissolve in water.

Exposure to PAHs may occur by inhaling airborne particles, drinking water, or accidentally ingesting soil or dust containing PAHs. In addition, smoking tobacco or eating charcoal-broiled food are common routes of exposure to PAHs.

Some PAHs are known carcinogens, and potential health effects caused by PAHs are usually discussed in terms of an individual PAH compound's carcinogenic or non-carcinogenic effects. Little attention has been paid to noncarcinogenic effects of PAHs. Rapidly growing tissues, such as the intestinal lining, bone marrow, lymphoid organs, blood cells, and testes seem to be especially susceptible targets to non-carcinogenic effects. Concentrations of 150 mg/kg or more administered to laboratory animals have been shown to inhibit body growth.

Exposure to benzo(a)pyrene (B[a]P) and other carcinogenic PAHs can cause cancer at the point of exposure. B(a)P was chosen as the surrogate for evaluation of the toxicity of all of the Class B2 carcinogenic PAHs in this assessment, because only B(a)P has been assigned a slope factor by EPA.

Animals exposed to high levels of B(a)P in air develop lung tumors; when exposed via the dietary route they develop stomach tumors; and when B(a)P is painted on skin, animals develop skin tumors. Although RfDs and SFs for dermal exposure to other chemicals are routinely extrapolated from oral-route values, it is inappropriate to use the oral SF of B(a)P to evaluate carcinogenic risks from dermal exposure, because dermal exposure to B(a)P directly causes skin cancer.

Polychlorinated Biphenyls (PCBs)

PCBs are a group of man-made chemicals composed of 209 individual compounds. They have been used widely in coolants, lubricants, and dielectric materials in transformers, capacitors, and other electrical equipment because of their insulating and flame-resistant properties. The industrial manufacture of PCBs in the United States was stopped in 1977 in response to the discovery that PCBs could accumulate and persist in the environment and might cause adverse health effects. Although PCBs are no longer manufactured in the United States, people can be exposed to PCBs spilled or leaked from older transformers, capacitors, and other kinds of equipment, and to low levels of PCBs that are widespread throughout the environment. PCBs bind tightly to soils, and can be found in high concentrations in some freshwater and marine sediments. Some freshwater fish have bioconcentrated PCBs; eating fish from contaminated areas may be a potentially significant source of human exposure.

PCBs can enter the body when fish, other foods, or water containing PCBs are ingested, when air that contains PCBs is breathed, or when skin contact with PCBs occurs. Skin irritations characterized by acne-like lesions and rashes, and liver effects were the only significant adverse health effects reported in PCB-exposed workers. Epidemiological studies of workers occupationally exposed to PCBs thus far have not found any conclusive evidence of an increased incidence of cancer in these groups.

Effects of PCBs in experimentally exposed animals include liver damage, skin irritations, low birth weights and other reproductive effects, and death. Some strains of rats and mice that were fed PCB mixtures throughout their lives showed increased incidence of cancer of the liver and other organs. Based on these animal studies, the EPA has classified PCBs as a Group B2-probable human carcinogen.

An MRL of 0.005 µg/Kg/day for chronic oral exposure to PCBs has been derived from animal studies.

1,1,2,2-Tetrachloroethane

1,1,2,2-Tetrachloroethane is a man-made, colorless, dense liquid with a penetrating, sweet, chloroform-like odor. In the past, it was used in large amounts as a chemical intermediate and as an industrial solvent. It was also used to clean and degrease metals and as an ingredient in varnishes. In the United States, present use of 1,1,2,2-tetrachloroethane is limited to closed industrial systems in order to prevent most worker contact.

1,1,2,2-Tetrachloroethane can enter the body through ingestion, inhalation, or skin contact. The most likely route of exposure is by inhalation of air or ingestion of water containing 1,1,2,2-tetrachloroethane. Exposure to large amounts by ingestion, inhalation, or dermal contact can cause fatigue, vomiting, dizziness, and possibly unconsciousness. There have been several reported cases of suicidal and accidental deaths by drinking 1,1,2,2-tetrachloroethane. The concentrations required to produce adverse effects via inhalation are high enough that the sickeningly sweet smell would be noticeable. Most people recover from these effects after exposure ends. The human health effects from long-term exposure to small amounts of the chemical are not known.

1,1,2,2-Tetrachloroethane was found to cause liver cancer in mice but not in rats. Based on these studies, it is classified as a Group C-possible human carcinogen. MRLs are not available for 1,1,2,2-tetrachloroethane.

Tetryl

Tetryl, or N-methyl-N,2,4,6-tetranitrobenzenamine, is a booster explosive used in munitions. Very little is known about the environmental fate and toxicology of tetryl.

When released in the environment, tetryl binds more tightly to soil than other explosives such as TNT. Tetryl will breakdown in sunlight and in water. It is not known if microorganisms will degrade tetryl.

Most of the toxicity data on tetryl is based on people exposed to tetryl dust in munitious plants during the 1930s and 1940s. In workers, dermal exposure to tetryl produced allergic skin rashes and skin discoloration. Inhalation of large amounts of tetryl caused nose and throat irritation, and nosebleeds in some workers.

There are few animals studies of tetryl. One study suggests long-term oral exposure to tetryl can interfere with blood clotting. Prolonged exposure to oral doses of tetryl may cause liver and kidney damage in laboratory animals. It is unknown whether tetryl causes similar effects in humans.

The carcinogenicity of tetryl has been tested in one study of inadequate design and length with inconclusive results. Therefore, it is not known whether tetryl causes cancer in animals or humans.

1,3,5-Trinitrobenzene (TNB)

TNB is a solid man-made chemical that is a formed as a by-product of TNT manufacture and by the environmental degradation of TNT.

When released to the environment, TNB does not degrade readily or evaporate.

Very little toxicological data are available for TNB. TNB was never produced in large quantities for commercial use, and there were no occupational health effects to spur toxicological research on TNB.

The few laboratory studies that were done used very few animals and often only one dose. These studies indicate TNB may cause minor toxic effects to the liver, kidneys, blood, and the reproductive system. It is not known whether TNB causes these effects in humans, or whether TNB causes cancer in animals or humans.

EPA extrapolates the health effects of TNB from DNB. The critical effect is enlargement of the spleen. No MRLs are available.

Vanadium

Vanadium is a naturally occuring grey metal. In the environment, vanadium is commonly found combined with other elements including oxygen and sulfur. Vanadium oxide is the compound of vanadium that is used most extensively by industry. The largest industrial use of vanadium oxide is in steel manufacturing, but it is also used in plastic, rubber, ceramic, and other chemical manufacturing.

Burning fuel oil and coal releases vanadium to the atmosphere. In water, vanadium is not very soluble, but is usually carried in surface water and groundwater in small particles.

Because vanadium is naturally occuring, people are likely to be exposed to low concentrations of vanadium in food and drinking water. People are likely to be exposed to vanadium in air near industries that use vanadium, waste disposal areas of these industries, or downwind of fuel oil or coal burning areas. Once in the body, most vanadium is not absorbed from the respiratory or digestive tract. Vanadium is not believed to be absorbed through skin.

Humans exposed to large amounts of vanadium in air have experienced coughs, and eye and throat irritation. However, these effects stop soon after exposure stops. Long-term oral exposure of rats to vanadium causes minor cell changes in the kidney and lungs. Female rats exposed to vanadium have offspring of decreased body weights. It is unknown whether humans experience effects similar to vanadium-exposed rats.

There have been no specific studies of the carcinogenicity of vanadium. No increase of cancer has been noticed in studies of long-term oral exposure of rats, but these studies are less sensitive than specific cancer studies.

MRLs have been developed for vanadium. An MRL of 0.006 mg/m^3 in air has been calculated based on human short-term exposure. An oral MRL of 0.003 mg/kg/day has been calculated based on studies of intermediate animal exposure.

Vinyl Chloride (VC)

VC, which is a gas or pressurized liquid at ambient temperature, is primarily used in the chemical manufacturing industry in the production of polymeric chemicals that are in turn used to manufacture a variety of plastic and polyvinyl chloride (PVC) products. In addition, VC is a known degradation product of many chlorinated solvents including tetra-, tri-, and dichloroethenes. Most of the VC in the environment comes from the plastic industry's releases to air or wastewater. In surface water or surface soil, VC evaporates readily. Once in the air, VC breaks down rapidly to nonhazardous chemicals. VC can dissolve in water and migrate to groundwater. Once in the groundwater VC can persist for many years.

People are most likely to be exposed to VC in the air, although it is also possible to be exposed to VC in drinking water. Levels of VC have not been detected in background air samples, but it has been detected in the air near some plastics factories, landfills, and chemical waste sites. VC has also been detected in tobacco smoke.

VC may cause adverse health effects following exposure by inhalation, ingestion, or by dermal or eye contact. VC inhalation can cause dizziness or sleepiness. Breathing very high levels of VC can cause unconsciousness and in some cases death. On skin, exposure to liquid VC can cause burns. Noncarcinogenic effects associated with long-term occupational VC exposure include hepatitis-like changes in the liver, immune reactions, and nerve damage.

VC has been shown to cause liver and lung cancer in rats, and liver cancer in workers occupationally exposed to air concentrations in the range of less than 25 ppm to greater than 200 ppm. Based on this evidence, VC is classified as a Group A-human carcinogen. Air standards as low as 1 ppm are specified for occupational exposure to VC in many countries.

An intermediate term inhalation MRL of 0.002 ppm a for six-day exposure has been calculated for VC based on animal studies. A chronic oral MRL of 2×10^{-5} mg/kg/day has also been derived.

Zinc

Zinc is a naturally occurring element that can be found in a variety of compounds. Zinc has many industrial uses including galvanizing steel and manufacturing zinc-containing alloys such as brass. Zinc is an essential nutrient, and an inadequate amount of zinc in the diet will lead to adverse health effects.

People are exposed to low concentrations of zinc every day in air, water, soil, and food. Sources of zinc exposure include drinking water containing elevated levels of zinc and breathing air containing elevated levels of zinc from galvanizing, smelting, welding, or brass foundry operations. Drinking water is thought to be the most significant exposure route to zinc at hazardous waste sites.

Zinc appears to be toxic only at levels at least 10 times higher than the recommended daily allowance. Symptoms of overexposure may include severe diarrhea, stomach cramping, nausea, and vomiting. Serious damage to the digestive system can occur if too much zinc is ingested over a long period of time. Ingesting too much zinc can cause deficiency in other nutrients such as iron (anemia) and copper. Anemia is the critical effect or most sensitive effect caused by zinc overexposure. Inhalation of zinc fumes or dusts has been associated with a condition called "metal fume fever" characterized by flu-like symptoms including throat irritation, body aches, weakness, and fatigue.

Zinc is not thought to cause cancer or birth defects. MRLs are not available for zinc because zinc is an essential nutrient.

8.1.4.3 Quantitative Indices of Toxicity

Quantitative indices of toxicity were compiled for the dose-response assessment to be used in estimating the relationship between the extent of exposure to a contaminant and the potential increased likelihood and/or severity of adverse effects. The methods for deriving indices of toxicity and estimating potential adverse effects are presented below. The indices of toxicity for the COPCs are presented at the end of this section.

Categorization of Chemicals as Carcinogens or Noncarcinogens

For the purpose of this risk assessment, COPCs were classified into two groups: potential carcinogens and noncarcinogens. The risks posed by these two types of compounds are assessed differently because noncarcinogens generally exhibit a threshold dose below which no adverse effects occur, while no such threshold can be proven to exist for carcinogens.

As used here, the term "carcinogen" means any chemical for which there is sufficient evidence that exposure may result in continuing uncontrolled cell division (cancer) in humans and/or animals. Conversely, the term "noncarcinogen" means any chemical for which the carcinogenic evidence is negative or insufficient. These classifications are dynamic; chemicals may be reclassified any time additional evidence becomes available that shifts the weight-of-evidence one way or the other.

COPCs have been classified as carcinogens or noncarcinogens based on weight-of-evidence criteria contained in the EPA carcinogenicity evaluation guidelines (1986c). Table 8-22 summarizes the five EPA weight-of-evidence categories. According to these EPA guidelines, chemicals in the first two Groups--A and B (B1 or B2)--are considered human carcinogens or probable human carcinogens based on sufficient evidence and should be the subject of nonthreshold carcinogenic risk estimation procedures. Depending upon the quality of the data, Group C chemicals may also be subjected to these procedures. The remaining chemicals--in Groups D and E--are defined as noncarcinogens and should be subjected to threshold-based toxicological risk estimation procedures.

Exposure to some chemicals may result in both carcinogenic and noncarcinogenic effects. In these cases, both the carcinogenic and noncarcinogenic effects were evaluated and considered in the risk assessment process.

Assessment of Noncarcinogens

Risks associated with noncarcinogenic effects (e.g., organ damage, immunological effects, birth defects, and skin irritation) are usually assessed by comparing the estimated average daily intake to the acceptable daily dose, now called the "reference dose" (RfD) by the EPA. The RfD is selected by identifying the lowest reliable no observed adverse effect level (NOAEL) or lowest observed adverse effect level (LOAEL) in the scientific literature, then applying a suitable uncertainty factor (usually ranging from 10 to 1,000) to allow for differences between the study conditions and the human exposure situation to which the RfD is to be applied. NOAELs and LOAELs can be derived from either human epidemiological studies or animal studies; however, they are usually based on laboratory experiments on animals in which relatively high doses are used. Consequently, uncertainty or safety factors are applied when deriving RfDs to compensate for data limitations inherent in the underlying experiments and for the lack of precision created by extrapolating from high doses in animals to lower

Table 8-22

FIVE EPA WEIGHT-OF-EVIDENCE
CATEGORIES FOR CHEMICAL CARCINOGENICITY

Group	Description
A	Human Carcinogen - sufficient evidence from epidemiological studies to support a causal association between exposure and cancer.
B	Probable Human Carcinogen -
B1	o At least limited evidence of carcinogenicity to humans from epidemiological studies;
B2	o Usually a combination of sufficient evidence of carcinogenicity in animals and inadequate evidence of carcinogenicity in humans.
C	Possible Human Carcinogen - limited evidence of carcinogenicity in animals in the absence of human data.
D	Not Classified - inadequate evidence of carcinogenicity in animals.
E	No Evidence of Carcinogenicity for Humans - no evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies.

RC424

Source: EPA 1986c.

doses in humans. The application of uncertainty factors in the derivation of RfDs is explained in RAGS-HHEM (USEPA 1989c) as follows.

> The RfD is derived from the NOAEL (or LOAEL) for the critical toxic effect by consistent application of uncertainty factors (UFs) and a modifying factor (MF). The uncertainty factors generally consist of multiples of 10 (although values less than 10 are sometimes used), with each factor representing a specific area of uncertainty inherent in the extrapolation from the available data. The bases for application of different uncertainty factors are explained below.
>
> - o A UF of 10 is used to account for variation in the general population and is intended to protect sensitive subpopulations (e.g., elderly, children).
> - o A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.
> - o A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.
> - o A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs
>
> In addition to the UFs listed above, a modifying factor (MF) is applied:
>
> - o An MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default value for the MF is 1.
>
> To calculate the RfD, the appropriate NOAEL (or the LOAEL if a suitable NOAEL is not available) is divided by the product of all of the applicable uncertainty factors and the modifying factor. That is:
>
> $$RfD = NOAEL \text{ or } LOAEL \; (UF_1 \times UF_2 \ldots \times MF)$$
>
> Oral RfDs are typically expressed as one significant figure in units of mg/kg-day.

The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a portion of the lifetime, in the case of a subchronic RfD, or during the entire lifetime, in the case of a chronic RfD. The RfD is used as a reference point for gauging the potential effects of other exposures. Usually, exposures that are less than the RfD are not likely to be associated with health risks. As the frequency of exposures exceeding the RfD increases and as the size of the excess increases, the probability increases that adverse health effects may be observed in a human population. Nonetheless, a clear distinction that would categorize all exposures below the RfD as "acceptable" (risk-free) and all exposures in excess of the RfD as "unacceptable" (causing adverse effects) cannot be made (HEAST 1991). Noncarcinogenic risks are usually assessed by calculating a hazard index, which is the ratio of the estimated exposure to the RfD as follows:

$$HI = \frac{ADI}{RfD}$$

where

HI = Hazard Index

ADI = Average Daily Intake (exposure)

RfD = Reference Dose (acceptable daily intake).

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 EPA is in the process of developing subchronic RfDs based on potential noncarcinogenic effects associated with exposure durations ranging from a few weeks to seven years. Short-term exposures can occur when an activity resulting in exposure is performed for a limited period of time or when a chemical degrades or disperses to negligible concentrations within a short period. The hazard index for subchronic exposure is obtained by dividing the estimated average daily dose by the subchronic RfDs. Exposures of greater than 7 years duration (adult and adolescent exposures) were evaluated using chronic RfDs. Exposures of 7 years duration or less (exposures to young children 0 to 6 years of age) were evaluated using subchronic RfDs.

Chronic and subchronic RfDs for the oral and inhalation exposure routes are presented in Table 8-23. Since inhalation is not a route of exposure for the non-volatile compounds at this site, their inhalation RfDs have been omitted. Other entries in the table that have not been discussed previously are as follows: the confidence level indicates the degree of confidence that should be placed in the RfD value and is

Table 8-23

TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Inorganics							
Arsenic	Oral	Chronic	3×10^{-4}	Medium	Hyperpigmentation, keratosis, and possible vascular complications	Human Oral/IRIS	UF=3 MF=1
		Subchronic	3×10^{-4}	NS	Keratosis and hyperpigmentation	Human Oral/HEAST	UF=1
Barium	Oral	Chronic	7×10^{-2}	Medium	Increased blood pressure	Drinking water/IRIS	UF=3 MF=1
		Subchronic	7×10^{-2}	NS	Increased blood pressure	Drinking water/HEAST	UF=100
Beryllium	Oral	Chronic	5×10^{-3}	Low	None observed	Drinking water/IRIS	UF=100 MF=1
		Subchronic	5×10^{-3}	NS	None observed	Drinking water/HEAST	UF=100
Cadmium	Oral	Chronic	5×10^{-4}	High	Significant proteinuria	Water, IRIS	UF=10 MF=1
		Subchronic	5×10^{-4}	NS	NA	Extrapolated from chronic	
Chromium (III)	Oral	Chronic	1	Low	None reported	Diet/IRIS	UF=100 MF=10
		Subchronic	1	NS	None reported	Diet/HEAST	US=1,000

RC424

Key at end of table.

Table 8-23 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Chromium (VI)	Oral	Chronic	5×10^{-3}	Low	None reported	Water/IRIS	UF=500 MF=1
		Subchronic	2×10^{-2}	NS	None reported	NA/HEAST	UF=100
Copper	Oral	Chronic	3.7×10^{-2}	NS	Local GI irritation	Derived from drinking water standard/ HEAST	NA
		Subchronic	3.7×10^{-2}	NS	Local GI irritation	Derived from drinking water standard/ HEAST	NA
Lead	Oral	Chronic	ND	NS	CNS effects	NA/HEAST	
		Subchronic	ND	NS	CNS effects	NA/HEAST	
Manganese	Oral	Chronic	1×10^{-1}	Medium	CNS effects	Diet/IRIS	UF=1 MF=1
		Subchronic	1×10^{-1}	NS	CNS effects	Diet/HEAST	UF=1
Mercury	Oral	Chronic	3×10^{-4}	NS	Kidney effects	Oral/HEAST	UF=1,000
		Subchronic	3×10^{-4}	NS	Kidney effects	Oral/HEAST	UF=1,000
Nickel	Oral	Chronic	2×10^{-2}	NS	Reduced body and organ weight	Diet/IRIS	UF=300 MF=1
		Subchronic	2×10^{-2}	NS	Reduced body and organ weight	Diet/HEAST	UF=300
Vanadium	Oral	Chronic	7×10^{-3}	NS	None observed	Drinking water/HEAST	UF=100
		Subchronic	7×10^{-3}	NS	None observed	Drinking water/HEAST	UF=100

RC424

Key at end of table.

Table 8-23 (Cont.)

Chemical	Route	Reference Dose (RfD) Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Inorganics (Cont.)							
Zinc	Oral	Chronic	2×10^{-1}	NS	Anemia	Therapeutic Dosage/ HEAST	UF=10
		Subchronic	2×10^{-1}	NS	Anemia	Therapeutic Dosage/ HEAST	UF=10
Organics							
1,3-Dinitro- benzene	Oral	Chronic	1×10^{-4}	Low	Increased splenic weight	Oral/IRIS	UF=3,000 MF=1
		Subchronic	1×10^{-3}	NS	Increased splenic weight	Drinking water/HEAST	UF=300
1,3,5-Trinitro- benzene	Oral	Chronic	5×10^{-5}	Medium	Increased splenic weight	Oral/IRIS	UF=10,000 MF=1
		Subchronic	5×10^{-4}	NS	Increased splenic weight	Drinking water/HEAST	UF=1,000
Chlordane	Oral	Chronic	6×10^{-5}	Low	Regional liver hypertrophy	Oral/IRIS	UF=1,000 MF=1
		Subchronic	6×10^{-5}	NS	Regional liver hypertrophy	Oral/HEAST	UF=1,000
	Inhalation	Chronic	6×10^{-5}	NS	NA	Extrapolated from oral	
		Subchronic	6×10^{-5}	NS	NA	Extrapolated from oral	

RC424

Key at end of table.

Table 8-23 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Chloroethane (Ethyl Chloride)	Oral	Chronic	3	NS	NA	Extrapolated from inhalation	
		Subchronic	3	NS	NA	Extrapolated from inhalation	
	Inhalation	Chronic	3	Medium	Developmental toxicity	Inhalation/IRIS	UF=300 MF=1
		Subchronic	3	NS	Developmental toxicity	Inhalation/HEAST	UF=300
Chloroform	Oral	Chronic	1×10^{-2}	Medium	Liver lesions	Oral/IRIS	UF=1,000 MF=1
		Subchronic	1×10^{-2}	NS	Liver lesions	Oral/HEAST	UF=1,000
	Inhalation	Chronic	1×10^{-2}	NS	NA	Extrapolated from oral	
		Subchronic	1×10^{-2}	NS	NA	Extrapolated from oral	
1,1-Dichloro-ethane	Oral	Chronic	1×10^{-1}	NS	None	Oral/HEAST	UF=1,000
		Subchronic	1	NS	None	Oral/HEAST	UF=100
	Inhalation	Chronic	1×10^{-1}	NS	Kidney damage	Inhalation/HEAST	UF=1,000
		Subchronic	1	NS	Kidney damage	Inhalation/HEAST	UF=100

RC424

Key at end of table.

Table 8-23 (Cont.)

	Reference Dose (RfD)						
Chemical	Route	Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Dichloromethane (methylene chloride)	Oral	Chronic	6×10^{-2}	Medium	Liver, toxicity	Drinking water/IRIS	UF=100 MF=1
		Subchronic	6×10^{-2}	NS	Liver toxicity	Drinking water/HEAST	UF=100
	Inhalation	Chronic	9×10^{-1}	NS	NA	Inhalation/HEAST	UF=100
		Subchronic	9×10^{-1}	NS	NA	Inhalation/HEAST	UF=100
Dieldrin	Oral	Chronic	5×10^{-5}	Medium	Liver lesions	Diet/IRIS	UF=100 MF=1
		Subchronic	5×10^{-5}	NS	Liver lesions	Diet/HEAST	UF=100
	Inhalation	Chronic	5×10^{-5}	NS	NA	Extrapolated from oral	
		Subchronic	5×10^{-5}	NS	NA	Extrapolated from oral	
Fluoranthene	Oral	Chronic	4×10^{-2}	Low	Nephropathy; liver weight changes; hematological changes	Oral/IRIS	UF=3,000 MF=1
		Subchronic	4×10^{-1}	NS	Nephropathy; liver weight changes; hematological changes	Oral/HEAST	UF=300
	Inhalation	Chronic	4×10^{-2}	NS	NA	Extrapolated from oral	
		Subchronic	4×10^{-1}	NS	NA	Extrapolated from oral	

RC424

Key at end of table.

Table 8-23 (Cont.)

Chemical	Route	Reference Dose (RfD) Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Heptachlor	Oral	Chronic	5×10^{-4}	Low	Increased liver weight	Diet/IRIS	UF=300 MF=1
		Subchronic	5×10^{-4}	NS	Increased liver weight	Diet/HEAST	UF=300
	Inhalation	Chronic	5×10^{-4}	NS	NA	Extrapolated from oral	
		Subchronic	5×10^{-4}	NS	NA	Extrapolated from oral	
Naphthalene	Oral	Chronic	4×10^{-2}	NS	Decreased body weight gain	Diet/HEAST	UF=1,000
		Subchronic	4×10^{-2}	NS	Decreased by weight gain	Diet/HEAST	UF=1,000
	Inhalation	Chronic	4×10^{-2}	NS	NA	Extrapolated from oral	
		Subchronic	4×10^{-2}	NS	NA	Extrapolated from oral	

RC424

Key at end of table.

Table 8-23 (Cont.)

Chemical	Route	Type	Value (mg/kg/day)	Confidence Level	Critical Effects	RFD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
	Reference Dose (RfD)						
Pyrene	Oral	Chronic	3×10^{-2}	Low	Kidney effects	Oral/IRIS	UF=3,000 MF=1
		Subchronic	3×10^{-1}	NS	Kidney effects	Oral/HEAST	UF=300 MF=1
	Inhalation	Chronic	3×10^{-2}	NS	NA	Extrapolated from oral	
		Subchronic	3×10^{-1}	NS	NA	Extrapolated from oral	

RC424

Note: There are no EPA-approved RfDs for benzene, 1,2-DCA, alpha-hexachlorocyclohexane, 1,1,2,2-tetrachloroethane, vinyl chloride, PCBs, phenanthrene, and carcinogenic PAHs.

Key:

HEAST = EPA's Health Effects Assessment Summary Tables.
IRIS = EPA's Integrated Risk Information System.
NS = Not specified.
ND = Not determined.
NA = Not available.

Source: Ecology and Environment, Inc. 1992.

usually obtained from the Integrated Risk Information System (IRIS) entry for a chemical; the critical effect is the effect or target organ affected by the smallest dose of the chemical that produces any adverse effect and that serves as the basis for the RfD; and the RfD source is the source or reference for the RfD. The preferred source is the EPA's IRIS data base, which contains confirmed values reflecting the consensus judgment of the agency. The second choice is the EPA's Health Effects Assessment Summary Tables (HEAST), which contain information taken from final documents prepared by the EPA Office of Health and Environmental Assessment. The third choice is to use values from other EPA documents, and the fourth choice would be to use values derived directly from the general literature. The RfD basis is the vehicle in which the chemical was administered or the medium of exposure in the study(ies) that served as the basis for the RfD.

Assessment of Carcinogens

In contrast to noncarcinogenic effects, for which thresholds are thought to exist, scientists have been unable to demonstrate experimentally a threshold for carcinogenic effects. This has led to the assumption by Federal regulatory agencies (e.g., EPA, Food and Drug Administration (FDA), and Occupational Safety and Health Administration (OSHA)) that any exposure to a carcinogen theoretically entails some finite risk of cancer. However, depending on the potency of a specific carcinogen and the level of exposure, such a risk could be vanishingly small.

Scientists have developed several mathematical models to estimate low-dose carcinogenic risks from observed high-dose risks. Consistent with current theories of carcinogenesis, the EPA has selected the linearized multistage model based on prudent public health policy (USEPA 1986g). In addition to using the linearized multistage model, the EPA uses the upper 95 percent confidence limit for doses or concentrations in animal or human studies to estimate low-dose slope factors (SFs). By using these procedures, the regulatory agencies are unlikely to underestimate the actual SFs (formerly called carcinogenic potency factors) for humans.

Using SFs, lifetime excess cancer risks can be estimated by:

$$\text{Risk} = \Sigma\, \text{LADI}_j \times \text{SF}_j$$

where

LADI_j = exposure route-specific lifetime average daily dose

SF_j = route-specific slope factor.

Using the multistage model, the carcinogenic risks for the oral, dermal, and inhalation routes of exposure are calculated as follows:

$$\text{Risk} = \text{LADI}_o\text{SF}_o + \text{LADI}_d\text{SF}_o + \text{LADI}_i\text{SF}_i$$

where subscript "o" indicates the oral route, subscript "d" the dermal route, and subscript "i" the inhalation route. SFs for the COPCs for the oral and inhalation exposure routes are presented in Table 8-24. The EPA's weight-of-evidence classification for the chemical and the type of cancer that may be associated with exposure to the chemical are also included in Table 8-24. COPCs that have not been classified by EPA do not appear in the table.

Route-to-Route Extrapolation of Reference Doses and Slope Factors

Once substances have been absorbed via the oral or dermal routes, their distribution, metabolism, and elimination patterns (biokinetics) are usually similar. For this reason, and because dermal route RfDs and SFs are usually not available, oral route RfDs and SFs are commonly used to evaluate exposures to substances by both the oral and dermal routes. When this is done, the dermal intake is adjusted to account for differences in a chemical's absorption between the oral and dermal routes of exposure. Although inhalation route biokinetics differ more from oral route kinetics than do the dermal route kinetics, oral RfDs and SFs may also be used to evaluate inhalation exposures if inhalation route RfDs and SFs are not available, and vice versa. Extrapolation of toxicological indices from one route to another is inappropriate if the critical effect for either route is at the point of contact.

8.1.4.4 Uncertainties Related to the Toxicity Assessment

Introduction

To evaluate the meaning of any risk assessment, one must consider the uncertainties in the assumptions made, the potential impact of quantitative changes in those assumptions on the risk estimates, and the relevance of the findings to real world exposures and risks. Due to the number of assumptions, data points, and calculations, a degree of uncertainty is necessarily associated with the numerical toxicity values in any risk assessment.

Evaluation of Carcinogenic Toxicity Assessment Assumptions

The COPCs have been evaluated by the EPA using its weight-of-evidence carcinogenicity evaluation criteria and have been placed in Group A-human carcinogens, or Group B-probable human carcinogens, based on sufficient data in humans or sufficient data in animals and insufficient data in humans, respectively (USEPA 1986c).

Rodent bioassay and epidemiological studies, such as those performed for the COPCs, would require tens of thousands of animals or humans to determine whether a chemical may be carcinogenic at low doses. As the relationship between tumor location, time to appearance, and the proportion of animals with cancer determines the estimated carcinogenic SF, animal bioassay or human epidemiological data are not routinely sufficient for directly estimating SFs at low doses. Therefore, by necessity, agencies such as the EPA use carcinogenic extrapolation

Table 8-24

TOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS

Chemical	Route	Slope Factor (SF) $(mg/kg/day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Basis/ SF Source
Inorganics					
Arsenic	Oral	1.75	A	Skin	Proposed unit dose for drinking water/IRIS
Beryllium	Oral	4.3	B2	Total tumors	Drinking water/ IRIS
Copper	Oral	ND	D	NA	NA/IRIS
Manganese	Oral	ND	D	NA	NA/IRIS
Mercury	Oral	ND	D	NA	NA/IRIS
Zinc	Oral	ND	D	NA	NA/IRIS
Organics					
Benzene	Oral	2.9×10^{-2}	A	Leukemia	Occupational/IRIS
	Inhalation	2.9×10^{-2}	A	Leukemia	Occupational/IRIS
Benzo(a)anthracene	Oral	7.3	B2	NA	Extrapolated from benzo(a)pyrene
	Inhalation	6.1	B2	NA	Extrapolated from benzo(a)pyrene
Chlordane	Oral	1.3	B2	Liver	Drinking water/ IRIS
	Inhalation	1.3	B2	NA	Oral/IRIS

RC424

Key at end of table.

Table 8-24 (Cont.)

Chemical	Route	Slope Factor (SF) $(mg/kg/day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Basis/ SF Source
Chloroform	Oral	6.1×10^{-3}	B2	Kidney	Drinking water/ IRIS
	Inhalation	8.1×10^{-2}	B2	Liver	Oral/IRIS
Chrysene	Oral	7.3	B2	NA	Extrapolated from benzo(a)pyrene
	Inhalation	6.1	B2	NA	Extrapolated from benzo(a)pyrene
1,1-Dichloroethane	Oral	ND	C	Hemangiosarcoma	NS/IRIS
	Inhalation	ND	C	NA	NA/HEAST
1,2-Dichloroethane	Oral	9.1×10^{-2}	B2	Circulatory System	Oral/IRIS
	Inhalation	9.1×10^{-2}	B2	Circulatory System	Oral/IRIS
Dichloromethane (Methylene Chloride)	Oral	7.5×10^{-3}	B2	Liver	Drinking water/ IRIS
	Inhalation	1.6×10^{-3}	B2	Lung, liver	Inhalation/IRIS
Dieldrin	Oral	16	B2	Liver	Diet/IRIS
	Inhalation	16	B2	Liver	Diet/IRIS
Heptachlor	Oral	4.5	B2	Liver	Oral/HEAST
	Inhalation	4.5	B2	Liver	Oral/HEAST
Alpha-hexachloro-cyclohexane	Oral	6.3	B2	Liver	Diet/IRIS
	Inhalation	6.3	B2	NA	Oral/IRIS

RC424

Key at end of table.

Table 8-24 (Cont.)

Chemical	Route	Slope Factor (SF) $(mg/kg/day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Basis/ SF Source
PCB 1260	Oral	7.7	B2	Liver	Oral/IRIS
	Inhalation	7.7	B2	NA	Extrapolated from Oral
1,1,2,2-Tetra chloroethane	Oral	2×10^{-1}	C	Liver	Oral/IRIS
	Inhalation	2×10^{-1}	C	Liver	Oral/IRIS
Vinyl chloride	Oral	1.9	A	Lung	Diet/HEAST
	Inhalation	2.9×10^{-1}	A	Liver	Inhalation/HEAST

RC424

Note: Chemicals with no EPA weight-of-evidence classification do not appear in this table.

Key:

HEAST = EPA's Health Effects Assessment Summary Tables.
IRIS = EPA's Integrated Risk Information System.
NA = Not available.
ND = Not determined.

Compiled by Ecology and Environment, Inc. 1992.

models for estimating low-dose SFs. Based upon prudent public policy, these agencies assume that there is no threshold dose below which carcinogenic risks will not occur. This is equivalent to the assumption that every dose above zero, no matter how low, carries with it a small but finite risk of cancer. They also assume that the dose-response relationship is linear at low doses. This is contrary to approaches used for other toxic effects, for which thresholds are assumed to exist.

The current model favored by the EPA and certain other Federal regulatory agencies is the linearized multistage model. The EPA then uses the statistically derived upper 95 percent confidence bounds, rather than a maximum likelihood value for the SF. The EPA has concluded, based on theoretical grounds consistent with human epidemiological and animal data, that cancer follows a series of discrete stages (i.e., initiation, promotion, and progression) that ultimately can result in the uncontrolled cell proliferation known as cancer. Consistent with this conclusion, the use of the linearized multistage model permits an estimation of SF that is not likely to be exceeded if the real slope could be measured. However, compelling scientific arguments can be made for several other extrapolative models which, if used, could result in significantly reduced values for SFs, some tens of millions of times lower than those estimated using the linearized multistage model. The one-hit model, used to estimate risks due to exposures above the linear range of the multistage model, is one such model. Thus, the current EPA SFs calculated in this fashion represent upper-bound values based on animal data which should not be interpreted as necessarily equivalent to actual human cancer potencies. It is this conservative value, nevertheless, that is used in this risk assessment on policy grounds for the protection of public health.

Evaluation of Noncarcinogenic Toxicity Assessment Assumptions

Key assumptions used in assessing the likelihood of noncarcinogenic effects are that threshold doses exist below which various noncarcinogenic effects do not occur and that the occurrence or absence of noncarcinogenic effects can be extrapolated between species and occasionally between routes of exposure and over varying exposure durations. The threshold assumption appears to be sound for most noncarcinogens based on reasonably good fits of experimental data to the usual dose response curves. One possible exception to this is lead, which may not have a threshold base for its noncarcinogenic effects (ATSDR 1991).

The other assumptions generally appear to be true to varying degrees. The effects observed in one species or by one route of exposure may not occur in another species or by another route, or they may occur at a higher or lower dose due to differences in the biokinetics of a compound in different species or when exposure occurs by different routes. The uncertainty in these assumptions is taken into account in the development of RfDs through the use of safety or uncertainty factors. These factors reflect uncertainty associated with species-to-species extrapolation and include safety factors to protect sensitive individuals. In addition to uncertainty factors, a modifying factor is applied to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The modifying factor ranges from greater than 0 to 10 with a default value of 1 (USEPA 1989c).

The uncertainty factors and modifying factors used by the EPA are conservative (health protective) in nature in that they tend to overestimate the uncertainties so that the RfDs obtained are unlikely to be too high. Use of the resulting RfDs tends to overestimate the potential for noncarcinogenic effects occurring at a given exposure level. Section 8.1.4.3 discusses uncertainty factors used to derive the RfDs for COPCs at Shepley's Hill Landfill.

Route-to-Route Extrapolation of Reference Doses and Slope Factors

Route-to-route extrapolation of RfDs and SFs adds another source of uncertainty to the risk estimates obtained through their use. Such extrapolation may result in either under- or overestimation of the true risks for the extrapolated route. Although this practice adds uncertainty to the risk assessment process, it appears to be preferable to omitting exposure to a chemical by a route for which no RfD or SF is available from the quantitative risk assessment, which would lead to underestimation of the overall risks posed by the chemical.

Summary of Toxicity Assessment Uncertainties

The basic uncertainties underlying the assessment of the toxicity of a chemical include:

- Uncertainties arising from the design, execution, or relevance of the scientific studies that form the basis of the assessment;
- Uncertainties involved in extrapolating from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposures within human and animal populations, between species, and between routes of exposure; and
- The absence of quantitative toxicological indices for bromide and lead, which made it necessary to evaluate the effects of the contaminants qualitatively rather than quantitatively, and will result in a slight underestimation of the total risks posed by the site.

These basic uncertainties could result in a toxicity estimate, based directly on the underlying studies, that either under- or overestimates the true toxicity of a chemical in the circumstances of interest.

The toxicity assessment process compensates for these basic uncertainties through the use of safety factors (uncertainty factors) and modifying factors when assessing noncarcinogens, and the use of the upper 95 percent confidence limit from the linearized multistage model for the SF when assessing carcinogens. The use of the safety factors and the upper 95 percent confidence limit in deriving the RfDs and SFs ensures that the toxicity values used in the risk estimation process are very unlikely to underestimate the true toxicity of a chemical.

8.1.5 Risk Characterization

8.1.5.1 Introduction

This section combines the information developed in the exposure and toxicity assessment sections to obtain estimates of the potential risks posed by the Shepley's Hill Landfill contaminants to human health. The process by which this is done is explained in this section.

Risks due to carcinogenic and noncarcinogenic contaminants are usually assessed as discussed previously. Potential carcinogenic risks are assessed by multiplying the estimated LADI of a carcinogen by its estimated SF to obtain the estimated risk, expressed as the probability of that exposure resulting in an excess incidence of cancer.

The potential for adverse effects resulting from exposure to noncarcinogens is assessed by comparing the CDI or SDI of a substance to its chronic or subchronic RfD. This comparison is performed by calculating the ratio of the estimated CDI or SDI to the corresponding RfD, which is called a hazard quotient. If the hazard quotient is less than 1, no adverse effects would be expected; however, if it is greater than 1, adverse effects could be possible.

The excess cancer risk or the hazard quotient for exposure to each chemical by each route of exposure, exposure pathway, category of receptor (i.e., adult or child), and exposure case (average or RME) initially are estimated separately. The separate cancer risk estimates are then summed across chemicals and across all exposure routes and pathways applicable to the same population to obtain the total excess cancer risk for that population. Hazard quotients for noncarcinogens normally are summed across chemicals that produce the same type of adverse effect (such as liver damage) but are kept separate if their effects are different. However, in this case, the vast majority of the estimated noncarcinogenic risks were due to a single chemical, i.e., arsenic. The remaining noncancer risks only account for a small fraction of the total, so they were not summed separately. The sum of hazard quotients is called the hazard index. Hazard quotients for subchronic and chronic effects are separately summed across all chemicals, exposure routes, and pathways applicable to the same population to obtain hazard indices for that population.

Section 8.1.5.2 describes a number of tables that contain the risk estimates just described. Section 8.1.5.3 discusses uncertainties associated with the risk estimates. Section 8.1.5.4 summarizes the risk estimation results and identifies the chemicals, pathways, and receptors that account for the most significant risks at the Shepley's Hill Landfill site.

8.1.5.2 Risk Estimates

Tables containing estimates of exposures and associated risks for the scenarios described earlier in Section 8.1.3 are located in Appendix N. The risk estimates are summarized and discussed in Section 8.1.5.4. The toxicity estimates (SFs and RfDs) used in calculating the risk estimates, along with key information qualifying the toxicity estimates, are presented in Tables 8-23 and 8-24.

Because of the number of exposure pathways, receptors, exposure cases, and chemicals that needed to be evaluated, a large number of tables are necessary to present the results. A directory has been included to assist the reader in locating the exposure and risk estimates for specific exposure pathways, etc. (see Table N-1).

The exposure and risk estimates which appear in Appendix N tables were made for reasonable maximum exposure and average exposure cases in compliance with regional EPA guidance. In order to satisfy MDEP requirements, similar tables were prepared for an average case in compliance with MDEP Risk Assessment guidance. These tables are presented in Appendix S.

8.1.5.3 Risk Characterization Uncertainties

The risk characterization combines and integrates the information developed in the exposure and toxicity assessments; therefore, uncertainties associated with these assessments also affect the degree of confidence that can be placed in risk characterization results. Sections 8.1.3.4 and 8.1.4.4 provide full discussions of the factors causing uncertainty in the exposure and toxicity assessments, respectively.

For the exposure assessment, factors that would likely cause overestimation of the true exposures were:

- The directed nature of the sampling program;
- The use of the maximum observed value for the source concentrations;
- The use of many 90th-percentile values in the exposure estimation calculations;
- The use of the steady state assumption for source concentration estimates; and
- The need to extrapolate exposure point or exposure media contaminant concentrations for sediment exposure and fish consumption from other measured results.

Two factors could lead to underestimation of the exposures:

- o The use of sample quantitation limits that could result in missing low concentrations of some compounds that might pose significant risks; and

- o Evaluation of the fruits and vegetable pathway for metals only (a minor factor).

The cumulative effect of all of the exposure uncertainties probably is to overestimate rather than underestimate the true potential exposures.

The basic uncertainties underlying the assessment of the toxicity of a chemical include:

- o Uncertainties arising from the design, execution, or relevance of the scientific studies that form the basis of the assessment;

- o Uncertainties involved in extrapolating from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposures within human and animal populations, between species, and between routes of exposure; and

- o The absence of quantitative toxicological indices for bromide and lead, which made it necessary to evaluate the effects of the contaminants qualitatively rather than quantitatively, and will result in a slight underestimation of the total risks posed by the site.

These basic uncertainties could result in a toxicity estimate, based directly on the underlying studies, that either under- or overestimates the true toxicity of a chemical in the circumstances of interest.

The toxicity assessment process compensates for these basic uncertainties through the use of safety factors (uncertainty factors) and modifying factors when assessing noncarcinogens, and the use of the upper 95 percent confidence limit from the linearized multistage model for the SF when assessing carcinogens. The use of the safety factors and the upper 95 percent confidence limit in deriving the RfDs and SFs ensures that the toxicity values used in the risk estimation process are very unlikely to underestimate the true toxicity of a chemical.

Two additional factors need to be considered when discussing uncertainties associated with the overall risk characterization: the cumulative effect of using conservative assumptions throughout the process, and the likelihood of the exposures postulated and estimated in the exposure assessment actually occurring.

The cumulative effect of using conservative assumptions throughout the risk estimation process could be a substantial overestimate of the true risks. The Risk Assessment Guidance for Superfund manual (USEPA 1989c) recommends that individual parameter values be selected so that the overall estimate of exposure represents a "reasonable maximum exposure." In many cases, the statistical distribution of a parameter is unknown and the risk assessor is left to select a value, using best professional judgment, that is sufficiently conservative to avoid underestimating the true risk, yet not so conservative that the resulting risk estimate turns out to be unreasonably high. When in doubt, the risk assessor will usually elect to err in favor of protecting human health and select a value that results in overestimating the true risk. In summary, the nature of the risk estimation process itself virtually ensures that the true risks are much more likely to be overestimated than underestimated.

The last uncertainty factor to consider is the likelihood of the postulated exposures actually occurring. The exposure pathways identified as complete under current land use conditions are all plausible and exposure is either presently occurring by these pathways or such exposure could reasonably be expected. The postulated frequencies of occurrence may overestimate average occurrence but could certainly reflect the reasonable maximum occurrence.

Fort Devens is scheduled to be closed and portions of the installation converted to nonmilitary uses. When this happens, portions of the base including areas around Shepley's Hill Landfill could be converted to residential use. However, in view of the past use of the landfill area and the availability of existing housing units on the base, construction of new residences in the immediate vicinity of the landfill is probably unlikely but cannot be ruled out. The base also has an existing water supply system which makes it unlikely that any new residences would use private wells for drinking water. If residences are actually constructed near the landfill and use private wells for drinking water, the postulated exposure levels, frequencies, and durations all reasonably reflect the exposures future site residents might actually experience.

8.1.5.4 Summary Discussion of the Risk Characterization

Characterization of Contamination Present at the Site

The RI was designed to characterize the nature, extent, and limits of contamination originating at Shepley's Hill Landfill and appears to have accomplished that goal. The possible source areas were identified based on a review of past activities at the site and previous sampling activities. All potential source areas and migration pathways were then investigated using various field techniques and by collection and analysis of samples. In this way, the nature of the contamination was characterized and its extent defined.

Given the information available about the site, it seems unlikely that any significant source areas or migration pathways were overlooked. Since samples were collected from a variety of media encompassing all of the likely source areas and migration pathways, and since most samples were analyzed for the full TCL and Tentatively Identified Compounds (TICs) were reviewed, it is also unlikely that any significant contaminants would have been missed.

Direct measurements of metals concentrations in filtered groundwater samples and contaminant concentrations in fish tissue could have improved the accuracy and reliability of the risk estimates for potential exposure to these media. However, estimates of these exposure point concentrations were made using the best available information, and exposure pathways involving these media were included in the risk assessments.

Magnitude and Sources of Risks Posed by Site Contaminants

EPA has adopted the policy that acceptable exposures to known or suspected carcinogens are generally those that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. In addition, the EPA uses the 10^{-6} risk level as the point of departure for determining remediation goals for National Priority List (NPL) sites (USEPA 1990c).

For systemic toxicants (noncarcinogens) the EPA defines acceptable exposure levels as those to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety (USEPA 1990c). This acceptable exposure level is best approximated by a hazard index of 1. If the hazard index is less than 1, adverse effects usually would not be expected. However, as the hazard index increases beyond 1, the possibility of adverse effects occurring also increases.

The magnitude of the potential excess cancer risks posed by the site-related contaminants are summarized in Tables 8-25 and 8-26. The hazard indices for potential noncarcinogenic effects are summarized in Tables 8-27 and 8-28. Hazard indices for adults and adolescents were calculated using chronic RfDs. Subchronic RfDs were used to estimate subchronic risks to children.

Based on the patterns of distribution in pond sediment, a number of additional contaminants found in Plow Shop Pond appear to have come from a source other than Shepley's Hill landfill. Potential risks from these contaminants were estimated and are summarized in Tables 8-29 and 8-30 for use in a future area- or base-wide risk assessment.

Based on the hydrogeological conditions found during the RI, the contaminants found in monitoring well SHL-15 and in group 6 wells (SHL-7, -8S, -8D, and -13) do not appear to be related to the landfill. However, since there was no other obvious source of these contaminants,

RC424

Table 8-25

SUMMARY OF ESTIMATED EXCESS CANCER RISKS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions by Chemical[a]
Fishing/fish ingestion	RME	1.8E-03	—	1.3E-03	Fish ingestion - >99%	Arsenic >99%
	Average	5.5E-04	—	4.0E-04	Water ingestion - <1%	
Sediment contact	RME	—	1.4E-04	—	Sediment ingestion - >99%	Arsenic - 100%
	Average	—	6.0E-05	—		

RC424

[a]RME case for receptor showing greatest risk.

Source: Ecology and Environment, Inc., 1992

Table 8-26

SUMMARY OF ESTIMATED EXCESS CANCER RISKS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions by Chemical[a]
Residential groundwater usage	**Original data**					
	RME	1.6E-02	—	2.9E-03	Water ingestion - 97%	Arsenic - 94%
	Average	2.8E-03	—	5.1E-04	Dermal contact - 2%	PCB 1260 - 3%
					Inhalation - <1%	Beryllium - 1%
					Fruits and vegetables - <1%	Vinyl Chloride - <1%
						Other chemicals[b] - <1%
	Adjusted data					
	RME	1.5E-02	—	2.8E-03	Water ingestion - 97%	Arsenic - 95%
	Average	1.8E-03	—	3.4E-04	Dermal contact - 2%	PCB 1260 - 3%
					Inhalation - <1%	Vinyl Chloride - 1%
					Fruits and vegetables - <1%	Beryllium - <1%
						Other chemicals[b] - <1%
Fishing/fish ingestion	RME	1.8E-03	—	1.3E-03	Fish ingestion - <99%	Arsenic - >99%
	Average	5.5E-04	—	4.0E-04	Water ingestion - <1%	
Sediment contact	RME	—	5.2E-04	—	Sediment ingestion - >99%	Arsenic - 100%
	Average	—	2.3E-04	—		
Total receptor risks	**Original GW data**					
	RME	1.8E-02	5.2E-04	4.2E-03		
	Average	3.4E-03	2.3E-04	9.1E-04		
	Adjusted GW data					
	RME	1.7E-02	5.2E-04	4.1E-03		
	Average	2.4E-03	2.3E-04	7.4E-04		

RC424

[a] RME case for receptor showing greatest risk.
[b] Other chemicals responsible for risks greater than 10^{-6} but less than 1% of the total are benzene, chloroform, 1,2-dichloroethane, heptachlor, methylene chloride, and 1,1,2,2-tetrachloroethane.

Source: Ecology and Environment, Inc., 1992

Table 8-27

SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child[b]	Risk Contributions by Exposure Route[a]	Hazard Index By Chemical[a]
Fishing/fish ingestion	RME	9.2	—	40	Fish ingestion - >99%	Arsenic - 34
	Average	3.1	—	14	Water ingestion - <1%	Cadmium - 6
Sediment contact	RME	—	1.8	—	Sediment ingestion - 100%	Arsenic - 1.8
	Average	—	0.81	-		

RC424

[a]RME case for receptor showing greatest risk.
[b]Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

Table 8-28

SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH SHEPLEY'S HILL LANDFILL - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child[b]	Risk Contributions by Exposure Route[a]	Hazard Index by Chemical[a]
Residential groundwater usage	**Original data**					
	RME	77	--	85	Water ingestion - 97%	Arsenic - 73
	Average	12	--	13	Fruits and vegetables - 3%	Cadmium - 9.2
					Dermal contact - <1%	Manganese - 2.4
					Inhalation - <1%	
	Adjusted data					
	RME	72	--	80	Water ingestion - 97%	Arsenic - 69
	Average	9.1	--	10	Fruits and vegetables - 3%	Cadmium - 9.2
					Dermal contact - <1%	Manganese - 2.2
					Inhalation - <1%	
Fishing/fish ingestion	RME	9.2	--	40	Fish ingestion - >99%	Arsenic - 34
	Average	3.1	--	14	Water ingestion - <1%	Cadmium - 6
Sediment contact	RME	--	7.1	--	Sediment ingestion - 100%	Arsenic - 7.0
	Average	--	3.1	--		
Total receptor risks	**Original GW data**					
	RME	86	7.1	125		
	Average	15	3.1	27		
	Adjusted GW data					
	RME	81	7.1	120		
	Average	12	3.1	24		

RC424

[a] RME case for receptor showing greatest risk.
[b] Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

Table 8-29

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH CONTAMINATION IN PLOW SHOP POND FROM SOURCES OTHER THAN SHEPLEY'S HILL LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Fishing/fish ingestion	RME	3.9E-05	—	2.8E-05	Fish ingestion - >99%	Heptachlor - 66%
	Average	1.2E-05	—	8.4E-06	Water ingestion - <1%	DDE - 34%
Sediment contact	RME	—	7.1E-07	—	Sediment ingestion - >99%	Beryllium - 35%
	Average	—	3.6E-07	—		PAHs[b] - 65%
Non-Cancer Hazard Indices[c]						
Fishing/fish ingestion	RME	18	—	78	Fish ingestion - >99%	Mercury - 77
	Average	4.0	—	17	Water ingestion - <1%	Copper - 1.1
Sediment contact	RME	—	0.080	—	Sediment ingestion - >99%	
	Average	—	0.046	—		

RC424

[a] RME case for receptor showing greatest risk.
[b] Carcinogenic PAHs detected in Plow Shop Pond include benzo(a)anthracene and chrysene.
[c] Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

Table 8-30

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH CONTAMINATION IN PLOW SHOP POND FROM SOURCES OTHER THAN SHEPLEY'S HILL LANDFILL - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Fishing/fish ingestion	RME	3.9E-05	—	2.8E-05	Fish ingestion - >99%	Heptachlor - 66%
	Average	1.2E-05	—	8.4E-05	Water ingestion - <1%	DDE - 34%
Sediment contact	RME	—	2.7E-06	—	Sediment ingestion - >99%	Beryllium - 35%
	Average	—	1.4E-06	—		PAHs[b] - 65%
Non-Cancer Hazard Indices[c]						
Fishing/fish ingestion	RME	18	—	78	Fish ingestion - >99%	Mercury - 77
	Average	4.0	—	17	Water ingestion - <1%	Copper - 1.1
Sediment contact	RME	—	0.31	—	Sediment ingestion - >99%	
	Average	—	0.18	—		

RC424

[a]RME case for receptor showing greatest risk.
[b]Carcinogenic PAHs detected in Plow Shop Pond include benzo(a)anthracene and chrysene.
[c]Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

the potential risks they could pose were estimated and are summarized in Tables 8-31 and 8-32 for use in a future area or basewide risk assessment.

Cancer risk and hazard index estimates corresponding to both average and RME cases are provided. As shown in the summary tables, exposure to contaminants related to Shepley's Hill Landfill appears to pose both significantly increased risks of developing cancer and increased risks of experiencing adverse noncarcinogenic health effects.

Under existing site conditions, estimated potential excess cancer risks ranged from 6×10^{-5} to 2×10^{-3}, and the estimated hazard indices ranged from 0.8 to 40. Consumption of potentially contaminated fish from Plow Shop Pond was responsible for the greatest estimated cancer and noncancer risks. Although the estimated cancer risks to adolescents coming in contact with contaminated sediment along the shore of the pond were about 10 times lower than the estimated risks of eating fish, the risks exceeded the benchmark level of 10^{-6}. Greater than 99 percent of all of the estimated cancer risks were due to arsenic in the sediment and in fish tissue. Arsenic, with an HI of 34, also accounted for about 85 percent of the estimated noncancer risk from eating fish and 93 percent of the sediment contact risk. The remaining 15 percent of the noncancer fish consumption risk was due to cadmium which had an HI of 6.

If future residential use of areas near the landfill is assumed, including use of the groundwater as a drinking water source, the total estimated potential excess cancer risks for receptors range from about 2×10^{-4} to about 2×10^{-2}, and the estimated hazard indices range from 3.1 to 85. The estimated risks associated with fish consumption are the same as for existing conditions. The estimated risks from contact with contaminated sediment along the shore of Plow Shop Pond increased about fourfold because of the greater frequency of contact assumed for adolescents living near the pond compared to those living nearby in Ayer, for example, and visiting the area occasionally to play. The greatest potential risks associated with residential use of the area are those arising from use of the groundwater as a drinking water source. Water ingestion accounts for 97 percent of both the cancer and noncancer risks estimated for domestic water usage. Arsenic again accounted for the vast majority of these estimated risks, 94 percent to 95 percent of the cancer risks and 86 percent of noncancer risks (HI=73); PCBs accounted for most of the remaining cancer risks; and cadmium (HI=9) and manganese (HI=2) accounted for the remaining noncancer risks.

The risks estimated for domestic use of contaminated groundwater were only about 10 percent to 35 percent lower when calculated using the metals concentrations adjusted to remove the contribution of suspended sediment than when calculated using the original unadjusted data. This is because many of the higher metals concentrations found in the groundwater appear to be due, at least in part, to actual contamination rather than suspended sediment. The major differences between the two data sets will be seen when assessing the areal extent of the actual contamination in planning potential remedial activities.

Table 8-31

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH GROUNDWATER AT SHL-15 - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Residential groundwater usage	**Original data**					
	RME	1.2E-02	---	2.3E-03	Ingestion - >99%	Arsenic - 98%
	Average	7.5E-03	---	1.4E-03	Dermal contact - <1%	Beryllium - 1%
					Inhalation - <1%	Dieldrin - <1%
					Fruits and vegetables - <1%	
	Adjusted data					
	RME	9.9E-03	---	1.8E-03	Ingestion - >99%	Arsenic - 99%
	Average	5.9E-03	---	1.1E-03	Dermal contact - <1%	Beryllium - 1%
					Inhalation - <1%	
					Fruits and vegetables - <1%	
Non-Cancer Hazard Indices[b]						
Residential groundwater usage	**Original data**					
	RME	58	---	65	Ingestion - 97%	Arsenic - 60
	Average	35	---	39	Dermal contact - <1%	Manganese - 2.9
					Inhalation - <1%	Cadmium - 2.7
					Fruits and vegetables - 3%	
	Adjusted data					
	RME	48	---	54	Ingestion - 97%	Arsenic - 49
	Average	28	---	32	Dermal contact - <1%	Cadmium - 2.7
					Inhalation - <1%	Manganese - 2.4
					Fruits and vegetables - 3%	

RC424

[a] RME case for receptor showing greatest risk.
[b] Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

Table 8-32

SUMMARY OF ESTIMATED EXCESS CANCER RISKS AND HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH GROUNDWATER AT SHL-7, -8S, -8D, and -13 - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions By Chemical[a]
Cancer Risks						
Residential groundwater usage	**Original data**					
	RME	1.5E-03	—	2.8E-04	Ingestion - >99%	Arsenic - 98%
	Average	4.7E-04	—	8.7E-05	Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Beryllium - 2%
	Adjusted data					
	RME	7.9E-05	—	1.5E-05	Ingestion - >99%	Arsenic - 89%
	Average	4.2E-05	—	7.8E-06	Dermal contact - <1% Inhalation - <1% Fruits and vegetables - <1%	Beryllium - 11%
Non-Cancer Hazard Indices[b]						
Residential groundwater usage	**Original data**					
	RME	7.7	—	8.4	Ingestion - 97%	Arsenic - 7.3
	Average	2.6	—	2.9	Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 3%	Manganese - 0.8
	Adjusted data					
	RME	1.0	—	1.2	Ingestion - 94%	Manganese - 0.7
	Average	0.61	—	0.68	Dermal contact - <1% Inhalation - <1% Fruits and vegetables - 6%	Arsenic - 0.4

RC424

[a] RME case for receptor showing greatest risk.
[b] Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

Lead and bromide were not included in the quantitative risk assessment because there are no RfDs or SFs available for these chemicals. There is a Safe Drinking Water Act (SDWA) action level for lead in drinking water of 15 µg/l, a level expected to avoid most of the significant adverse effects of lead in young children who are most sensitive to the effects of lead. Since the greatest exposure to lead in groundwater is likely to result from using this groundwater as drinking water, the action level is an appropriate criterion to use in assessing the lead concentrations in groundwater.

Table 8-33 summarizes the findings about lead in the groundwater at the landfill. Using the original unadjusted groundwater data, one background well sample (SHL-23, Round 1) and 13 out of 26 samples from wells within the landfill's zone of influence had lead concentrations greater than 15 µg/l. Using the data adjusted to remove the effect of suspended sediment, no background well samples, and only 3 out of 26 samples from within the landfill's zone of influence (SHL-4, Round 1; SHL-12, Round 2; and SHL-19, Round 2) had lead concentrations greater than 15 µg/l. The lead concentrations in SHL-15, which is outside the landfill's zone of influence, also exceeded 15 µg/l in both adjusted and unadjusted results. The lead concentrations in SHL-13, one of the four remaining wells outside the landfill's zone of influence, exceeded 15 µg/L in the original data but not after the data was adjusted. From these results it appears that lead concentrations in the groundwater at a few locations around the landfill could pose a significant risk to human health. Using the original data, the average and maximum lead concentrations within the zone of influence exceeded the action level by factors of about 2 and 13, respectively. Using the adjusted data, the average and maximum concentrations are 0.4 and 5 times the action level, respectively.

No suitable criterion could be located for use in evaluating bromide concentrations in the groundwater. However, comparison of the oral LD_{50} values reported in Sax and Lewis (1989) for sodium bromide and sodium chloride for rats, mice and rabbits given in Table 8-34 suggests that bromide is comparable in toxicity to chloride and that the concentrations of bromide found in the groundwater (up to 517 µg/l) are unlikely to result in any adverse health effects.

Perspective on Arsenic Exposure and Risks

Most of the estimated risks associated with Shepley's Hill Landfill are due to potential exposure to site-related arsenic concentrations in several environmental media. Arsenic is also present in natural background 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 non-site-related exposures to arsenic and the risks that could be associated with that exposure.

Table 8-33

EVALUATION OF LEAD
CONCENTRATIONS IN GROUNDWATER

Area	Detection Frequency	Frequency of Concentration >15 μg/L	Average Concentration (μg/L)	Maximum Concentration (μg/L)
Original Data				
Background	3/8	1/8	14	78
Within zone of influence	21/26	13/26	27	190
Adjusted Data				
Background	1/8	0/8	2	9
Within zone of influence	12/26	3/26	6	78

RC424

Source: Ecology and Environment, Inc., 1992

Table 8-34

COMPARISON OF ORAL LD_{50} VALUES
FOR BROMIDE AND CHLORIDE

	Oral LD_{50} (mg/kg)	
Species	Sodium Bromide	Sodium Chloride
Rat	3,500	3,000
Mouse	7,000	4,000
Rabbit	580	8,000

RC424

Source: Sax and Lewis, 1989.

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 1991; 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. The fact that the majority of the United States population does not appear to be suffering adverse effects from arsenic despite the estimated risks associated with everyday arsenic exposure is attributable to the conservative, health-protective nature of the EPA's toxicity assessment process.

To help the reader put the estimated potential site-related arsenic exposures in perspective, the estimated arsenic intakes for each exposure pathway are compared to the estimated daily exposure for the general population in Table 8-35. The last column is the ratio of estimated site-related arsenic intake by the pathway described to the estimated total daily intake of arsenic by the general population. Under current site conditions, the estimated average site-related arsenic intakes were less than the estimated intake for the general population. For the RME case, the estimated intakes ranged from slightly less than that of the general population to about 7 times higher. Assuming future residential use of the landfill area, estimated site-derived arsenic intakes range from about two to about 27 times the estimated intake of the general population.

The estimated arsenic intake for the general population is based on measured arsenic concentrations in food items and drinking water, and on excretion of arsenic in the urine of individuals assumed be at steady state (i.e., intake equals output) with respect to arsenic and not known to have any unusual exposure to arsenic. Therefore, the estimates of the typical arsenic intake by the general population should be quite reliable. On the other hand, the estimates of potential site-related arsenic exposure are based on conservative (health protective) exposure assumptions, and for the RME case, the highest observed arsenic concentrations in environmental media. Therefore, the estimated site-related exposures almost certainly overestimate any actual exposures that might occur.

Nature of Potential Adverse Health Effects

The site contaminants estimated to pose potential excess lifetime cancer risks greater than the 10^{-6} benchmark include arsenic, beryllium, benzene, chloroform, 1,2-dichloroethane, dichloromethane, dieldrin, heptachlor, alpha-hexachlorocyclohexane, PCB, 1,1,2,2-tetrachloroethane, and vinyl chloride.

Three of these chemicals, arsenic, benzene, and vinyl chloride, are classified as Group A human carcinogens. Oral exposure to arsenic is known to cause skin cancer, and there is mounting evidence that

Table 8-35

**SITE 5: SHEPLEY'S HILL LANDFILL
COMPARISON OF ESTIMATED POTENTIAL
SITE-RELATED ARSENIC INTAKES TO
ESTIMATED INTAKES FOR THE GENERAL POPULATION**

Exposure Pathway	Receptor	Exposure Case	Estimated Intake (mg/kg/day)	The Estimated Fraction of Daily Intake by the General Population[a]
Current Site Conditions				
Fishing, fish consumption	Adult	Average	7.36E-4	1.03
		RME	2.37E-3	3.32
	Child	Average	3.22E-4	0.21
		RME	1.04E-2	6.66
Sediment contact	Adolescent	Average	2.39E-4	0.29
		RME	5.43E-4	0.65
Future Residential Use				
Sediment contact	Adolescent	Average	9.20E-4	1.10
		RME	2.09E-3	2.51
			Unadjusted Data	
Domestic groundwater usage	Adult	Average	3.58E-3	5.01
		RME	1.96E-2	27.4
	Child	Average	4.00E-3	2.56
		RME	2.18E-2	14.0
			Adjusted Data	
	Adult	Average	2.39E-3	3.35
		RME	1.85E-2	25.9
	Child	Average	2.66E-3	1.70
		RME	2.06E-2	13.2

RC424

[a]Assumed to be 50 μg/day for adults, 35 μg/day for adolescents, and 25 μg/day for children.

Source: Ecology and Environment, Inc., 1992

ingestion of arsenic may cause liver, kidney, bladder, or lung cancer. Benzene has caused leukemia, and vinyl chloride has caused liver cancer in occupationally-exposed workers.

Except for 1,1,2,2-tetrachloroethane, which is classified as a Group C-possible human carcinogen, the rest are classified as Group B2-probable human carcinogens, based on carcinogenicity in animals. Beryllium has caused various types of tumors in exposed animals. Most of the remaining organic carcinogens are associated with cancers of the liver or kidneys. 1,2-DCA causes cancer of the circulatory system.

Site contaminants that pose potentially significant noncarcinogenic adverse health effects include arsenic, cadmium, chromium, and manganese. Overexposure to arsenic can cause damage to the kidneys and blood, weight changes, and possible keratosis and hyperpigmentation of the skin in humans. Chronic exposure to cadmium leads to renal dysfunction, hypertension, and anemia. Long-term oral exposure to chromium VI may cause kidney or liver damage. A few studies suggest that excessive ingestion of manganese can cause changes in brain chemistry; however, reports of adverse health effects in humans from ingestion of manganese are rare.

Summaries of the toxic effects of all of these chemicals are provided in Section 8.1.4.2.

Level of Confidence/Uncertainty in the Risk Estimates

These matters are discussed fully in earlier sections of this report; briefly, the level of confidence in the exposure estimates range from medium to high. The level of confidence in the toxicity estimates varies from chemical to chemical as shown in Tables 8-23 and 8-24.

Overall, the level of confidence in the risk estimates also ranges from low to high. Confidence in the risk estimates for future groundwater usage is high because it is based directly on the contaminant concentrations measured in the groundwater.

Confidence in the risk estimates for direct contact with shoreline sediments is low for several reasons. Because no samples were collected along the shore where exposure is assumed to occur, concentrations in bottom sediments taken close to shore had to be used to estimate the exposure point concentrations. It is possible the bottom sediments may be richer in organics that could trap metals and may also have greater contact with contaminated groundwater discharging to the pond than shoreline sediments. Both factors could result in higher metals concentrations in bottom sediments than in shoreline sediments, thus overestimating the potential exposure and risk. In addition, for arsenic, the major COPC in terms of risk, the dermal absorption from sediment and the associated health risks are both uncertain.

Confidence in the risk estimates for fish consumption is also moderate because no data about contaminant concentrations in fish from

Plow Shop Pond were available. Consequently, contaminant concentrations in fish had to be estimated from sediment concentrations using bioaccumulation factors. Arsenic, the chemical of greatest concern in the sediment, accounted for 98 percent to 100 percent of the estimated risks associated with fish consumption. However, there is limited information in the literature on the relationship between arsenic concentrations in sediment and fish tissue. More information is available for cadmium, but it is highly variable and seems to depend heavily on local conditions. The approach used to estimate the bioaccumulation factors for arsenic and cadmium seems reasonable and appropriate given the information available; however, the variable nature of that information results in a moderate level of confidence in the bioaccumulation factors and in the risk estimates derived from them.

Major Factors Driving the Estimated Site Risks

The major factors driving the estimated site risks are:

- The presence of elevated concentrations of metals in Plow Shop Pond sediments, principally arsenic and cadmium, coupled with use of the pond for fishing, consumption of fish caught in the pond, and possible use of the pond shoreline as a play area by adolescents, which provide pathways of exposure to these contaminants; and

- The presence of elevated concentrations of metals, principally arsenic and cadmium, and other contaminants in the groundwater, coupled with the possible future use of the groundwater as a source of drinking water.

Characteristics of the Potentially Exposed Populations

The potential receptors consist of adolescents who might play along the shore of Plow Shop Pond, fishermen and their families and friends who might eat fish caught in the pond, and potential future residents that might live in homes built near the landfill. Fishermen and their families, and future residents, would be expected to include a mixture of children, adults, and the elderly, which reflects the general demographic characteristics of the area. Adolescent site visitors and future residents who might play along the shoreline would probably be representative of those segments of the local population.

8.2 COLD SPRING BROOK LANDFILL

8.2.1 Introduction

8.2.1.1 Overview

Little is known about the history of the Cold Spring Brook Landfill. It was not recognized as a former disposal area until November 1987, when fourteen 55-gallon drums were uncovered along the edge of Cold Spring Brook. Based on the identification number on the drums, it was determined that they were 15 to 20 years old and originally contained antifreeze manufactured by Union Carbide. The drums had apparently been repainted and reused. It is not known whether the drums are related to any other materials disposed of at the landfill.

The landfill extends for about 900 feet along the north side of Patton Road and covers an area of about 3.5 acres between the road and Cold Spring Brook (see Figure 8-4). Waste materials that have been found in the landfill include concrete slabs, wire, tanks, rebar, timber, and debris.

The landfill surface slopes gently from south to north and is densely covered with small trees and shrubs. The north edge of the landfill falls off abruptly to a wetland or to the pond itself, with an elevation drop of perhaps 15 to 20 feet on average. Surface runoff and groundwater from most of the landfill discharge to Cold Spring Brook along the landfill's northern edge. Some of the groundwater from the western end of the landfill appears to be drawn westward toward the Patton well, one of Fort Devens' three water supply wells, when it is pumping.

The landfill is located in the southeastern part of the main cantonment area but is relatively isolated from most of the facilities in this part of the base. A small convenience store called the Shoppette is located about 500 feet east of the eastern edge of the fill area; the magazine area is located about 400 feet northwest of the western end of the fill, and the Patton well is located about 400 feet west-southwest of the western end of the fill.

The United States Army Environmental Hygiene Agency (USAEHA) installed a series of monitoring wells around the landfill in 1988 and has since been monitoring groundwater quality in the area. Elevated concentrations of arsenic have been found repeatedly in wells CSB-4 and -5 located near the northern edge of the fill toward the landfill's western end.

During the RI, two rounds of groundwater samples were collected from the existing wells, several surface soil samples were collected from the landfill area, and 10 surface water and 10 sediment samples were collected from Cold Spring Brook adjacent to the landfill. Elevated concentrations of arsenic and several other metals were found

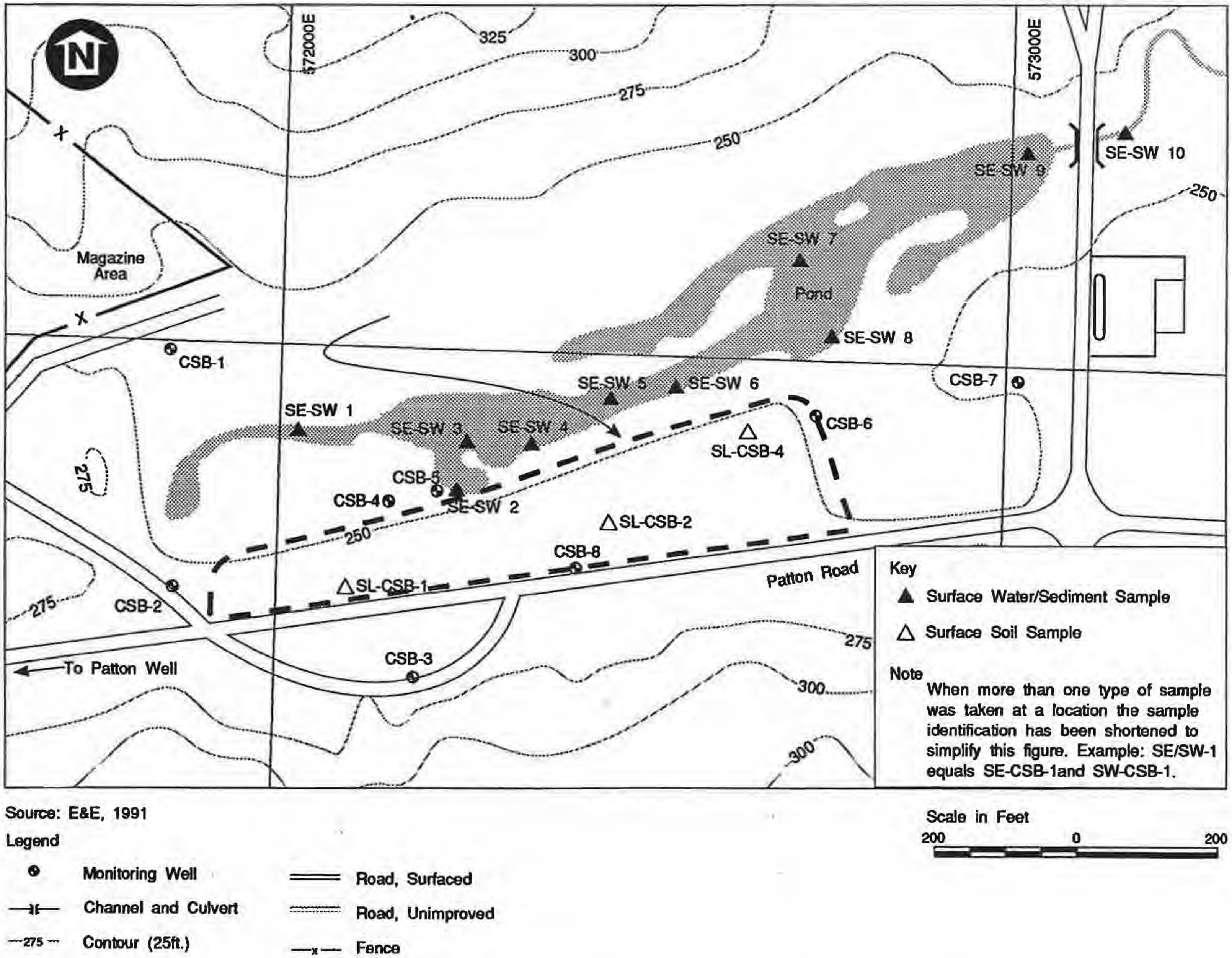

Figure 8-4 COLD SPRING BROOK LANDFILL AREA AND SAMPLING LOCATIONS

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in several wells; however, these levels may be due to suspended sediment. Elevated levels of arsenic and one or two other metals were also found in surface water and sediment samples from locations adjacent to the western half of the landfill. Low levels of a number of PAHs were found in two soil samples and three sediment samples. Low levels of DDT residues were also found in one soil sample and eight out of 10 sediment samples.

8.2.1.2 Site Background

Detailed descriptions of the site, its history and setting, the nature of previous investigations, and the nature and extent of contamination are provided in previous sections of this report.

8.2.1.3 Conceptual Site Model

A conceptual site model has been prepared and is presented in Figure 8-5. As shown in the figure, there appear to be three main exposure pathways under current conditions:

- o Direct contact with contaminated surface soil on the landfill;
- o Direct contact with contaminated sediments along the shore of Cold Spring Brook; and
- o Ingestion of surface water while fishing in Cold Spring Brook Pond and consumption of contaminated fish caught from the pond.

These pathways would also apply in the future if the site were converted to residential use. In addition, future exposures could potentially occur through use of groundwater as a source of potable water for domestic supply purposes.

There are three primary groups of potential receptors under existing site conditions: site visitors, such as hikers, who might come in contact with contaminated surface soils; adolescent site visitors who might play along the edge of the pond; and fishermen and their families who might eat contaminated fish caught from the pond. Swimming in the pond is not considered to be a likely pathway of exposure because the pond is shallow and abundantly vegetated.

The hydrogeological investigation showed that pumping of the Patton well draws groundwater from the western end of the landfill westward toward the well. However, comparison of the water quality data for the Patton well with that from the Cold Spring Brook monitoring wells indicates that little if any of the water captured by the Patton well comes from the landfill area (see Section 5.2.2.1). Groundwater from the area around monitoring wells CSB-4 and -5, which show the greatest contamination, discharges to Cold Spring Brook. Apart from the Patton well, the groundwater is not presently used for drinking water supply

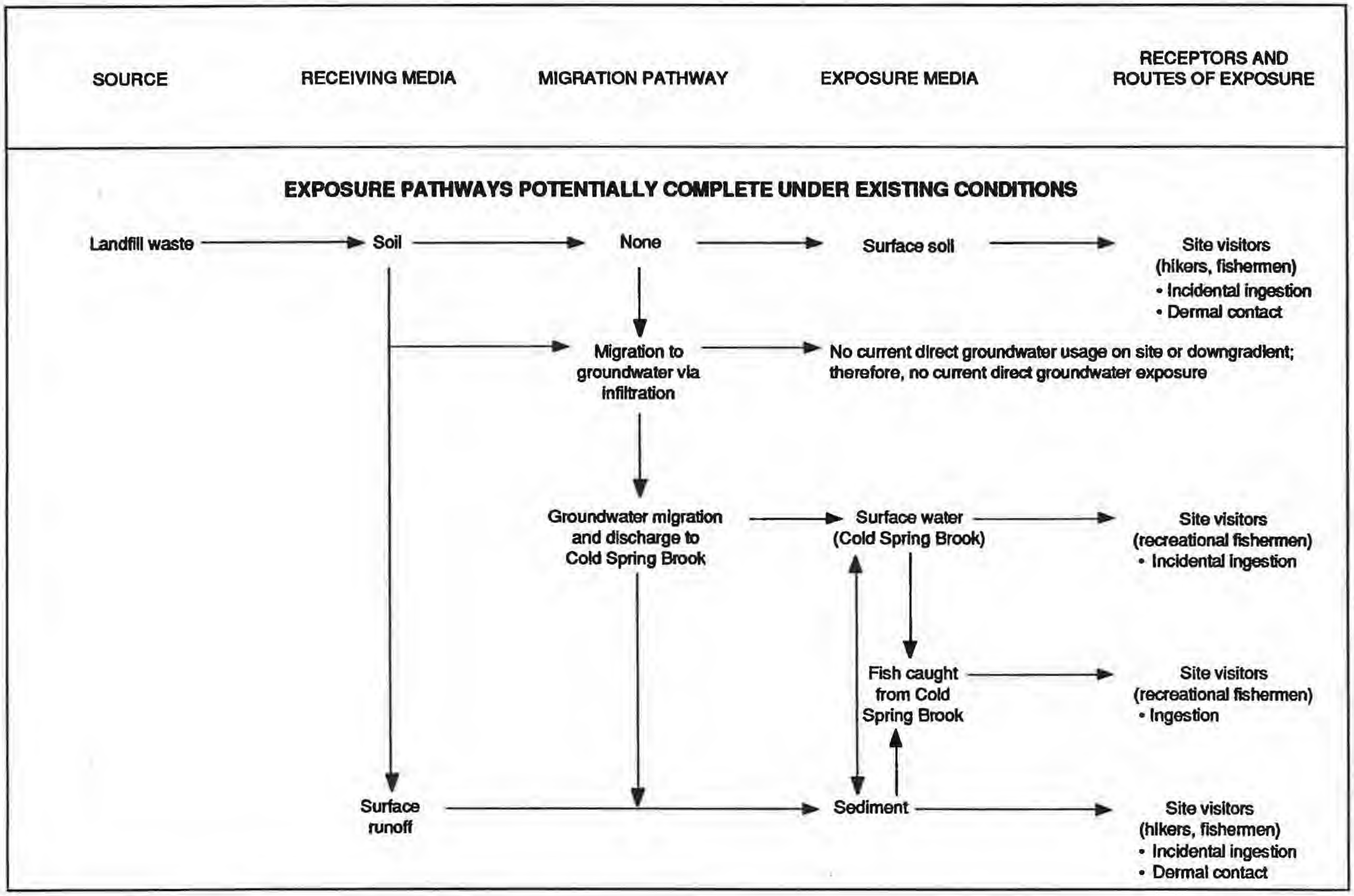

Figure 8-5 CONCEPTUAL SITE MODEL FOR COLD SPRING BROOK LANDFILL

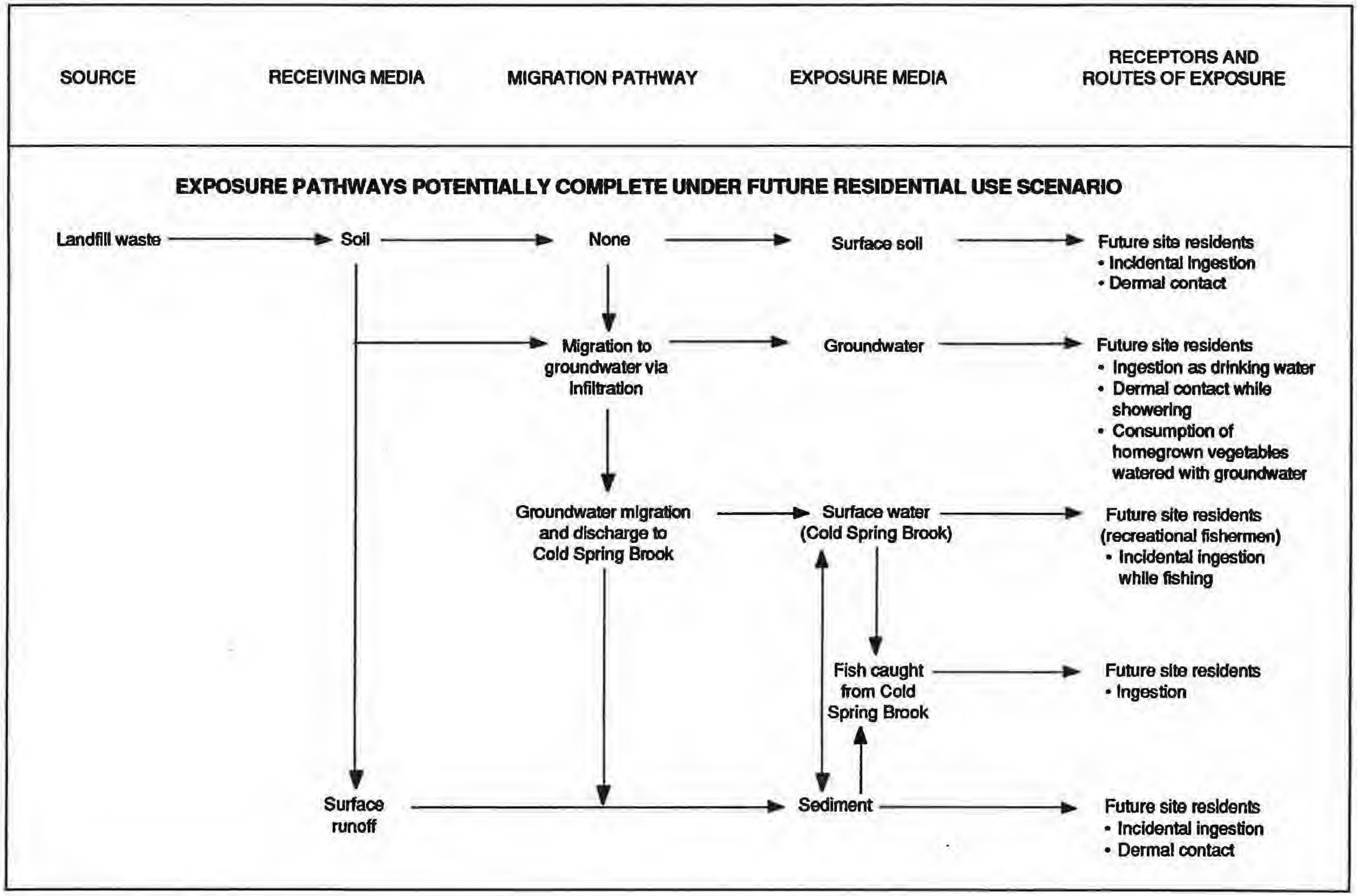

Figure 8-5 (Cont.) CONCEPTUAL SITE MODEL FOR COLD SPRING BROOK LANDFILL

purposes in the vicinity of the landfill, so there are no receptors currently exposed to groundwater contaminants.

Fort Devens is scheduled to be closed in the near future. After closure, parts of the base including areas around the landfill might be converted to residential use. If this happens and wells are installed to supply these new residences with drinking water, the future residents could be exposed to the groundwater contaminants. Residents living in these homes could be exposed to contaminants in the surface soil, and adolescent residents also may play along the shore of the pond and be exposed to contaminated sediments in that area.

8.2.1.4 Organization of the Human Health Risk Assessment Section

Like the assessment for Shepley's Hill Landfill, this Cold Spring Brook Landfill risk assessment has been prepared and organized in accordance with EPA's Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (RAGS-HHEM) (USEPA 1989c), other related EPA Guidance, and Massachusetts Guidance for Disposal Site Risk Characterization and Related Phase II Activities (MDEP 1989a).

The remainder of the risk assessment is organized as follows. In Section 8.2.2, E & E reviews the site characterization data available; in Section 8.2.3, E & E assesses the potential exposure of receptors to the chemicals of potential concern; in Section 8.2.4, E & E provides toxicity assessments for the chemicals of potential concern at the site; and in Section 8.2.5, E & E integrates the exposure and toxicity assessments from Section 8.2.3 and 8.2.4 into an overall risk assessment. The main risks associated with the site are identified, along with the pathways and chemicals giving rise to those risks.

8.2.2 Identification of Chemicals of Potential Concern

8.2.2.1 Data Collection

The objective of the RI was to characterize the nature and extent of contamination associated with the Cold Spring Brook Landfill AOC as well as the site topography, geology, hydrogeology, climate and demographics in order to identify and evaluate potential migration and exposure pathways. The investigative activities carried out to achieve these objectives are described in Section 2 of the report and the results of the RI are described in Sections 3 and 5.

General Considerations

The origin and history of the Cold Spring Brook Landfill are unknown; however, much of the waste material disposed there appears to be construction or demolition debris. It also is not known whether there was anything in the drums found on the northern edge of the landfill along Cold Spring Brook when they were originally left there. Fort Devens' magazine area, another potential source of contaminants, is located just west of the landfill. Cold Spring Brook originates as drainage from a wetland in the center of the magazine area and passes through several other wetlands after passing the landfill and before reaching Grove Pond. The Patton well, one of three water supply wells for Fort Devens, is located just over 400 feet from the southwestern corner of the landfill. Both Cold Spring Brook and the Patton well could be affected by contaminants from the landfill. The Army is conducting an ongoing groundwater monitoring program for the landfill area using a network of eight monitoring wells around the site.

With these considerations in mind, the following sampling program was implemented to characterize the nature and extent of contamination associated with the landfill. The existing monitoring well network appeared to provide adequate coverage of the area, so no new wells were installed. Two rounds of unfiltered groundwater samples were collected to satisfy the EPA's requirement for use of unfiltered samples for assessing contamination of potential drinking water sources. Because the Patton well was potentially impacted by the landfill, it was also sampled. Since the landfill is not capped, surface soil samples were collected to assess possible contamination in this medium. Surface water and sediment samples were collected from Cold Spring Brook adjacent to and downstream from the landfill to assess its potential impact on the brook. Finally, an air quality survey that included VOCs and respirable size particulate matter (PM_{10}) was conducted to investigate potential air emissions from the landfill.

Sampling locations for each medium were selected in a directed or purposive manner taking into consideration the physical characteristics of the landfill and the surrounding area, and the potential contaminant migration patterns that might exist. Neither systematic nor random sampling--employing a grid to select sampling locations--was used because of the complex site conditions.

Twenty background soil samples, 16 surface and four subsurface, were collected from locations throughout Fort Devens (see Figure 5-1) that did not appear to be affected by any known or suspected sources of contamination. These samples were analyzed for metals to determine the normal range of metals concentrations in soils at the base.

Sampling, analytical, and QA/QC methods are USATHAMA methods that were approved by the EPA and are described in Sections 2 and 4 of this report, in the Field Sampling Plan (FSP) (E & E 1991a), and the Quality Assurance Project Plan (QAPjP) (E & E 1991b).

8.2.2.2 Data Evaluation

Data validation, evaluation of quantitation limits, and evaluation and use of qualified data for Cold Spring Brook Landfill are identical to the procedures described for Shepley's Hill Landfill in Section 8.1.2.2. All of the COPCs for Cold Spring Brook Landfill are included in Table 8-1 and the adequacy of their quantitation limits are discussed in Section 8.1.2.2.

8.2.2.3 Selection of Chemicals of Potential Concern - General Approach and Selection Criteria

Several factors complicated the identification and selection of the COPCs for the Cold Spring Brook Landfill. These factors include the following:

- o Complicated and heterogeneous geological and hydrogeological settings made it difficult to site true upgradient and downgradient wells;
- o The apparent presence of suspended sediment in many of the groundwater samples, which made interpretation of the metals results difficult; and
- o The presence of other source areas that appear to have contributed contamination to the AOC under consideration.

This section describes how the usual COPC selection process was implemented and the ways the complicating factors described above were addressed.

Data Usability

The usability of the data for risk assessment purposes was determined using established EPA guidelines (USEPA 1992b). For example, sample values that did not exceed five times the blank values (10 times for common laboratory contaminants) were not included in the risk assessment. A number of pesticides were detected in many of the samples at concentrations slightly above their detection limits; however, many of these hits were not confirmed by second column analysis. Because unconfirmed hits such as these are often analytical artifacts, or noise, they were not included in the quantitative risk assessment. The analytical results are reviewed in detail and the confirmed hits summarized in Section 5 this report.

Comparison With Natural Background Concentrations

Many metals and anions are naturally present in water, soils, and sediments. The metals concentrations in the soils and sediments were compared to the upper tolerance limits of the concentrations found in the 20 background soil samples from Fort Devens. (See Figure 5-1 for background soil sample locations.) The upper tolerance limit is the statistic recommended for comparison of individual investigative sample results to the distribution of concentrations found in natural background populations (USEPA 1989i). The geometric means, upper tolerance limits, and maximum observed concentrations of metals in background soils from Fort Devens are provided in Table 8-2.

As noted earlier, the geological/hydrogeological setting of the landfill has made it very difficult to locate true upgradient monitoring wells. The groundwater flow pattern in the landfill area is shown in Figure 8-6. Figure 8-6 also shows the area in which the groundwater could potentially be affected by the landfill based on the evident groundwater flow patterns.

As shown, groundwater under the landfill flows generally northward discharging into Cold Spring Brook. There appears to be a slight groundwater mound located under the western part of the fill area south of CSB-4 that may be due to low permeability soils beneath the fill in that area. Groundwater appears to flow radially outward from the mound. The pumping of the Patton well seems to be drawing groundwater from under the western end of the landfill westward toward the Patton well. As shown in Figure 8-6, the only monitoring wells that are definitely outside of the landfill's zone of influence are CSB-1 and -7. Neither of these wells is upgradient from the landfill; however, except for a few contaminants apparently coming from other sources (discussed below), these wells probably provide a good indication of the general background groundwater quality in the area.

Surface water and sediment samples were collected throughout Cold Spring Brook Pond adjacent to the landfill. In designing the sampling program, it was expected that samples from the western, upstream end of the pond, particularly SE/SW-CSB-1, would serve as background samples. However, the analytical results indicated that that location evidently receives contaminants from the western end of the landfill. As a result, none of the samples appears to provide reliable information on the natural background surface water and sediment quality upstream from the part of the pond potentially affected by the landfill.

A general area background air sampling location was identified for the air quality survey based on the meteorological data collected at Shepley's Hill Landfill and historical data from Moore Airfield. The background air quality samples were collected at the Fort Devens Elementary School, about 1.25 miles north of the landfill.

Spatial Distribution

The spatial distribution of chemicals detected in environmental media with respect to the source area under investigation, as well as other potential sources, were considered in assessing whether a chemical originated from the study area or from other potential sources. Chemicals that were present at elevated levels but that did not appear to be site-derived were excluded from the quantitative risk assessment for the Cold Spring Brook AOC. For example, 1,3,5-trinitrobenzene was found in CSB-1 on the opposite side of Cold Spring Brook from the landfill. The most likely source of this explosive compound appears to be the magazine area west of this well location. Elevated levels of sodium, chloride, and sulfate were also found in several wells, particularly CSB-8, located close to roadways, and are probably more likely related to the use of road salt than to the landfill.

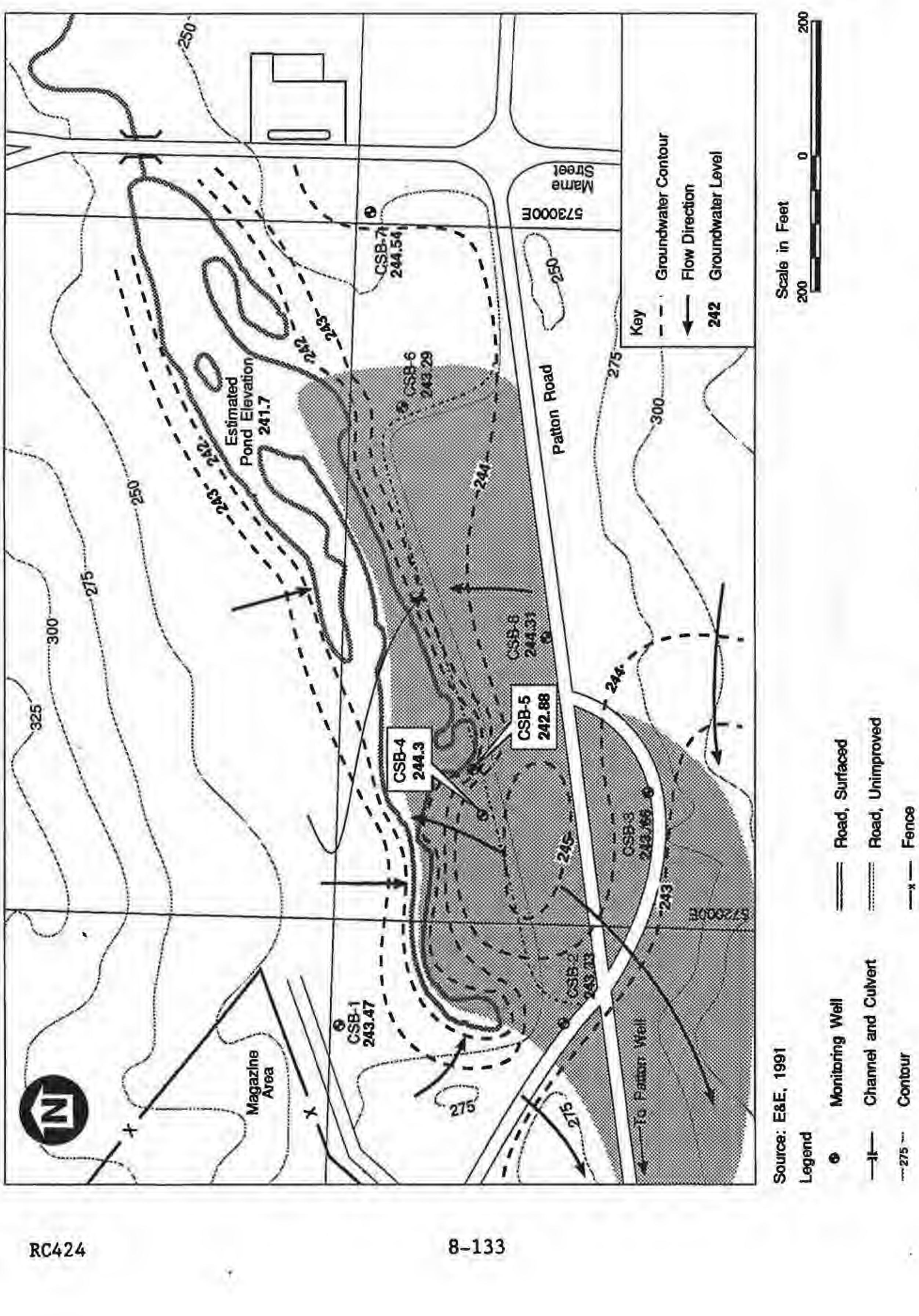

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Figure 8-6 AREA IN WHICH THE GROUNDWATER COULD POTENTIALLY BE AFFECTED BY THE COLD SPRING BROOK LANDFILL

Suspended Sediment

Many of the unfiltered groundwater samples collected from monitoring wells at the Cold Spring Brook Landfill contained substantial amounts of suspended sediment as judged by their markedly elevated aluminum and iron concentrations. The effect of this on the observed concentrations of metals in the samples and the usability of the data are discussed in Section 8.1.2.3. Metals concentrations were again adjusted to remove the effect of suspended sediment using the method described in Appendix K.

In light of the regional EPA guidance on the use of data for unfiltered samples in risk assessments, the adjusted metals concentrations were not used in the selection of COPCs. However, exposure and risk estimates were derived using both adjusted and unadjusted metals to provide an indication of the uncertainty introduced into the risk estimates by the presence of suspended sediment in the samples.

8.2.2.4 Summary of Analytical Results and Chemicals of Potential Concern

Surface Soils

Detailed analytical results for surface soils at Cold Spring Brook Landfill are discussed in Section 5 and presented in Table 5-10. The results are summarized in Table 8-36. Only four metals, calcium, potassium, sodium, and zinc, exceeded their upper tolerance limits for background soils at Fort Devens. The remaining metals that did not exceed their upper tolerance limits were excluded as COPCs for this reason. Calcium, potassium, sodium, and zinc are all essential nutrients that exhibit relatively low toxicities. No RfDs or SFs are available for use in assessing calcium, potassium, or sodium, and zinc exceeded its upper tolerance limit by less than 5 percent in one of three samples. None of these metals are carcinogens and none are likely to contribute significantly to any risks posed by site contamination. Therefore, calcium, potassium, sodium, and zinc were also excluded as COPCs.

Eleven PAH compounds were found in SL-CSB-2, and two were found in SL-CSB-1. Six of the PAHs found in SL-CSB-2, but neither of those in SL-CSB-1, are classified as carcinogens. All of the PAH compounds were selected as COPCs. DDT residues (4,4-'DDD and 4,4'-DDE) had confirmed hits in one sample and were selected as COPCs.

Groundwater

Detailed analytical results for groundwater at Cold Spring Brook Landfill are discussed in Section 5 and presented in Tables 5-11 and 5-12. The results are summarized in Tables 8-37 and 8-38. The results for the Patton well were also included in these tables because it might potentially be affected by contaminants from the landfill.

Table 8-36

SUMMARY OF SOIL RESULTS FOR
STUDY AREA 40 - COLD SPRING BROOK LANDFILL

Chemical	Detection Frequency	Range of Detected Concentrations (µg/g) Min	Max	Upper Tolerance Limit Background Soil Concentrations (µg/g)	Exceedance Frequency
Inorganics					
Aluminum	2/3	10,000	20,000	30,300	0/3
Arsenic	3/3	22	45	66	0/3
Barium	2/3	23.6	77	91	0/3
Beryllium	2/3	0.126	0.128	1.0	0/3
Cadmium	0/3	—	—	5.5	0/3
Calcium	1/3	—	4,700	3,460	1/3
Chromium	2/3	24.3	54.3	89	0/3
Copper	2/3	13.0	18.3	51	0/3
Iron	3/3	16,000	21,000	40,500	0/3
Lead	3/3	23.5	60.3	275	0/3
Magnesium	3/3	4,800	10,000	15	0/3
Manganese	2/3	230	430	590	0/3
Mercury	2/3	0.095	0.382	0.88	0/3
Nickel	2/3	15.2	30.2	53	0/3
Potassium	3/3	1,300	4,600	4,000	1/3
Silver	1/3	—	0.140	0.26	0/3
Sodium	3/3	123	1,300	570	2/3
Vanadium	3/3	16	28.6	64	0/3
Zinc	1/3	—	110	105	1/3
Organics					
4,4'-DDD[a]	1/3	—	0.101	—	—
4,4'-DDE[a]	1/3	—	0.232	—	—
Anthracene	1/3	—	0.514	—	—

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Table 8-36 (Cont.)

Chemical	Detection Frequency	Range of Detected Concentrations (μg/g) Min	Max	Upper Tolerance Limit Background Soil Concentrations (μg/g)	Exceedance Frequency
Organics (Cont.)					
Benzo(a)anthracene	1/3	---	1.04	---	---
Benzo(a)pyrene	1/3	---	1.30	---	---
Benzo(b)fluoranthene	1/3	---	0.969	---	---
Benzo(k)fluoranthene	1/3	---	1.72	---	---
Chrysene	1/3	---	1.20	---	---
Fluoranthene	2/3	0.732	2.56	---	---
Indeno(1,2,3-cd) pyrene	1/3	---	0.275	---	---
Phenanthrene	1/3	---	1.11	---	---
Pyrene	2/3	0.600	2.49	---	---

RC424

[a]Selected as COPCs.
bSuspected laboratory contaminant.

Source: Ecology and Environment, Inc., 1992

Table 8-37

SUMMARY OF RI GROUNDWATER RESULTS FOR COLD SPRING BROOK LANDFILL INORGANIC CHEMICALS

	Background Wells CSB-1 and CSB-7			Wells Within Landfill's Zone of Influence CSB-2, CSB-3, CSB-6, and CSB-8			Patton Well		
					Range			Range	
Chemical	Detection Frequency	Minimum	Maximum	Detection Frequency	Minimum	Maximum	Detection Frequency	Minimum	Maximum
Metals (μg/L)									
Aluminum	4/4	1,490	19,000	8/8	72	47,000	1/2	—	145
Arsenic[a]	4/4	4.71	79	8/8	3.49	220	1/2	—	3.96
Barium[a]	4/4	254	140	8/8	7.67	140	2/2	7.67	11.6
Beryllium[a]	1/4	—	0.584	4/8	0.633	1.08	0/2	—	—
Cadmium[a]	0/4	—	—	1/8	—	3.53	1/2	—	6.53
Calcium	4/4	5,000	14,000	8/8	12,000	51,000	2/2	41,000	47,000
Chromium[a]	3/4	6.12	14.7	8/8	8.52	150	1/2	—	8.59
Copper[a]	4/4	11.4	20.9	8/8	7.77	94.8	2/2	3.13	51.3
Iron	4/4	2,500	18,000	8/8	1,300	57,000	2/2	122	204
Lead[a]	4/4	5.58	37.6	8/8	5.85	85.0	1/2	—	7.54
Magnesium	4/4	1,400	4,400	8/8	2,600	45,000	2/2	6,100	6,400

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Table 8-37 (Cont.)

Chemical	Background Wells CSB-1 and CSB-7			Wells Within Landfill's Zone of Influence CSB-2, CSB-3, CSB-6, and CSB-8			Patton Well		
					Range			Range	
	Detection Frequency	Minimum	Maximum	Detection Frequency	Minimum	Maximum	Detection Frequency	Minimum	Maximum
Manganese[a]	4/4	350	2,400	8/8	27.4	6,200	2/2	300	350
Nickel[a]	0/4	—	—	7/8	13.8	90.6	2/2	9.56	9.65
Potassium	4/4	1,110	2,020	8/8	1,120	8,900	2/2	2,080	2,450
Silver[a]	0/4	—	—	2/8	0.683	1.19	0/2	—	—
Sodium	3/4	2,560	24,000	6/8	3,170	30,000	1/2	—	21,000
Vanadium[a]	2/4	—	—	4/8	10.6	56.9	0/2	—	—
Zinc[a]	4/4	22	127	7/8	0.9	230	2/2	131	147
Anions (μg/L)									
Bromide	0/4	—	—	2/8	52.2	68.8	0/2	—	—
Chloride	4/4	2,170	74,000	8/8	1,240	250,000	2/2	25,000	27,000
Fluoride	1/4	—	200	1/8	—	189	0/2	1,200	19,000
Nitrate	4/4	68.3	3,900	8/8	20.9	4,600	2/2	420	500
Sulfate	4/4	8,100	16,000	8/8	8,800	27,000	2/2	15,000	16,000

RC424

[a]Selected as COPC.

Source: Ecology and Environment, Inc., 1992

Table 8-38

**SUMMARY OF RI GROUNDWATER RESULTS FOR
COLD SPRING BROOK LANDFILL
ORGANIC COMPOUNDS (µg/L)**

	Background Wells		Wells Within Landfill's Zone of Influence			Patton Well	
				Range			
Chemical	Detection Frequency	Maximum	Detection Frequency	Minimum	Maximum	Detection Frequency	Maximum
1,3-Dinitrobenzene	1/6	2.86	0/8	---	---	0/2	---
1,3,5-Trinitrobenzene	2/6	7.94	0/8	---	---	0/2	---

RC424

Key:

[a]Selected as COPC.
[b]Attributed to laboratory contamination.

Source: Ecology and Environment, Inc., 1992

The presence of suspended sediment in most of the groundwater samples makes it very difficult to interpret the metals results. Because of the suspended sediment, meaningful comparisons between the metals concentrations in wells within the landfill's zone of influence and the concentrations in the background wells cannot be made using the unadjusted data. Consequently, only metals that were not detected or detected only once or twice could be eliminated as COPCs based on detection frequencies and unadjusted metals concentrations. Metals eliminated on this basis included cobalt and mercury.

Several other metals were eliminated as COPCs because they are commonly found in groundwater at comparable concentrations. They are essential nutrients generally regarded as having low toxicities, and there are no quantitative toxicological indices (RfDs and SFs) available to use in assessing them. Metals in this group included calcium, iron, magnesium, potassium, and sodium. Aluminum also exhibits relatively low toxicity and lacks quantitative toxicological indices, and was eliminated for this reason. The remaining metals, arsenic, barium, beryllium, cadmium, chromium, copper, lead, manganese, nickel, silver, vanadium, and zinc were selected as COPCs.

The anions generally had similar concentrations in the background wells and the wells within the zone of influence or were attributable to other sources such as road salt (see Section 5.2.2.1). The anions were excluded as COPCs.

Nitrobenzenes were found only in well CSB-1 outside of the landfill's zone of influence and close to the magazine area. These compounds do not appear to be related to the landfill and were not selected as COPCs.

Sediment

Detailed results for sediment from Cold Spring Brook are discussed in Section 5 and presented in Table 5-14. These results are summarized in Table 8-39. Only sediment concentrations of arsenic, calcium, iron, lead, manganese, and zinc exceeded their upper tolerance limits for Fort Devens soils. The remaining metals that did not exceed their upper tolerance limits were excluded as COPCs on that basis. Calcium and iron are essential nutrients with relatively low toxicities, and there are no RfDs or SFs available for use in assessing calcium and iron. Neither metal is a carcinogen and neither is likely to contribute significantly to any site-related risks; therefore, calcium and iron were not selected as COPCs. The remaining metals, arsenic, lead, manganese, and zinc, were selected as COPCs.

A number of organic compounds were detected in the sediment. 2-Butanone, which was detected only once, has a relatively low toxicity and is not a carcinogen. It was not selected as a COPC for these reasons. The remaining organic compounds detected in sediments, which includes DDT residues and PAHs, were selected as COPCs.

Table 8-39

SUMMARY OF SEDIMENT RESULTS FOR
COLD SPRING BROOK LANDFILL

Chemical	Detection Frequency	Range of Detected Concentrations (µg/g) Min		Max	Upper Tolerance Limit of Local Background Soil Concentrations (µg/g)	Exceedance Frequency
Inorganics						
Aluminum	10/10	3,800		17,000	30,300	0/10
Arsenic[a]	10/10	6.5		160	66	2/10
Barium	10/10	12.1		67.4	91	0/10
Beryllium	1/10	—		0.408	1.0	0/10
Cadmium	0/10	—		–	5.5	0/10
Calcium	6/10	1,100		13,000	3,460	4/10
Chromium	6/10	7.24		50.7	89	0/10
Copper	7/10	6.07		34.9	51	0/10
Iron	10/10	3,800		45,000	40,500	1/10
Lead[a]	10/10	11.4		345	275	1/10
Magnesium	10/10	923		7,000	15	0/10
Manganese[a]	10/10	110		3,000	590	2/10
Mercury	7/10	0.040		0.724	0.88	0/10
Nickel	4/10	4.51		26.3	53	0/10
Potassim	10/10	294		3,000	4,000	0/10
Sodium	5/10	74.4		403	570	0/10
Vanadium	10/10	5.57		41.1	64	0/10
Zinc[a]	6/10	14.6		690	105	1/10
Organics						
Acetone	8/10	0.016	–	0.167	—	—
2-Butanone	1/10	—		0.025	—	—
4,4'-DDD[a]	8/10	0.034	–	1.290	—	—
4,4'-DDE[a]	7/10	0.017	–	0.202	—	—

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Key at end of table.

Table 8-39 (Cont.)

Chemical	Detection Frequency	Range of Detected Concentrations (μg/g) Min	Max	Upper Tolerance Limit of Local Background Soil Concentrations (μg/g)	Exceedance Frequency
Organics (Cont.)					
Acenaphthylene[a]	1/10	---	2.88	---	---
Anthracene[a]	1/10	---	3.06	---	---
Benzo(a)anthracene[a]	3/10	0.385	4.31	---	---
Benzo(a)pyrene[a]	3/10	0.469	5.96	---	---
Benzo(b)fluoranthene[a]	3/10	0.377	5.30	---	---
Benzo(g,h,i)perylene[a]	1/10	---	1.43	---	---
Benzo(k)fluoranthene[a]	1/10	---	9.62	---	---
Chrysene[a]	3/10	0.539	7.51	---	---
Fluoranthene[a]	4/10	1.17	14.7	---	---
Indeno(1,2,3-cd)pyrene[a]	1/10	---	1.64	---	---
Phenanthrene[a]	2/10	0.432	5.88	---	---
Pyrene[a]	4/10	1.03	15.3	---	---

RC424

[a]Selected as COPCs.
bSuspected laboratory contaminant.

Source: Ecology and Environment, Inc., 1992

Surface Water

Detailed analytical results for surface water samples from Cold Spring Brook are discussed in Section 5 and presented in Table 5-13. The results are summarized in Table 8-40. Since the most upstream sample locations for surface water in Cold Spring Brook (SE/SW-CSB-1 and -2) appear to be affected by landfill-related contaminants, there are no surface water samples that can confidently be regarded as representing background surface water quality. In the absence of reliable background samples, the chemical concentrations found were compared to Ambient Water Quality Criteria (AWQC) for human health based on water and fish consumption. No AWQC has been established for zinc, so its secondary drinking water MCL was used as a reference point. Of the metals detected in the surface waters, the highest concentrations of barium, chromium, copper, silver, and zinc were at least 10 times lower than their AWQCs (or MCL in the case of zinc). These metals were excluded as surface water COPCs on that basis.

Arsenic, iron, and manganese exceeded their AWQCs. The AWQCs for iron and manganese appear to be based on their secondary drinking water MCLs, which in turn are based on aesthetic considerations (taste, odor, and appearance) rather than health effects. Iron is an essential nutrient with relatively low toxicity. In addition, no toxicological indices are available for use in assessing iron. Iron was excluded as a COPC for these reasons. Arsenic and manganese were selected as COPCs.

Air

The results of the air quality survey are presented in Tables 6-1 and 6-2 in Appendix G. No chemicals were found in ambient air samples at concentrations significantly different from background concentrations; therefore, no COPCs were selected for air.

Methane generation can sometimes be a problem at municipal landfills. Because the waste disposed of at Cold Spring Brook Landfill was largely building debris, concrete, rebar, etc., the generation of methane is unlikely to be of concern and it was not investigated. Therefore, there is no basis upon which to assess potential migration of vapors by this pathway.

Summary of Chemicals of Potential Concern

The chemicals selected as being of potential concern in environmental media potentially affected by Cold Spring Brook Landfill are summarized in Table 8-41.

RC424

Table 8-40

SUMMARY OF RI SURFACE WATER RESULTS FOR COLD SPRING BROOK

Chemical	Detection Frequency	Range of Detected Concentrations (μg/L) Minimum	Maximum	Benchmark Health Risk Value (MCLs) (μg/L)	Ambient Water[a] Quality Criteria, Human Health (μg/L)
Inorganics					
Arsenic[d]	10/10	4.51	17.7	50	2.2×10^{-3}
Barium	10/10	9.17	13.4	1,000	1,000
Calcium	10/10	19,000	31,000		
Chromium	2/10	4.67	4.76	100	50[c]
Copper	7/10	4.69	6.75	1,300	1,300
Iron	10/10	1,100	32,000	300[b]	300
Magnesium	10/10	2,900	3,300		
Manganese[d]	10/10	53.3	400	50[b]	50[d]
Silver	1/10	---	0.708	---	91
Zinc	5/10	28.5	86.3	5,000[b]	---

RC424

[a]Based on water and fish consumption, USEPA Clean Water Act value for hexavalent chromium.
[b]Secondary MCL based on aesthetic considerations.
[c]Hexavalent chromium.
[d]Selected as COPC.

Source: Ecology and Environment, Inc., 1992

Table 8-41

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN FOR COLD SPRING BROOK LANDFILL[a]

Chemical	Soil	Groundwater	Surface Water	Sediment
Inorganics				
Arsenic		X	X	X
Barium		X		
Beryllium		X		
Cadmium		X		
Chromium		X		
Copper		X		
Lead		*		X
Manganese		X	X	X
Nickel		X		
Silver		X		
Vanadium		X		
Zinc		X		X
Pesticides/PCBs				
4,4'-DDD	X			X
4,4'-DDE	X			X
BNA Compounds				
Acenaphthylene	X			X
Anthracene	X			X
Benzo(a)anthracene	X			X
Benzo(a)pyrene	X			X
Benzo(b)fluoranthene	X			X

RC424

Key at end of Table.

Table 8-41 (Cont.)

Chemical	Soil	Groundwater	Surface Water	Sediment
Benzo(g,h,i)perylene	X			
Benzo(k)fluoranthene	X			X
Chrysene	X			X
Fluoranthene	X			X
Indenopyrene	X			X
Phenanthrene	X			o
Pyrene	X			X

RC424

Key:

XChemical selected as a COPC.
*Chemical selected as a COPC but will be evaluated qualitatively because reference doses (RfDs) and slope factors (SFs) have not been established.
[a]No COPCs were identified in seep area sediments or ambient air.

Source: Ecology and Environment, Inc., 1992

8.2.3 Exposure Assessment

8.2.3.1 Exposure Setting

The physical setting of the site, including geology, hydrogeology, climate, and current land uses, is discussed in Section 1.3.

Potentially Exposed Populations

Chemicals of potential concern have been found in surface soil at Cold Spring Brook Landfill, in groundwater in the landfill's zone of influence, and in surface water and sediment in Cold Spring Brook Pond adjacent to the landfill. No COPCs were found in ambient air. The potentially exposed populations are therefore the groups that might come in contact with contaminants in the soil at the landfill, the surface water or sediment in Cold Spring Brook Pond, or the groundwater affected by the landfill. These would include visitors to the landfill (e.g., hikers) who might come into contact with contaminated soil; visitors to the pond shoreline (most likely adolescents playing) who might come in contact with contaminated sediment; fishermen who could be exposed to the water in Cold Spring Brook while fishing and who, along with their families and friends, might eat contaminated fish caught in the pond; and possible future users of the affected groundwater. All of these groups would probably consist of individuals living or working on the base either now or in the future.

The landfill is located near the southeast corner of Fort Devens' main cantonment area, along the south edge of Cold Spring Brook. This landfill, which is surrounded by Fort Devens property, is less accessible to visitors from off base than is Shepley's Hill Landfill near the Town of Ayer. The nearest base housing is located about 0.25 mile north of the landfill; other housing areas are farther to the north and northwest, at least 0.5 mile from the site. The landfill is somewhat isolated from these populated areas by the brook to the north and a magazine area to the west.

There is no evidence of regular entry into the landfill area or fishing in the pond. Nevertheless, it is conceivable that hikers or fishermen from the base might occasionally visit the area, potentially contacting site-derived contaminants in the soil, sediment, surface water, or fish.

There are currently no private water supply wells at or downgradient of the landfill. The Patton well is located approximately 400 feet west-southwest of the landfill. Although it draws groundwater from the direction of the landfill, no site-related contamination has been found in the Patton well.

Since Fort Devens is slated for closure, additional areas of the base, including areas around the landfill, could be converted to residential use in the future and private wells might be installed to provide the new homes with drinking water (although, since the base has an existing water supply system, this is probably unlikely). Individuals living in these homes might be exposed to landfill-related contaminants in the groundwater in addition to those found in the other environmental media.

8.2.3.2 Potential Exposure Pathways

A schematic depiction of the potential pathways is shown in Figure 8-5, the conceptual site model.

Sources and Receiving Media

Cold Spring Brook landfill was discovered in November 1987 when 14 drums were uncovered along Cold Spring Brook. The contents of the drums at the time they were placed in the landfill is unknown. Most of the landfill waste appears to be mainly construction or demolition debris. Drums and debris are visible in spots along the face of the landfill, with some drums right at the edge of the pond.

Elevated levels of arsenic and other metals have been detected in groundwater within the landfill's zone of influence and in surface water and sediment near the west end of the landfill where the drums were located. Other contaminants found in pond sediments and surface soils included PAHs and pesticides.

Contaminant Fate and Transport

The fate and transport of contaminants in the environment are influenced by a variety of site- and chemical-specific factors. Environmental fate and transport processes for the COPCs at the Cold Spring Brook Landfill site, which are discussed in Section 6, are summarized briefly in this section.

Metals are persistent in the environment, but their chemical and physical forms can change depending on environmental conditions. Metals in soils and sediment may be in a metallic form, sorbed or chelated by organic matter or oxides, sorbed on exchange sites of soil colloids, or dissolved in soil water. Most metals are immobile at usual soil pH ranges and become significantly leachable only if acidic solutions percolate through the soils. At the normal range of soil pH values, metals usually do not leach at an appreciable rate. Other environmental factors that influence metal mobility include soil clay content, organic content, oxidation-reduction potential, carbonate content, and groundwater chemistry.

Speciation of metals is also an important factor in their mobility. If the metals are present as oxides or hydroxides, they will remain relatively immobile in soils and sediments. If they are present as soluble salts, the most likely reaction that may occur is the hydrolysis of metals to either oxides or hydroxides, or the precipitation of low solubility sulfates or carbonates. At Cold Spring Brook Landfill, elevated levels of metals have been detected in site groundwater, which discharges to Cold Spring Brook. Elevated concentrations of several of the metals present in groundwater have been found in the pond sediments in a localized area adjacent to the landfill. Some metals, such as arsenic and zinc, can bioaccumulate in aquatic organisms.

PAHs generally have low to very low water solubilities and a strong tendency to adsorb to organic carbon in soils. In aquatic systems, PAHs tend to concentrate in the sediment and are transported with it. PAHs are metabolized by aquatic organisms and do not bioconcentrate to a significant degree (Eisler 1987).

The pesticides, which have low water solubilities and a tendency to adsorb to soils, are also relatively immobile in the subsurface. Some pesticides are persistent in the environment and may bioaccumulate in aquatic environments.

Complete Exposure Pathways

As shown in Figure 8-5, the following exposure pathways are potentially complete under existing site conditions:

- o Direct contact (dermal contact and incidental ingestion) with contaminated surface soil at the landfill by site visitors;
- o Incidental ingestion of surface water while fishing in Cold Spring Brook and consumption of fish caught in Cold Spring Brook by recreational fisherman and their families; and
- o Direct contact (dermal contact and incidental ingestion) with contaminated pond sediments along the landfill shoreline by site visitors.

If land surrounding the landfill is converted to residential use without prior remediation, the same exposure pathways would exist for future residents. In addition, if the groundwater is used as a potable water source by future site residents, three routes of exposure associated with groundwater usage could potentially be complete:

- o Ingestion of contaminated groundwater as drinking water;
- o Dermal contact with contaminated groundwater while bathing or showering, or through other household water uses; and
- o Consumption of homegrown fruits and vegetables watered with groundwater.

The potentially complete exposure pathways and receptors are summarized in Table 8-42.

Table 8-42

POTENTIAL HUMAN EXPOSURE PATHWAYS
COLD SPRING BROOK LANDFILL

Potentially Exposed Population	Exposure Pathway	Pathway Selected for Evaluation?	Rationale
CURRENT LAND USE			
Site Visitors (Fishermen and their families)	Consumption of contaminated fish caught from Cold Spring Brook Pond.	Yes (1A)	Arsenic, zinc, and pesticides in sediment can bioaccumulate in fish.
	Incidental ingestion of surface water while fishing.	Yes (1B)	Low levels of COPCs in surface water.
Site visitors (mainly adolescents)	Dermal contact and incidental ingestion of shoreline pond sediments.	Yes (3A and 3B)	Probable low exposure rate but COPCs are present in the sediments.
Site visitors (hikers and fisherman)	Dermal contact and incidental ingestion of site soils.	Yes (2A and 2B)	COPCs are present in surface soils
FUTURE RESIDENTIAL USE			
Residents	Consumption of groundwater as drinking water; dermal contact with groundwater contaminants while showering or bathing.	Yes (7A and 7B)	Presence of COPCs in groundwater; use of groundwater for domestic supply is possible.
Residents	Consumption of homegrown produce watered with groundwater.	Yes (7C)	Accumulation of COPCs in produce is possible.

RC424

Key at end of table.

Table 8-42 (Cont.)

Potentially Exposed Population	Exposure Pathway	Pathway Selected for Evaluation?	Rationale
Residents	Dermal Contact and incidental ingestion of site soils	Yes (5A and 5B)	COPCs are present in site surface soil.
Residents (mainly adolescents)	Dermal contact and incidental ingestion of shoreline sediments.	Yes (6A and 6B)	COPCs are present in the sediments.
Residents	Consumption of contaminated fish caught from Cold Spring Brook Pond.	Yes (4A)	Arsenic and cadmium in sediment can bioaccumulate in fish.
	Incidental ingestion of surface water while fishing.	Yes (4B)	Low levels of COPCs detected in surface water.

RC424

Source: Ecology and Environment, Inc., 1992

8.2.3.3 Quantification of Exposure

This section describes how the quantitative exposure estimates were obtained. The first part describes how the exposure point contaminant concentrations used in the exposure assessment calculations were selected or derived, and the second part describes the exposure estimation calculations for each receptor and route of exposure.

Exposure Media Concentrations

The exposure media of concern at this site are groundwater, surface water, sediment, and fish from Cold Spring Brook Pond. For each of these media, the average chemical concentration and the maximum observed concentrations from the relevant RI data were used as estimates of exposure point concentrations for the average exposure and reasonable maximum exposure (RME) cases. For calculating averages, non-detects were regarded as one-half the detection limit if there was reason to believe the chemical might be present. Otherwise, they were regarded as zero.

As discussed in Section 8.2.2.3, most of the groundwater samples contained suspended sediments (soil minerals), which resulted in artificially high concentrations of many metals in these samples due to the natural metals content of the entrained soil minerals. Since metals associated with suspended sediments found in monitoring well samples are unlikely to pose a health risk, a method was devised for estimating the contribution of suspended sediment to the observed metals concentrations. The observed values were then adjusted by deducting the estimated sediment contribution (see Appendix K). The adjusted concentrations for each sample is given in Table 8-43.

The estimated contribution of the sediment was obtained from the regression equation for each of the metals concentrations versus the aluminum concentration. Because of the natural variability in both metals concentrations, some of the actual sample values fell above or below the regression line, as can be seen in the scatterplots in Appendix K. Thus, when the estimated sediment contributions taken from the regression line are deducted from the observed metals concentrations, some of the adjusted concentration values are positive and some are negative. The positive values were incorporated directly into Table 8-43; however, because negative concentration values are meaningless, they were simply reported in the table as less than the metal's CRL.

Some samples had adjusted metals concentrations that fell farther above the regression line (above the upper prediction limit - see Appendix K) than would be expected based just on sample variability. These metals concentrations are not entirely attributable to suspended sediment and are regarded as reflecting soluble metals concentrations in the groundwater. Values in this category are flagged in Table 8-43.

Table 8-43

CONCENTRATIONS OF METALS IN GROUNDWATER
ADJUSTED TO REMOVE THE EFFECT OF SUSPENDED SEDIMENT
AOC 40 - COLD SPRING BROOK
(μg/L)

	Group 1 Wells				Group 2 Wells		
Chemical	CSB-2	CSB-3	CSB-6	CSB-8	CSB-1	CSB-7	Patton Well
Arsenic	<3.090[a]	66.723	<3.090	<3.090	<3.090	1.922	3.233
	<3.090[b]	<3.090	<3.090	<3.090	<3.090	<3.090	<3.090
Barium	12.017	26.816	<1.520	88.443	<1.520	14.088	9.009
	<1.520	60.240	<1.520	125.513	<1.520	<1.520	1.891
Beryllium	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341
	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341
Cadmium	3.051	<2.670	<2.670	<2.670	<2.670	<2.670	<2.670
	<2.670	<2.670	<2.670	<2.670	<2.670	<2.670	6.399
Chromium	4.513	103.203	<4.470	24.686	<4.470	<4.470	<4.470
	<4.470	20.798	<4.470	<4.470	<4.470	<4.470	5.140
Copper	21.513[c]	40.573	12.288	39.699	8.543	<4.290	49.271[c]
	5.116	<4.290	<4.290	<4.290	<4.290	<4.290	27.634[c]
Iron	527.254	3420.440	<24.600	<24.600	<24.600	<24.600	10.644
	1449.584	<24.600	<24.600	<24.600	<24.600	<24.600	<24.600
Lead	12.014[c]	16.037	<.4740	0.439	4.927	1.150	7.058[c]
	<.4740	<.4740	<.4740	<.4740	<.4740	<.4740	2.370
Manganese	4756.527[c]	<6.880	<6.880	<6.880	375.857	<6.880	292.783[c]
	5818.369[c]	<6.880	<6.880	<6.880	2006.932[c]	<6.880	329.771[c]
Nickel	0.958	69.563[c]	15.461	41.006[c]	4.380	4.380	<8.760
	2.729	17.574	4.380	<8.760	4.380	4.380	<8.760
Vanadium	<4.000	17.331	<4.000	<4.000	<4.000	<4.000	<4.000
	<4.000	<4.000	<4.000	<4.000	<4.000	<4.000	<4.000
Zinc	61.176[c]	0.501	<19.400	124.465	85.679[c]	<19.400	116.185[c]
	<19.400	<19.400	9.700	<19.400	31.738	<19.400	125.728[c]

RC424

[a] Round 1.
[b] Round 2.
[c] Original value was above the upper prediction limit for sediment-related concentrations; therefore, the adjusted value is not entirely attributable to suspended sediment.

Source: Ecology and Environment, Inc., 1992

In Table 8-43, the wells are arranged in three groups. The first group is located within the landfill's zone of influence, the second group is located outside the landfill's zone of influence and the third is the Patton well.

Groundwater exposures were evaluated for the set of wells within the landfill's zone of influence (CSB-2, -3, -4, -5, -6, and -8). Groundwater exposure point concentrations were determined first using the original groundwater data from the RI, and then using adjusted data with metals concentrations reduced by the amount attributable to suspended sediment in the groundwater (presented in Table 8-43). CSB-4 and -5 have historically had the highest arsenic concentrations. CSB-4 failed to yield enough water for metals analysis during the RI sampling events and CSB-5 had been destroyed prior to the RI field work. Consequently, historical data on the metals concentrations in these wells were used. Arsenic concentrations for CSB-4 and -5 from Tables 1-17 and 1-18 were used in the derivation of exposure point concentrations for groundwater. Samples collected prior to 1991 were not filtered; this data was used with unadjusted data from other wells in the zone of influence. Data for filtered samples, collected in 1991, were used with adjusted data to estimate adjusted groundwater exposure point concentrations.

The groundwater exposure point concentrations were used to evaluate drinking water ingestion, dermal absorption while showering, and consumption of homegrown fruits and vegetables. The groundwater exposure point concentrations for homegrown fruits and vegetables were combined with transfer coefficients to estimate concentrations in plant tissue. This procedure is described in detail in Appendix M.

The data from all surface water samples from Cold Spring Brook were used to estimate average and maximum surface water exposure point concentrations. For sediment exposures, only the sediment samples collected from the pond near the shoreline adjacent to the landfill were used to estimate the exposure concentrations because the contaminant concentrations in these sediments are most likely to be representative of concentrations that may be present at the shoreline where direct contact exposure might occur.

A chemical's concentration in fish is a function of its concentrations in the surface water and sediment, and its tendency to bioaccumulate. The estimated contaminant concentrations in fish muscle, or the filet, were used to estimate exposure of fish eaters to site contaminants. The fish muscle concentration was estimated by multiplying the average or maximum observed sediment or surface water concentration in the pond by a bioaccumulation factor.

The COPCs in the pond sediment are arsenic, manganese, zinc, 4,4'-DDD, 4,4'-DDE, and PAHs. Bioaccumulation factors for the metals were based on sediment-to-fish concentration ratios reported in the literature. The bioaccumulation factors used for arsenic and zinc were

0.002 and 0.6, respectively. These values differ from those used in the ecological assessment because they pertain to the concentration in the filet rather than the whole body concentration. Suitable sediment and fish tissue data for manganese could not be located. A discussion of the selection of bioaccumulation factors can be found in Section 9, the ecological risk assessment.

Pesticide concentrations in fish from sediment were derived using an equilibrium partitioning approach, also described in Section 9. The resulting bioaccumulation factors for 4,4'-DDD and 4,4'-DDE were 2.8 and 4.0, respectively. No bioaccumulation factors were derived for the PAHs because they are metabolized by aquatic organisms and do not bioconcentrate significantly.

Arsenic is the only COPC in the surface water. A fish bioconcentration factor for arsenic, 44 l/kg, was obtained from AWQC documents (USEPA 1980b; 1986g). Since neither the water nor sediment contaminant concentrations were expected to be the dominant source of contaminant uptake by fish at Cold Spring Brook, the uptake of arsenic from the surface water was added to that from sediment to estimate the total arsenic concentration in fish.

The exposure point concentrations used to estimate receptor exposures are included in the detailed exposure and risk estimate tables in Appendix O.

Exposure Estimation Methods

As explained previously, two exposure scenarios were selected for the quantitative risk assessment: a site visitor scenario under current land uses, and a future residential scenario. The exposure estimates for these scenarios are described in this section and combine the following:

- o Estimates of exposure media (surface water, sediment, and groundwater) contaminant concentrations developed in the previous two sections;
- o Estimates of contact rate and the frequency and duration of exposure that receptor populations are likely to experience; and
- o Estimates of various physiological parameters (e.g., breathing rate, body weight, and average life expectancy).

The equations used to estimate the exposure for each pathway and route of exposure are given in Tables 8-44 through 8-58. The parameter values used to evaluate the equations along with the rationale for their selection and a reference source are also given.

Two cases were evaluated for each exposure route and receptor to satisfy EPA Region I requirements. The RME case uses the highest observed contaminant concentrations and the average case uses the

Table 8-44

AOC 40: COLD SPRING BROOK LANDFILL
CURRENT EXPOSURE:
PATHWAY 1A - INGESTION OF CONTAMINATED FISH
(FISHERMEN AND THEIR FAMILIES)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW/S \times BAF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CW/S = Contaminant Concentration in Water/Sediment (mg/L or mg/kg)
BAF = Bioaccumulation Factor (L/kg or kg/kg)
IR = Ingestion Rate (kg/day) Average Daily Fish Consumption
FI = Fraction of Fish Consumption from Contaminated Source (Unitless)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW/S	Adult/Child	Average	Average concentration in pond sediment or water
		RME	Maximum observed concentration in pond sediment or water
BAF	Adult/Child	Average/RME	Chemical-specific
IR	Adult/Child	Average/RME	0.054 kg/day (USEPA 1991b)
FI	Adult/Child	Average/RME	0.05 (assumed)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-45

AOC 40: COLD SPRING BROOK LANDFILL
CURRENT EXPOSURE:
PATHWAY 1B - INGESTION OF SURFACE WATER WHILE FISHING
(FISHERMEN AND THEIR FAMILIES)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CW = Contaminant Concentration in surface water (mg/L)
IR = Ingestion Rate (kg/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average RME	Average concentration in pond water Maximum observed concentration in pond water
IR	Adult/Child	Average/RME	0.01 L/day (professional judgement)
EF	Adult/Child	Average/RME	5 days/year
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-46

AOC 40 - COLD SPRING BROOK LANDFILL
CURRENT EXPOSURE:
PATHWAY 2A - DERMAL CONTACT WITH CHEMICALS IN SOIL
(ADULT AND CHILD SITE VISITORS)

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times ABS \times CF \times SA \times AF \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Soil (mg/kg)
ABS = Absorption Factor (Unitless)
CF = Conversion Factor (10^{-6} kg/mg)
SA = Skin Surface Area Available for Contact (cm^2/event)
AF = Soil to Skin Adherence Factor (mg/cm^2)
EF = Exposure Frequency (events/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source
CS	Adult/Child	Average	Average concentrations in soil
	Adult/Child	RME	Maximum observed concentrations in soil
ABS	Adult/Child	Average/RME	Negligible for metals; 0.05 for DDD, DDE, and PAHs (EPA 1989e)
SA	Adult	Average/RME	4050 cm^2 (hands, one-half arms, and one-half legs; surface areas; USEPA 1989f)
	Child	Average/RME	3230 cm^2 (hands, arms, and legs; surface areas; USEPA 1989f)
AF	Adult/Child	Average/RME	0.5 mg/cm^2 (LePow 1975)
EF	Adult/Child	Average/RME	5 days/year (Professional judgement)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-47

AOC 40 - COLD SPRING BROOK LANDFILL
CURRENT EXPOSURE:
PATHWAY 2B - INGESTION OF CHEMICALS IN SOIL
(ADULT AND CHILD SITE VISITORS)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times RAF \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Soil (mg/kg)
IR = Ingestion Rate (mg soil/day)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
FI = Fraction Ingested from Contaminated Source (unitless)
EF = Exposure Frequency (days/years)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adult/Child	Average	Average concentrations in soil
	Adult/Child	RME	Maximum observed concentrations in soil
IR	Adult	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991b)
	Child	Average/RME	200 mg/day (children 1-6 years old; USEPA 1991b)
RAF	Adult/Child	Average/RME	1.0 for metals and PAHs; 0.3 for DDD and DDE (USEPA 1989e)
FI	Adult/Child	Average/RME	1.0 (assumed)
EF	Adult/Child	Average/RME	5 days/year
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (entire duration of 1-6 year old age group)
BW	Adult	Average/RME	70 kg (average; USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-48

**AOC 40 – COLD SPRING BROOK LANDFILL
CURRENT EXPOSURE:
PATHWAY 3A – DIRECT DERMAL CONTACT WITH CHEMICALS IN SEDIMENT
(ADOLESCENT SITE VISITORS)**

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times ABS \times CF \times SA \times AF \times EF \times ED}{BW \times AT}$$

where:
- CS = Chemical Concentration in Sediment (mg/kg)
- ABS = Absorption Factor (unitless)
- CF = Conversion Factor (10^{-6} kg/mg)
- SA = Skin Surface Area Available for Contact (cm^2/event)
- AF = Soil-to-Skin Adherence Factor (mg/cm^2)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentrations in shoreline sediments
	Adolescent	RME	Maximum observed concentration in shoreline sediment
ABS	Adolescent	Average/RME	Negligible for metals; 0.05 for DDD, DDE, and PAHs (EPA 1989e)
SA	Adolescent	Average/RME	3500 cm^2 (hands, one-half arms and one-half legs; surface area; USEPA 1989f)
AF	Adolescent	Average/RME	0.5 mg/cm^2 (Lepow 1975)
EF	Adolescent	Average/RME	5 days/year (professional judgement)
ED	Adolescent	Average/RME	10 years (entire duration of age group 6-16)
BW	Adolescent	Average/RME	42 kg (median body weight for age group 6-16; USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year); and 70-year lifetime for carcinogenic effects (i.e. 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure

Source: Ecology and Environment, Inc. 1992.

Table 8-49

AOC 40 - COLD SPRING BROOK LANDFILL
CURRENT EXPOSURE:
PATHWAY 3B - INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT
(ADOLESCENT SITE VISITORS)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times RAF \times CF \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Sediment (mg/kg)
IR = Ingestion Rate (mg soil)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in shoreline sediment
		RME	Maximum observed concentration in shoreline sediment
IR	Adolescent	Average/RME	100 mg/day (USEPA 1991b)
RAF	Adolescent	Average/RME	1.0 for metals and PAHs; 0.3 for DDD and DDE (USEPA 1989e)
EF	Adolescent	Average/RME	5 days/year (professional judgement)
ED	Adolescent	Average/RME	10 years (entire duration of age group 6-16)
BW	Adolescent	Average/RME	42 kg (median body weight for age group 6-16; USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogens (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effect (i.e., 70 years x 365 days/year.

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-50

**AOC 40: COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 4A - INGESTION OF CONTAMINATED FISH
(FISHERMEN AND THEIR FAMILIES)**

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW/S \times BAF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CW/S = Contaminant Concentration in Water/Sediment (mg/L or mg/kg)
BAF = Bioaccumulation Factor (L/kg or kg/kg)
IR = Ingestion Rate (kg/day) Average Daily Fish Consumption
FI = Fraction of Fish Consumption from Contaminated Source (Unitless)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW/S	Adult/Child	Average	Average concentration in pond sediment or water
		RME	Maximum observed concentration in pond sediment or water
BAF	Adult/Child	Average/RME	Chemical-specific
IR	Adult/Child	Average/RME	0.054 kg/day (USEPA 1991b)
FI	Adult/Child	Average/RME	0.5 (assumed)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-51

AOC 40: COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 4B - INGESTION OF SURFACE WATER WHILE FISHING
(FISHERMEN AND THEIR FAMILIES)

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CW = Contaminant Concentration in surface water (mg/L)
IR = Ingestion Rate (kg/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average RME	Average concentration in pond water Maximum observed concentration in pond water
IR	Adult/Child	Average/RME	0.01 L/day (professional judgement)
EF	Adult/Child	Average/RME	50 days/year (professional judgement)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-52

**AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 5A - DERMAL CONTACT WITH CHEMICALS IN SOIL
(ADULT AND CHILD RESIDENTS)**

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times ABS \times CF \times SA \times AF \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Soil (mg/kg)
ABS = Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
SA = Skin Surface Area Available for Contact (cm^2/event)
AF = Soil to Skin Adherence Factor (mg/cm^2)
EF = Exposure Frequency (events/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source
CS	Adult/Child	Average	Average concentrations in soil
	Adult/Child	RME	Maximum observed concentrations in soil
ABS	Adult/Child	Average/RME	Negligible for metals; 0.05 for DDD, DDE, and PAHs (EPA 1989e)
SA	Adult	Average/RME	4050 cm^2 (hands, one-half arms, and one-half legs; surface areas; USEPA 1989f)
	Child	Average/RME	3230 cm^2 (hands, arms, and legs; surface areas; USEPA 1989f)
AF	Adult/Child	Average/RME	0.5 mg/cm^2 (LePow 1975)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (duration of age group)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-53

**AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 5B - INGESTION OF CHEMICALS IN SOIL
(ADULT AND CHILD RESIDENTS)**

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times RAF \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Soil (mg/kg)
IR = Ingestion Rate (mg soil/day)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
FI = Fraction Ingested from Contaminated Source (unitless)
EF = Exposure Frequency (days/years)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adult/Child	Average	Average concentrations in soil
	Adult/Child	RME	Maximum observed concentrations in soil
IR	Adult	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991b)
	Child	Average/RME	200 mg/day (children 1-6 years old; USEPA 1991b)
RAF	Adult/Child	Average/RME	1.0 for metals and PAHs; 0.3 for DDD and DDE (USEPA 1989e)
FI	Adult/Child	Average/RME	1.0 (assumed)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (national upper bound time (90th percentile) at one residence; USEPA 1991b)
	Child	Average/RME	5 years (entire duration of 1-6 year old age group)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989b)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-54

AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 6A - DIRECT DERMAL CONTACT WITH CHEMICALS IN SEDIMENT
(ADOLESCENT RESIDENTS 6-16 YEARS OLD)

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CS \times ABS \times CF \times SA \times AF \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Sediment (mg/kg)
ABS = Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
SA = Skin Surface Area Available for Contact (cm^2/event)
AF = Soil-to-Skin Adherence Factor (mg/cm^2)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in sediments
	Adolescent	RME	Maximum observed concentrations in sediments
ABS	Adolescent	Average/RME	Negligible for metals; 0.05 for DDD, DDE, and PAHs (EPA 1989e)
SA	Adolescent	Average/RME	3,500 cm^2 (area of hands, one-half arms, and one-half legs; USEPA 1989f)
AF	Adolescent	Average/RME	0.5 mg/cm^2 (Lepow 1975)
EF	Adolescent	Average/RME	100 days/year (professional judgement)
ED	Adolescent	Average/RME	10 years (entire duration of 6-16 year old age group)
BW	Adolescent	Average/RME	42 kg (median body weight for age group, USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year).

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-55

**AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 6B - INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT
(ADOLESCENT RESIDENTS 6-16 YEARS OLD)**

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times RAF \times CF \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical Concentration in Sediment (mg/kg)
IR = Ingestion Rate (mg soil)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10^{-6} kg/mg)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in sediments
		RME	Maximum observed concentrations in sediments
IR	Adolescent	Average/RME	100 mg/day (USEPA 1991b)
RAF	Adolescent	Average/RME	1.0 for metals and PAHs; 0.3 for DDD and DDE (USEPA 1989e)
EF	Adolescent	Average/RME	100 days/year (professional judgment)
ED	Adolescent	Average/RME	10 years (entire duration of 6-16 year old age group)
BW	Adolescent	Average/RME	42 kg (median body weight for age group, USEPA 1989f)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year).

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-56

**AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 7A - INGESTION OF CHEMICALS IN DRINKING WATER
(ADULT AND CHILD RESIDENTS)**

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CW = Chemical Concentration in Water (mg/L)
IR = Ingestion Rate (L/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentration in groundwater
	Adult/Child	RME	Maximum observed concentration in groundwater
IR	Adult	Average/RME	2.0 L/day (MDEP 1989a, 90th percentile; USEPA 1991b)
	Child	Average/RME	0.50 l/day (90th percentile intake; USEPA 1989f)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1991b)
	Child	Average/RME	5 years (entire period of life in age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1989b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-57

**AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 7B - DERMAL CONTACT WITH CHEMICALS DURING SHOWERING
(ADULT AND CHILD RESIDENTS)**

Equation:

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times PC \times SA \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW = Chemical Concentration in Water (mg/liter)
PC = Chemical-Specific Dermal Permeability Constant (cm/hr)
SA = Skin Surface area Available for Contact (cm^2)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1,000 cm^3)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentrations in groundwater
	Adult/Child	RME	Maximum detected concentrations in groundwater
PC	Adult/Child	Average/RME	Chemical-specific values used
SA	Adult	Average/RME	1.94 m^2 (total body SA for adults; MDEP 1989a; USEPA 1989f)
	Child	Average/RME	0.72 m^2 (average total body SA, 3- to 6-year old child; USEPA 1989f)
ET	Adult/Child	Average/RME	0.2 hour/day (12 minutes; 90th percentile; USEPA 1989f)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991b)
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1991b)
	Child	Average/RME	5 years (entire period of life in age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year.)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

Table 8-58

**AOC 40 - COLD SPRING BROOK LANDFILL
FUTURE RESIDENTIAL EXPOSURE:
PATHWAY 7C - INGESTION OF CHEMICALS IN
HOMEGROWN FRUITS AND VEGETABLES IRRIGATED WITH GROUNDWATER
(ADULT AND CHILD RESIDENTS)**

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times (UFF \times IRF + UFV \times IRV) \times EF \times ED}{BW \times AT}$$

where:

CW = Chemical Concentration in Water (mg/L)
UFF = Uptake Factor for Fruit (L/g)
IRF = Ingestion Rate for Fruit (g/day)
UFV = Uptake Factor for Vegetables (L/g)
IRV = Ingestion Rate for vegetables (g/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentration in groundwater
	Adult/Child	RME	Maximum observed concentration in groundwater
UFF	Adult/Child	Average/RME	Chemical-specific value - see Appendix M
IRF	Adult/Child	Average/RME	42 g/day (USEPA 1991b)
UFV	Adult/Child	Average/RME	Chemical-specific value - see Appendix M
IRV	Adult/Child	Average/RME	80 g/day (USEPA 1991b)
EF	Adult/Child	Average/RME	350 days/year
ED	Adult	Average/RME	30 years (90th percentile time at one residence, USEPA 1991b)
	Child	Average/RME	5 years (entire period of life in age group 1-6 years)
BW	Adult	Average/RME	70 kg (USEPA 1991b)
	Child	Average/RME	16 kg (USEPA 1989f)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for non-carcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year)

RC424

Key:

RME = Reasonable Maximum Exposure.

Source: Ecology and Environment, Inc. 1992.

average contaminant concentration in the exposure media, in accordance with EPA Region I Guidance (USEPA 1989e), along with the standard default exposure factors given in EPA's Supplemental Risk Assessment Guidance for Superfund (USEPA 1991b). Exposure factors not specified in these guidances are taken from the EPA Exposure Factors Handbook, (USEPA 1989f) when possible, or are based on professional judgment.

A third exposure case was evaluated to comply with MDEP risk assessment guidelines. This case uses the average contaminant concentration measured or estimated in each exposure medium along with the default exposure assumptions from Appendix B of Massachusetts Guidance for Disposal Site Risk Characterization and Related Phase II Activities (MDEP 1989a). Exposure parameters and equations for this case are presented in Appendix T.

Two groups of receptors (adults exposed for 30 years, and children one to six years old) were considered for most of the pathways evaluated for both site visitor and residential exposures. The child receptor was used to evaluate potential risks from subchronic exposures of this potentially sensitive age group, which might otherwise be "diluted" and be overlooked if only a 30-year exposure was considered. Receptors potentially exposed to shoreline sediments were assumed to be adolescents from six to 16 years old.

Acute exposures were not evaluated quantitatively for several reasons. First, the metals, pesticides, and PAHs, which are the principal contaminants at this site, tend to accumulate in the body, and their most serious adverse effects are usually associated with repeated or chronic exposure. A number of the contaminants are carcinogens, and cancer risks are estimated and expressed as excess lifetime risks. Second, the exposure frequencies postulated are high enough, either in the current or future exposure scenarios, that estimates of potential risks would not be unduly diluted by long averaging times relative to the frequency of exposure. Finally, none of the COPCs are known to produce serious acute toxic effects out of proportion to their chronic or subchronic effects.

For Pathway 1A, ingestion of contaminated fish by fishermen and their families, all of the parameters will be described and discussed in the text; for subsequent pathways, only the key parameters for that pathway and parameters not previously mentioned will be described.

Scenario 1: Exposure of Site Visitors

Pathway 1A - Ingestion of Contaminated Fish by Fisherman and Their Families.

The contaminant concentrations in sediment (CS) and surface water (CW) are the average or the maximum concentrations detected. The bioaccumulation factor (BAF) is a measure of the uptake of the COPCs by fish directly from surface water and sediment and through the aquatic food chain. BAFs were determined as described earlier in this section.

Two key variables specific to the fish ingestion pathways are the fish ingestion rate (IR) and the fraction of fish ingested (FI). The IR is an estimate of the daily fish consumption rate. The IR value from EPA for the RME case (equivalent to about two 7-ounce portions per week) is 0.054 kg/day. The FI is the estimated proportion of total fish consumption that comes from Cold Spring Brook. Since fishing in the pond is expected to occur infrequently, if at all, the FI is unlikely to exceed 5 percent of the total fish eaten per year (see Table 8-44).

The exposure frequency is 350 days per year for both the average and RME case. This represents year-round exposure allowing for two weeks of the year spent away from the area. The exposure duration (ED) is the total number of years during which exposure could occur. The values used are self explanatory. The body weights (BW) used for both exposure cases are the average body weights for the age groups indicated (adult males, or children one to six years old).

Averaging time (AT) is the period over which the estimated exposure is averaged. For noncarcinogens, the averaging time is equal to the exposure duration, while for carcinogens it is taken as the standard life expectancy of 70 years because the carcinogenic potency slope factors (described in Section 8.1.4) are based on lifetime exposure.

Pathway 1B - Ingestion of Surface Water While Fishing

The IR is the key variable for the inadvertent ingestion of surface water pathway. This value (0.01 l/day) is an estimation of the amount of pond water a fisherman might ingest through hand-to-mouth contact. The exposure frequency (EF) was conservatively estimated to be five days per year (see Table 8-45).

Pathway 2A - Direct Dermal Contact with Chemicals in Soil

Several parameters are specific to this pathway. The ABS is a chemical-specific value which describes the fraction that is likely to be absorbed through the skin relative to the absorption in the laboratory study from which the toxicological index was derived. Default relative absorption factors for dermal contact with soils, from Region I guidance (EPA 1989e), were used. The skin area (SA) that might come into contact with surface soil was assumed to be equivalent to that of the hands, one-half of the arms, and one-half of the legs. The soil-to-skin adherence factor (AF) is an estimate of the amount of sediment that might adhere to the skin and serve as a source of exposure. Potential exposure frequency (EF) was assumed to be five days a year, the same as for fishing exposure (see Table 8-46).

Pathway 2B - Incidental Ingestion of Chemicals in Soil

The key parameter is the IR, an estimate of the surface soil a site visitor might ingest through hand-to-mouth contact. An RAF is included to account for the differing bioavailability between the contaminant in soil or sediment and in the administered medium (e.g. food, water) that is the basis for the toxicological index. Default values from Region I guidance (EPA 1989e) were used (see Table 8-47). The fraction of soil ingested (FI) from the contaminated landfill soil was conservatively assumed to be 1.

Pathway 3A - Direct Dermal Contact with Chemicals in Sediment

The exposure equation is the same as was used for dermal contact with soils. However, parameter values reflect the potential exposure of an adolescent from age six to 16, the most likely receptor for this pathway (see Table 8-48).

Pathway 3B - Incidental Ingestion of Chemicals in Sediment

This equation is the same as was used for soil ingestion but the exposure parameter values correspond to an adolescent receptor (see Table 8-49).

Scenario 2: Future Residential Exposure

The pathways that are potentially complete under current land use conditions would also exist under a future residential scenario; however, the frequency of exposure and other exposure factors may be greater for the future on-site resident. In addition, the future resident could potentially be exposed to site-derived contaminants by using the groundwater for domestic purposes.

The equations and parameters used to estimate the potential future residential exposures for each route of exposure are given in tables as follows:

- o Recreational fishing - Pathways 4A and 4B (Tables 8-50 and 8-51);
- o Direct contact with surface soils - Pathways 5A and 5B (Tables 8-52 and 8-53);
- o Direct contact with sediment - Pathways 6A and 6B (Tables 8-54 and 8-55); and
- o Groundwater usage - Pathways 7A and 7B (Tables 8-56 through 8-57).

The recreational fishing, soil contact, and sediment contact pathways have already been discussed. The groundwater usage pathways is described below.

Pathway 7A - Ingestion of Chemicals in Drinking Water

For tap water consumption, the key variable is the IR. The value used is the EPA 90th percentile intake value (see Table 8-56).

Pathway 7B - Dermal Contact with Chemicals While Showering

The permeability constant (PC) is a measure of the COPCs' transfer through skin from water. Chemical-specific permeability constant (Kp) values recommended by EPA's Dermal Exposure Assessment document (USEPA 1992a) were used. The values used for SA are average total body areas for the two age groups (see Table 8-57).

Pathway 7C - Consumption of Homegrown Fruits and Vegetables Irrigated with Groundwater

The uptake factors for fruits and vegetables (UFF and UFV) are transfer factors relating the contaminant concentrations in the water used on the homegrown fruits and vegetables to the concentrations in the plant tissue. These factors were derived from information in Baes et al. (1984), the Exposure Factors Handbook (USEPA 1989f), and are described in detail in Appendix M. The intake rates for fruits and vegetables (IRF and IRV) are 42 and 80 g/day, respectively, which are the standard default values for this pathway (see Table 8-58).

The exposure estimates from the equations described above are expressed as chronic daily intakes (CDIs), subchronic daily intakes (SDIs), or lifetime average daily intakes (LADIs) for each complete pathway and exposure case in the detailed exposure and risk estimation tables in Appendix O. CDIs and SDIs are used to estimate non-carcinogenic risks. CDIs are calculated for exposure durations greater than 7 years (adults and adolescents in this RA) while SDIs are calculated for exposure durations less than 7 years (children). LADIs are used to estimate excess lifetime cancer risks. The exposure estimates are combined with toxicity estimates for each chemical listed in Section 8.2.4 to obtain risk estimates. The exposure estimates can be found in the detailed exposure and risk estimation tables in Appendix O.

8.2.3.4 Uncertainty in the Exposure Assessment

A number of factors will cause the exposure levels estimated in this section to differ from the exposures that potential receptor populations may actually experience. These factors are discussed thoroughly in Section 8.1.3.4.

Several of the factors adding uncertainty to the estimates tend to result in overestimation of the exposure. These include:

- The directed nature of the sampling program;
- The use of maximum observed values for source concentrations;
- The use of estimated and extrapolated values for some exposure point concentrations;

The basic uncertainties underlying the assessment of the toxicity of a chemical include:

- o Uncertainties arising from the design, execution, or relevance of the scientific studies that form the basis of the assessment;
- o Uncertainties involved in extrapolating from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposures within human and animal populations, between species, and between routes of exposure; and
- o The absence of quantitative toxicological indices for lead and for dermal exposure to PAHs, which made it necessary to evaluate their effects qualitatively rather than quantitatively, and which will result in a slight underestimation of the total risks posed by the site.

These basic uncertainties could result in a toxicity estimate, based directly on the underlying studies, that either under- or overestimates the true toxicity of a chemical in the circumstances of interest.

The toxicity assessment process compensates for these basic uncertainties through the use of safety factors (uncertainty factors) and modifying factors when assessing noncarcinogens, and the use of the upper 95 percent confidence limit from the linearized multistage model for the SF when assessing carcinogens. The use of the safety factors and the upper 95 percent confidence limit in deriving the RfDs and SFs ensures that the toxicity values used in the risk estimation process are very unlikely to underestimate the true toxicity of a chemical.

Two additional factors need to be considered when discussing uncertainties associated with the overall risk characterization: the cumulative effect of using conservative assumptions throughout the process, and the likelihood of the exposures postulated and estimated in the exposure assessment actually occurring.

The cumulative effect of using conservative assumptions throughout the risk estimation process could lead to substantial overestimation of the true risks as discussed in Section 8.1.5.3.

The last uncertainty factor to consider is the likelihood of the postulated exposures actually occurring. The exposure pathways identified as complete under current land use conditions are all plausible and exposure is either presently occurring by these pathways or such exposure could reasonably be expected. The postulated frequencies of occurrence may overestimate average occurrence but could certainly reflect the reasonable maximum occurrence.

Fort Devens is scheduled to be closed and converted to nonmilitary uses. When this happens, portions of the base, including areas around Cold Spring Brook Landfill, could be converted to residential use. However, in view of the past use of the landfill area and the availability of existing housing units on the base, construction of new residences in the immediate vicinity of the landfill is probably unlikely but cannot be ruled out. The use of private wells for drinking water also is unlikely since the base has an existing water supply system. If residences are actually constructed near the landfill, and drinking water is obtained from private wells, the postulated exposure levels, frequencies, and durations all reasonably reflect the exposures future site residents might actually experience.

8.2.5.4 Summary Discussion of the Risk Characterization

Characterization of Contamination Present at the Site

The RI was designed to characterize the nature, extent, and limits of contamination originating at Cold Spring Brook Landfill and appears to have accomplished that goal. The possible source areas were identified based on a review of previous sampling and investigative activities. All potential source areas and migration pathways were then investigated using various field techniques, by collection and analysis of samples, and by using various exposure point and exposure media concentration estimation techniques. In this way, the nature of the contamination was characterized and its extent defined.

Given the information available about the site, it seems unlikely that any significant source areas or migration pathways were overlooked. Since samples were collected from a variety of media encompassing all of the likely source areas and migration pathways, and since most samples were analyzed for the full TCL and TICs were reviewed, it is also unlikely that any significant contaminants would have been missed.

Direct measurements of metals concentrations in filtered groundwater samples and contaminant concentrations in fish tissue could have improved the accuracy and reliability of the risk estimates for potential exposure to these media. However, estimates of these exposure point concentrations were made using the best available information, and exposure pathways involving these media were included in the risk assessments.

Magnitude and Sources of Risks Posed by Site Contaminants

EPA has adopted the policy that acceptable exposures to known or suspected carcinogens are generally those that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. In addition, the EPA uses the 10^{-6} risk level as the point of departure for determining remediation goals for National Priority List (NPL) sites (USEPA 1990c).

For systemic toxicants (noncarcinogens) the EPA defines acceptable exposure levels as those to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety (USEPA 1990c). This acceptable exposure level is best approximated by a hazard index of 1. If the hazard index is less than 1, adverse effects usually would not be expected. However, as the hazard index increases beyond 1, the possibility of adverse effects occurring also increases.

The magnitude of the potential excess cancer risks posed by the site-related contaminants are summarized in Tables 8-61 and 8-63. The hazard indices for potential noncarcinogenic effects are summarized in Tables 8-62 and 8-64. Hazard indices for adults and adolescents were calculated using chronic RfDs. Subchronic RfDs were used to estimate subchronic risks to children.

Cancer risk and hazard index estimates corresponding to both average and RME cases are provided. The exposure estimates were calculated using exposure factors and source area and exposure point concentrations derived as recommended by regional and national EPA guidance. As shown in the summary tables, exposure to contaminants related to Cold Spring Brook Landfill appears to pose both significantly increased risks of developing cancer and increased risks of experiencing adverse noncarcinogenic health effects.

Under existing site conditions, total estimated potential excess cancer risks ranged from 6×10^{-7} to 5×10^{-5}, and the total estimated hazard indices ranged from 5×10^{-3} to 0.9. Since all hazard indices were less than 1, noncarcinogenic adverse health effects would not be expected under existing site conditions. Consumption of potentially contaminated fish from Cold Spring Brook Pond was responsible for the greatest estimated cancer risks. Although the estimated risks to adolescents coming in contact with contaminated sediment along the shore of the pond was about 10 times lower than the estimated risks of eating fish, the risks were still significant for the RME case. Most of the estimated cancer risks from fish consumption were due to arsenic (63 percent) and the remainder were due to pesticides. Arsenic also accounted for 53 percent of the estimated cancer risk from direct contact with sediment. The remaining 47 percent of the estimated risk from sediment was due to ingestion of PAHs. Note that these risk estimates do not include cancer risks from dermal exposure to some PAHs, because no appropriate toxicity indices exist.

If future residential use of areas near the landfill is assumed, including use of the groundwater as a drinking water source, the total estimated potential excess cancer risks for receptors range from about 1×10^{-5} to about 6×10^{-3}, and the estimated hazard indices range from 0.1 to 39. The estimated risks associated with fish consumption by future residents are 10 times the risks under existing conditions. The estimated risks from contact with contaminated sediment along the shore of Cold Spring Brook Pond are 20 times the current risk. The higher

Table 8-61

SUMMARY OF ESTIMATED EXCESS CANCER RISKS ASSOCIATED WITH COLD SPRING BROOK LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions by Chemical[a]
Soil contact	RME	4.0E-07	—	5.8E-07	Soil ingestion - >99%	PAHs[b] - >99%
	Average	1.9E-07	—	2.8E-07	Dermal contact - <1%	
Fishing/fish ingestion	RME	4.9E-05	—	3.5E-05	Fish ingestion - >99%	Arsenic - 63%
	Average	1.8E-05	—	1.3E-05	Water ingestion - <1%	DDD - 28%
						DDE - 9%
Sediment contact	RME	—	2.5E-06	—	Sediment ingestion - >99%	Arsenic - 53%
	Average	—	5.9E-07	—		PAHs[b] - 47%
Total receptor risks	RME	4.9E-05	2.5E-06	3.6E-05		
	Average	1.8E-05	5.9E-07	1.3E-05		

RC424

Note: Cancer risks from dermal contact with PAHs are not included in risk estimates.

[a]RME case for receptor showing greatest risk.

[b]Carcinogenic PAHs detected at Cold Spring Brook Landfill include: Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

Source: Ecology and Environment, Inc., 1992

Table 8-62

SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH COLD SPRING BROOK LANDFILL - CURRENT LAND USE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child[b]	Risk Contributions by Exposure Route[a]
Soil contact	RME	1.7E-05	—	9.8E-05	Soil ingestion - 99%
	Average	8.8E-06	—	5.6E-05	Dermal contact - 1%
Fishing/fish ingestion	RME	2.1E-01	—	9.3E-01	Fish ingestion - >99%
	Average	6.7E-02	—	2.9E-01	Water ingestion - <1%
Sediment contact	RME	—	1.9E-02	—	Sediment ingestion - >99%
	Average	—	5.3E-03	—	
Total receptor risks	RME	2.1E-01	1.9E-02	9.3E-01	
	Average	6.7E-02	5.3E-03	2.9E-01	

[a]RME case for receptor showing greatest risk.
[b]Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

RC424

Table 8-63

SUMMARY OF ESTIMATED EXCESS CANCER RISKS ASSOCIATED WITH COLD SPRING BROOK LANDFILL – ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child	Risk Contributions by Exposure Route[a]	Risk Contributions by Chemical[a]
Residential groundwater usage	**Original data**					
	RME	5.6E-03	—	1.0E-03	Water ingestion – >99%	Arsenic – 99%
	Average	1.4E-03	—	2.5E-04	Dermal contact – <1%	Beryllium – 1%
					Fruits and vegetables – <1%	
	Adjusted data					
	RME	2.9E-03	—	5.4E-04	Water ingestion – 99%	Arsenic – >99%
	Average	2.5E-04	—	4.7E-05	Dermal contact – <1%	Beryllium – <1%
					Fruits and vegetables – <1%	
Soil contact	RME	2.8E-05	—	4.1E-05	Soil ingestion – >99%	PAHs[b] – >99%
	Average	1.4E-05	—	1.9E-05	Dermal contact – <1%	
Fishing/fish ingestion	RME	4.9E-04	—	3.5E-04	Fish ingestion – >99%	Arsenic – 63%
	Average	1.8E-04	—	1.3E-04	Water ingestion – <1%	DDD – 28%
						DDE – 9%
Sediment contact	RME	—	4.9E-05	—	Sediment ingestion – 91%	Arsenic – 57%
	Average	—	1.2E-05	—	Dermal contact – 9%	PAHs[b] – 43%
Total receptor risks	**Original GW data**					
	RME	6.1E-03	4.9E-05	1.4E-03		
	Average	1.6E-03	1.2E-05	4.0E-04		
	Adjusted GW data					
	RME	3.4E-03	4.9E-05	9.3E-04		
	Average	4.4E-04	1.2E-05	2.0E-04		

RC424

Note: Cancer risks from dermal contact with PAHs are not included in risk estimates.

[a]RME case for receptor showing greatest risk.

[b]Carcinogenic PAHs detected at Cold Spring Brook Landfill include: Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, and Indeno(1,2,3-cd)pyrene.

Source: Ecology and Environment, Inc., 1992

Table 8-64

SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH COLD SPRING BROOK LANDFILL - ASSUMING FUTURE RESIDENTIAL USE OF THE SITE

Pathway	Case	Receptor: Adult	Receptor: Adolescent	Receptor: Child[b]	Risk Contributions by Exposure Route[a]	Hazard Index by Chemical[a]
Residential groundwater usage	**Original data**					
	RME	27	—	30	Water ingestion - 97%	Arsenic - 28
	Average	6.9	—	7.6	Dermal contact - <1%	Manganese - 2
					Fruits and vegetables - 3%	
	Adjusted data					
	RME	15	—	16	Water ingestion - 96%	Arsenic - 14
	Average	1.5	—	1.6	Dermal contact - <1%	Manganese - 2
					Fruits and vegetables - 3%	
Soil contact	RME	1.2E-03	—	6.9E-03	Soil ingestion - 99%	
	Average	6.2E-04	—	3.9E-03	Dermal contact - 1%	
Fishing/fish ingestion	RME	2.1	—	9.3	Fish ingestion - >99%	Arsenic - 5.9
	Average	0.67	—	2.9	Water ingestion - <1%	Zinc - 3.4
Sediment contact	RME	—	0.37	—	Sediment ingestion - 70%	
	Average	—	0.11	—	Dermal contact - 30%	
Total receptor risks	**Original GW data**					
	RME	29	0.37	39		
	Average	7.6	0.11	10		
	Adjusted GW data					
	RME	17	0.37	25		
	Average	2.2	0.11	4.5		

RC424

[a] RME case for receptor showing greatest risk.
[b] Child risks are assessed using subchronic RfDs.

Source: Ecology and Environment, Inc., 1992

estimated risks result from the greater frequency of contact assumed for future residents living in the area compared to occasional site visitors. The greatest potential risks associated with residential use of the area are those arising from use of the groundwater as a drinking water source. Water ingestion accounts for greater than 99 percent of both the cancer and noncancer risks estimated for domestic water usage. Arsenic accounted for the vast majority of these estimated risks, 99 percent of the cancer risks and 93 percent of noncancer risks (HI=28); beryllium accounted for most of the remaining cancer risks; and manganese (HI=2) accounted for the remaining noncancer risk.

The risks estimated for domestic use of contaminated groundwater were substantially lower but still significant when calculated using the metals concentrations adjusted to remove the contribution of suspended sediment. This is because many of the higher metals concentrations found in the groundwater appear to be due, at least in part, to actual groundwater contamination rather than to suspended sediment.

Lead, which has no EPA-verified RfD or SF, was not included in the quantitative risk estimates. Instead, lead concentrations in site sediment were assessed using the UBK model. The current EPA recommendation (USEPA 1991i) for using the UBK model to develop soil lead cleanup levels is "a model projection benchmark of either 95 percent of the sensitive population having blood lead levels below 10 µg/dl or a 95 percent probability of an individual having a blood lead level below 10 µg/dl." In other words, cleanup goals should be selected so that the percentage of exposed children expected to have blood lead levels above 10 µg/dl or the probability of an individual child having a blood lead level above 10 µg/dl does not exceed 5 percent. When the UBK model is run using this benchmark and default values for all parameters other than soil lead concentration, the acceptable soil lead level is estimated to be approximately 840 mg/kg.

The UBK model is designed to use the mean lead concentration, either geometric or arithmetic, in its calculations and specifically requires it as the input value. The geometric mean of sediment samples collected from the Cold Spring Brook is 53.1 mg/kg, the arithmetic mean is 86.3 mg/kg, and the highest observed value was 345 mg/kg. All of these values are less than the 840 mg/kg benchmark soil lead level from the UBK model and less than the 500 mg/kg level deemed adequately protective for direct contact in residential settings by the OSWER Directive (USEPA 1989j; 1991i). Therefore, the lead concentrations in the Cold Spring Brook sediments would not appear to pose a significant health risk if areas around the landfill were to be converted to residential use in the future.

There is a Safe Drinking Water Act (SDWA) action level for lead in drinking water of 15 µg/l, a level expected to avoid most of the significant adverse effects of lead in young children who are most sensitive to the effects of lead. Since the greatest exposure to lead in groundwater is likely to result from using this groundwater as drinking water, the action level is an appropriate criteria to use in assessing the lead concentrations in groundwater.

Table 8-65 summarizes the findings about lead in the groundwater at the landfill. Using the original unadjusted groundwater data, two of four background well samples (both from CSB-7) and four out of eight samples from wells within the landfill's zone of influence had lead concentrations greater than 15 µg/l. Using the data adjusted to remove the effect of suspended sediment, no background well samples, and only one out of eight samples from within the landfill's zone of influence (CSB-3, Round 1) had a lead concentration greater than 15 µg/l. From these results it appears that lead concentrations in the groundwater at CSB-3 are slightly elevated and could potentially pose a significant risk to human health.

Perspective on Arsenic Exposure and Risks

As for Shepley's Hill Landfill, most of the estimated risks associated with Cold Spring Brook Landfill are due to potential site-related arsenic exposure. The estimated magnitude and risks of everyday exposure of the general population to arsenic are discussed in Section 8.1.5.4. The estimated potential site-related intakes of arsenic associated with the Cold Spring Brook Landfill by each exposure pathway are compared with estimated total intake by the general population in Table 8-66. As shown, under current site conditions, the estimated potential site-related arsenic intakes are all well below the everyday intake by the general population. Assuming future residential use of the landfill area, the potential arsenic intakes associated with sediment contact and fish consumption are still less than that of the general population. The estimated potential exposures associated with domestic use of groundwater range from less than half to about 10 times that of the general population. As discussed in Section 5.1.5.4, the estimates of everyday arsenic intake by the general population should be quite reliable, whereas the estimates of potential site-related intakes are based on conservative assumptions and almost certainly overestimated any actual exposures that might occur.

Nature of Potential Adverse Health Effects

The site contaminants estimated to pose potentially significant excess lifetime cancer risks include arsenic, beryllium, 4,4'-DDD, 4,4'-DDE, and the carcinogenic PAHs.

Arsenic is classified as a Group A human carcinogen. Oral exposure to arsenic is known to cause skin cancer, and there is mounting evidence that ingestion of arsenic may cause liver, kidney, bladder, or lung cancer.

Beryllium, 4,4'-DDD, 4,4'-DDE, and the carcinogenic PAHs are classified as Group B2-probable human carcinogens, based on carcinogenicity in animals. Beryllium has caused various types of tumors in exposed animals. DDD and DDE are associated with cancer of

Table 8-65

EVALUATION OF LEAD
CONCENTRATIONS IN GROUNDWATER

Area	Detection Frequency	Frequency of Concentration >15 μg/L	Average Concentration (μg/L)	Maximum Concentration (μg/L)
Original Data				
Background	4/4	2/4	17	38
Within zone of influence	8/8	4/8	30	85
Adjusted Data				
Background	0/4	0/4	2	5
Within zone of influence	3/8	1/8	2	16

RC424

Source: Ecology and Environment, Inc., 1992

Table 8-66

**SITE 40: COLD SPRING BROOK LANDFILL
COMPARISON OF ESTIMATED POTENTIAL
SITE-RELATED ARSENIC INTAKES TO
ESTIMATED INTAKES FOR THE GENERAL POPULATION**

Exposure Pathway	Receptor	Exposure Case	Estimated Intake (mg/kg/day)	Fraction of the Estimated Daily Intake by General Population[b]
Current Site Conditions[a]				
Sediment Contact	Adolescent	Average	1.51E-6	0.002
		RME	5.22E-6	0.006
Fishing, Fish Consumption	Adult	Average	1.64E-5	0.023
		RME	4.07E-5	0.057
	Child	Average	7.19E-5	0.046
		RME	1.78E-4	0.11
Future Residential Use[a]				
Sediment Contact	Adolescent	Average	3.03E-5	0.036
		RME	1.04E-4	0.12
Fishing, Fish Consumption	Adult	Average	1.64E-4	0.23
		RME	4.07E-4	0.57
	Child	Average	7.19E-4	0.46
		RME	1.78E-3	1.1
			Unadjusted Data	
Domestic Groundwater Usage	Adult	Average	1.78E-3	2.49
		RME	7.45E-3	10.4
	Child	Average	1.99E-3	1.3
		RME	8.32E-3	5.3
			Adjusted Data	
	Adult	Average	3.26E-4	0.46
		RME	3.87E-3	5.4
	Child	Average	3.64E-4	0.23
		RME	4.32E-3	2.8

RC424

[a] Arsenic was not a COPC for the soil contact pathway.
[b] Assumed to be 50 µg/day for adults, 35 µg/day for adolescents and 25 µg/day for children.

Source: Ecology and Environment, Inc., 1992

the liver. The PAHs cause cancer at the point of contact and have caused skin, stomach, and respiratory tract cancers.

Site contaminants that pose potentially significant noncarcinogenic adverse health effects include arsenic, chromium, and manganese. Overexposure to arsenic can cause damage to the kidneys and blood, weight changes, and possible keratosis and hyperpigmentation of the skin in humans. Long-term oral exposure to chromium VI may cause kidney or liver damage. A few studies suggest that excessive ingestion of manganese can cause changes in brain chemistry; however, reports of adverse health effects in humans from ingestion of manganese are rare.

Summaries of the toxic effects of all of these chemicals are provided in Section 8.1.4.2.

Level of Confidence/Uncertainty in the Risk Estimates

These matters are discussed fully in earlier sections of this report; briefly, the level of confidence in the exposure estimates range from low to high. The level of confidence in the toxicity estimates varies from chemical to chemical as shown in Tables 8-59 and 8-60.

Overall, the level of confidence in the risk estimates also ranges from low to high. Confidence in the risk estimates for future groundwater usage and direct contact with surface soils is high because they are based directly on the contaminant concentrations measured in the groundwater and surface soils.

Confidence in the risk estimates for direct contact with shoreline sediments is moderate because no samples were collected along the shore where exposure is assumed to occur. Therefore, concentrations in bottom sediments taken close to shore had to be used to estimate the exposure point concentrations. It is possible the bottom sediments may be richer in organics that could trap metals and may also have greater contact with contaminated groundwater discharging to the pond than shoreline sediments. Both factors could result in higher metals concentrations in bottom sediments than in shoreline sediments, thus overestimating the potential exposure and risk.

Confidence in the risk estimates for fish consumption is also moderate because no data about contaminant concentrations in fish from Cold Spring Brook were available. Consequently, contaminant concentrations in fish had to be estimated from water and sediment concentrations using bioaccumulation factors. The pesticides DDD and DDE together account for about 72 percent of the estimated cancer risk from consumption of fish. The bioconcentration factors for these compounds were calculated using an equilibrium partitioning (EP) approach. The model used, which is taken from EPA interim guidance, is based on empirical evidence and the estimated bioaccumulation factors should be moderately reliable. Arsenic accounted for 27 percent of the estimated risks associated with fish consumption. However, there is limited information in the literature on the relationship between arsenic concentrations in sediment and fish tissue. More information is available for zinc, but it is highly variable and seems to depend heavily on local conditions. The approach used to estimate the bioaccumulation factors for arsenic and zinc seems reasonable and appropriate given the information available; however, the variable nature of that information results in a moderate level of confidence in the bioaccumulation factors and in the risk estimates derived from them.

Major Factors Driving the Estimated Site Risks

The major factors driving the estimated site risks are:

- The presence of arsenic, DDD, and DDE in Cold Spring Brook Pond sediments coupled with the potential use of the pond for fishing, consumption of fish caught in the pond, and possible use of the pond shoreline as a play area by adolescents, which provide pathways of exposure to these contaminants; and

- The presence of elevated concentrations of metals, principally arsenic, in the groundwater, coupled with the possible future use of the groundwater as a source of drinking water.

Characteristics of the Potentially Exposed Populations

The potential receptors consist of adolescents who might play along the shore of Cold Spring Brook Pond, fishermen and their families and friends who might eat fish caught in the pond, miscellaneous site visitors that might enter the site and come in contact with surface soil contaminants, and potential future residents that might live in homes built near the landfill. Under existing site conditions, site visitors, and fisherman and their families would probably include a mixture of adults and children typical of the existing base population, which includes military personnel and their dependents. After the base closes, fishermen and their families, and future residents would be expected to include a mixture of children, adults, and the elderly, which reflects the general demographic characteristics of the area. Adolescent site visitors and future residents who might play along the shoreline would probably be representative of that segment of the local population.

9. ECOLOGICAL RISK ASSESSMENT

9.1 INTRODUCTION

Baseline ecological risk assessments for the Shepley's Hill Landfill and Cold Spring Brook Landfill sites were performed in accordance with current regional and national EPA guidance for ecological assessment at hazardous waste sites. This guidance includes:

- <u>Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual</u> (USEPA 1989d);
- <u>Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference</u> (USEPA 1989b);
- <u>Region I Supplemental Risk Assessment Guidance for the Superfund Program, Part 2, Guidance for Ecological Risk Assessments</u> (USEPA 1989e); and
- <u>Ecological Assessment of Superfund Sites: An Overview</u> (USEPA 1991).

This ecological risk assessment is structured in general accordance with the outlines provided in the Region I guidance and EPA's updated framework for ecological assessment (USEPA 1991). The report includes the following components:

- A discussion of the general objectives and scope of the risk assessment;
- Screening and identification of the contaminants of ecological concern;
- A summary of the principal ecological receptors and potential exposure pathways, and selection of ecological endpoints;
- An exposure assessment providing quantitative or qualitative exposure scenarios and estimates of exposure point concentrations for selected ecological receptors;
- An ecological effects assessment summarizing the known effects of the contaminants of concern and providing benchmark toxicity values for selected ecological receptors;
- A risk characterization combining the information from the exposure assessment and ecological effects assessment to obtain estimates of the ecological risks posed by the contaminants of concern; and
- Conclusions and recommendations of the risk assessment.

The general objectives and scope of the ecological risk assessment for both sites are discussed in the next section. Following this, separate sections are provided for each site to discuss contaminants of concern, ecological endpoints, exposure assessment, ecological effects assessment, and risk characterization. A single section summarizes the conclusions and recommendations for both sites. Recommendations are general rather than specific, consistent with the objectives of this ecological assessment.

9.2 GENERAL OBJECTIVES AND SCOPE

The ecological risk assessment integrates information gathered from the site investigations with toxicological information to determine whether contamination at the site presents potential risks to the environmental receptors. Baseline risks are evaluated for current and future conditions at the site, assuming no remedial action is taken. This assessment will help to determine whether remedial actions are needed and whether further phases of site investigation are required to develop appropriate remedial goals.

The ecological risk assessment for the Shepley's Hill Landfill and Cold Spring Brook Landfill sites is a screening-level assessment. The decision to conduct a screening-level risk assessment was made in discussions and correspondence with the EPA Regional Project Manager and representatives of the EPA Region I Superfund Exposure Assessment Team (SEAT), Commonwealth of Massachusetts DEP, United States Fish and Wildlife Service, USATHAMA, and Fort Devens. As defined in the Region I guidance, a screening-level risk assessment is "a simple ecological risk assessment that uses available or easily obtainable data and is often based on established criteria and worst case assumptions concerning exposure." More detailed risk assessments are warranted if a significant concern is identified by the screening-level assessment. Detailed ecological risk assessments may include toxicity testing of field-collected media, additional chemical analyses of media or biological tissues, modeling, or a variety of bioassessment techniques (USEPA 1989e). Such investigations are beyond the scope of this initial screening-level assessment. In addition, evaluation of habitats further removed form the site, such as Grove Pond and downstream reaches of Cold Spring Brook, were also considered beyond the scope of this assessment.

The screening-level risk assessment for Shepley's Hill Landfill and Cold Spring Brook Landfill was initiated with a field ecological survey conducted by two E & E biologists in August 1991. The detailed results of the survey are provided in Section 3 of this report. The ecological survey was intended to be a descriptive characterization and mapping of habitats at the site. The biological field survey provided information on upland, wetland, and aquatic habitats adjacent to the site. However, fish and aquatic invertebrates were not collected pending the results of the screening-level risk assessment.

Information is provided in earlier sections of this report on site contaminants, geology, hydrology, soils, and other characteristics. To avoid redundancy, reference is made to these sections and to the human health risk assessment when appropriate.

9.3 ECOLOGICAL RISK ASSESSMENT FOR SHEPLEY'S HILL LANDFILL

The ecological risk assessment for the Shepley's Hill Landfill site is provided in the following sections.

9.3.1 Contaminants of Ecological Concern

Selection of contaminants of potential concern (COPCs) for ecological receptors was based on the general screening criteria outlined for the human health risk assessment, but ecological criteria were substituted for health-based criteria where appropriate. The use of ecological criteria to screen the data allows identification of COPCs to which ecological receptors may be highly sensitive.

The general screening criteria used for COPCs included the following:

- o Usability of the data for risk assessment;
- o Comparison with natural background concentrations;
- o Spatial distribution of contaminants; and
- o Presence at elevated levels in groundwater samples.

Since the application of these criteria is extensively discussed in Section 8.1.2, they are not discussed in great detail in the ecological risk assessment. The data usability criterion refers to data validation issues as discussed in Section 8.

The results of screening chemicals in sediment, surface water, and other media are provided below.

9.3.1.1 Surface Water

As described in Section 2.1.6 of the RI report, a total of 15 surface water samples were collected for chemical analysis from the Shepley's Hill Landfill site. A total of 13 samples were taken from Plow Shop Pond, one sample was taken from the Nonacoicus Brook stream channel just below the dam retaining Plow Shop Pond, and one sample was taken from the wetlands north of the landfill. The sampling locations are shown in Figure 2-4, and analytical results are summarized in Table 5-7 of the RI report.

The metals concentrations in the surface water at the site are generally low and probably reflect background concentrations. As discussed in the human health risk assessment, however, the presence of elevated metals in pond sediments and historical evidence of contamination from Grove Pond suggest that Plow Shop Pond cannot be regarded as representative of background water quality (see Section 8.1.2). Therefore, in addition to the general screening criteria applied in the human health risk assessment, chemicals in surface water samples were compared to EPA Ambient Water Quality Criteria (AWQC) for protection of aquatic life. Chemicals not detected at concentrations approaching or exceeding AWQC would not be expected to pose a significant ecological risk and were not regarded as COPCs for the risk assessment. Chronic AWQC were used for screening if available; otherwise, acute AWQC or Lowest Observed Effect Level (LOEL) were used. If no AWQC or LOEL were available for a given chemical, that chemical was not eliminated on the basis of these ecological criteria. The AWQC for all chemicals of potential ecological concern listed in Table 5-7 are provided in Table 9-1.

The range of chemical concentrations in surface water was determined for three areas. Area 1 is defined by sampling stations SW-SHL-09 through SW-SHL-12, which are located on the eastern shore of Plow Shop Pond opposite from the landfill. These sampling stations are likely influenced by other sources of contamination such as the culvert leading from Grove Pond and the railroad (see Section 8.1.2). Area 2 is defined by Plow Shop Pond samples SW-SHL-01 through SW-SHL-08 and SW-SHL-13, which are located adjacent to the landfill on the western shore of the pond. Area 3 is defined by Nonacoicus Brook stream channel sample SW-SHL-14 and wetland sample SW-SHL-15. Surface water quality in Areas 2 and 3 could be related to effects from the site due to their proximity to the landfill.

Contaminants detected in sediments (see below, Section 9.3.1.2) might also be considered for their potential to contaminate surface water through resuspension due to extreme events such as high winds. However, the modeling of contaminant release from sediments to surface water was considered beyond the scope of this screening-level assessment. The actual measurements of the 15 samples taken from Plow Shop Pond and Nonacoicus Brook were considered to be reasonable estimates of typical conditions, although the data may not account for various other conditions and circumstances such as seasonal overturn and high winds. The assessment of sediment contaminants (Section 9.3.1.2) likely accounts for some of the COPCs not explicitly chosen for evaluation in the surface water environment.

The results of the screening are provided in Table 9-2.

Metals

In Area 1, chronic AWQC were exceeded for copper at three of the four sampling stations, and acute AWQC were exceeded for silver at one of the four sampling stations. These were the only exceedances of AWQC in the eastern edge of Plow Shop Pond.

In Area 2, AWQC were exceeded for copper, silver, and zinc. Silver was above AWQC at only one sampling location, SW-SHL-06. Zinc was above AWQC at only one location, SW-SHL-04. Copper exceeded AWQC at several

Table 9-1

**EPA AMBIENT WATER QUALITY CRITERIA
PROTECTION OF AQUATIC LIFE
SHEPLEY'S HILL LANDFILL**

Parameter	AWQC[a] (μg/l) or Other Criteria	Notes
Inorganic Substances		
Arsenic	190/360	(1), (3)
Barium	50,000	(6)
Chromium	88/740	(1), (3), (4)
Copper	4.8/6.6	(1), (4)
Iron	1,000	(5)
Manganese	1,000	(7)
Nickel	65/585	(1), (4)
Silver	0.12/0.7	(1), (4)
Zinc	44/48	(1), (4)
Organic Substances		
Endosulfan Sulfate Endrin	0.0023/0.18	(1)
Chloroform	1,240/28,900	(1), (2)

RC424

[a]Ambient Water Quality Criteria.

NOTES:

(1) Fresh Water Chronic Criterion/Fresh Water Acute Criterion or Value.
(2) Insufficient Data to Develop Criterion. Values presented are the Lowest Observed Effect Level (LOEL).
(3) Values presented are for the trivalent species.
(4) Hardness Dependent Criterion (35.1 mg/l, site-specific value of hardness in the surface water).
(5) Fresh Water Chronic Criterion.
(6) Soluble barium concentrations would have to exceed this level before toxicity would be expected (USEPA 1986b).
(7) Manganese is rarely found in surface waters at concentrations higher than this level (USEPA 1986b).

Source: Ecology and Environment, Inc. 1992.

Table 9-2

COMPARISON OF CHEMICALS IN PLOW SHOP POND SURFACE WATER TO AWQC

	Area 1 (Plow Shop Pond - Eastern Edge)			
	Range (μg/l)		Elevation Frequency	
Parameter	Minimum	Maximum	Chronic	Acute
Inorganic Substances				
Arsenic	3.11 -	6.84	0/4	--
Barium	4.39 -	11.8	0/4	--
Chromium		<4.47	0/4	--
Copper	<4.29 -	8.33	3/4	1/4
Iron	24.8 -	538	0/4	--
Manganese	45.6 -	139.0	0/4	--
Nickel	<8.76 -	10.2	0/4	--
Silver	<0.316 -	3.60	1[a]	1/4
Zinc		<19.4	0/4	--
Organic Substances				
Endosulfan Sulfate Endrin		<0.008	0[a]	0/4
Chloroform		<0.830	0/4	--

RC424

Table 9-2 (Cont.)

	Area 2 (Plow Shop Pond - Western Edge)				Area 3 (Nonacoicus Brook)			
	Range (μg/l)		Elevation Frequency		Range (μg/l)		Elevation Frequency	
Parameter	Minimum	Maximum	Chronic	Acute	Minimum	Maximum	Chronic	Acute
Inorganic Substances								
Arsenic	2.99 -	6.26	0/9	--	4.28 -	6.96	0/2	--
Barium	3.35 -	8.48	0/9	--	13.0 -	15.2	0/2	--
Chromium		<4.47	0/9	--	<4.47 -	4.9	0/2	--
Copper	<4.29 -	48.7	8/9	7/9	4.59 -	21.6	1/2	1/2
Iron	214 -	538	0/9	--		1,100	2/2	--
Manganese	7.81 -	41.6	0/9	--	490 -	500	0/2	--
Nickel	<8.76 -	44.2	0/9	--	<8.76 -	36.0	0/2	--
Silver	<0.316 -	0.564	1[a]	0/9		<0.316	0[a]	--
Zinc	<19.4 -	58.1	1/9	1/9	<19.4 -	28.4	0/2	--
Organic Substances								
Endosulfan Sulfate Endrin		<0.008	1[a]	0/9[a]		<0.008	0[a]	0/2[a]
Chloroform	<0.830 -	1.41	0/9	--		<0.83	0/2	--

RC424

[a]AWQC is below the detection limit.

Source: Ecology and Environment, Inc. 1992.

locations. Copper, silver, and zinc are not considered COPCs for the following reasons:

- o The AWQC exceedances for both silver and zinc were relatively small and isolated to one location.
- o The highest surface water concentration of silver was detected in Area 1 on the far opposite edge of the pond (SW-SHL-09) from the landfill, suggesting an alternate source of silver contamination.
- o Zinc and copper were detected at elevated concentrations in sediment samples taken from Area 1 (see below), whereas concentrations of these metals in Area 2 sediments were relatively low. If mobilization from sediment were to be considered a major source of copper and zinc contamination in the surface water, then the AWQC exceedances appear to be related to Area 1 sediments and do not appear to be attributable to the site.
- o Groundwater data do not show elevated levels of these metals in wells located adjacent to the landfill (see Section 8.1.2). Thus, groundwater discharge from the site does not appear to be a source of copper, silver, or zinc contamination in the pond.

Therefore, on the basis of this screening, none of the metals in Area 2 surface water was considered a COPC and, consequently, none was included in the ecological risk assessment. It is noted, however, that silver is difficult to evaluate as the detection limit was higher than the AWQC (see Table 9-2). Copper is acknowledged to occur at potentially toxic concentrations but the source is undetermined and cannot be attributed to the site with the available information.

In Area 3, AWQC were exceeded for copper and iron. Copper exceeded AWQC at one sampling location, SW-SHL-14. Iron exceeded AWQC at both locations SW-SHL-14 and SW-SHL-15. Copper and iron are not considered COPCs in Area 3 for the following reasons:

- o The AWQC exceedances for iron were relatively small. Iron is an essential nutrient with relatively low toxicity to aquatic life (USEPA 1986b). Moreover, natural background concentrations of iron are frequently high in wetlands due to the reducing conditions that occur in anaerobic wetland soils and sediments. Mean total iron concentrations of 1.86 mg/l and 3.55 mg/l have been reported for swamp forests, for example (Lugo et al. 1990).
- o Concentrations of copper in Area 3 sediments were relatively low. If mobilization from sediment were considered to be a major source of copper contamination of the surface water, then the AWQC exceedance does not appear to to be attributable to the site.

- o Groundwater data do not indicate elevated levels of copper from wells located adjacent to the landfill (see Section 8.1.2). Thus, groundwater discharge from the site does not appear to be a source of copper contamination in Nonacoicus Brook.

Therefore, on the basis of this screening, none of the metals in Area 3 surface water was considered a COPC, and, consequently, none was included in the ecological risk assessment. However, as with Plow Shop Pond (Area 2), copper is acknowledged to occur at potentially toxic concentrations but the source is undetermined and not attributable to the site with the available information.

Organic Substances

On the basis of the screening, no organic substances were identified as COPCs in the surface water in Areas 2 or 3. Endrin was found in one sample from Area 2 at the detection limit and does not appear to be of concern because it is present at a level only slightly above the chronic AWQC. Low-level methylene chloride detections are attributable to laboratory contamination. Low levels of chloroform were detected in a few samples from Area 2 but were well below chronic AWQC. No other organic substances were detected.

9.3.1.2 Sediment

A total of 15 sediment samples were collected for chemical analysis from the Shepley's Hill Landfill site. The sediment samples were collected from the same locations as the surface water samples (13 samples from Plow Shop Pond and one sample each from the Nonacoicus Brook stream channel and the wetlands north of the landfill). The sampling locations are shown in Figure 2-4, and chemical results are summarized in Table 5-8 of the RI report.

Metals

As discussed in the human health risk assessment (Section 8.1.2), several metals detected in the sediments of Plow Shop Pond were found at levels considerably elevated above background. However, the spatial distribution of metals indicates that only the following four metals are clearly and unambiguously related to the site and potentially of concern: arsenic, barium, cadmium, and manganese.

Inorganics in sediments were compared to background soil concentrations because background sediment concentrations were unavailable. This is justified because background levels of inorganic contaminants in soils and sediments are generally comparable. For example, average concentrations of several contaminants in U.S. freshwater sediments (Bolton et al. 1985) and soils (Shacklette and Boerngen 1984) are as follows: arsenic (4.0 mg/kg in sediments, 5.2 mg/kg in soils); copper (4.0 mg/kg in sediments, 17 mg/kg in soils); lead (16 mg/kg in sediments, 16 mg/kg in soils); nickel (13 mg/kg in sediments, 13 mg/kg in soils); and zinc (41 mg/kg in sediments, 48 mg/kg in soils). For cadmium, the average concentration in worldwide soils is 0.35 mg/kg (Adriano 1986), compared to 1.0 mg/kg in U.S. freshwater sediments (Bolton et al. 1985). Although copper concentrations are somewhat higher in soils than sediments, the average soil concentration of copper is less than the 95th percentile for sediments of 32 mg/kg (Bolton et al. 1985). Thus, comparison of sediment concentrations of inorganics to background soil concentrations is believed to be appropriate for screening purposes.

In addition to the general screening criteria applied in the human health risk assessment, metals in sediments were compared to a range of published freshwater sediment quality criteria. Metals not detected at concentrations approaching or exceeding these ecological criteria would not be expected to pose a significant ecological risk and were not regarded as COPCs for the risk assessment. The proposed regulatory criteria for sediments are not consistent, however, and uniform national or Commonwealth of Massachusetts criteria have not been established. Comparative sediment criteria for the four metals of potential concern are shown in Table 9-3.

The ecological criteria shown in Table 9-3 are generally well below background concentrations for soils at the site. The ecological criteria values in Table 9-3 are derived from other States and regions and may not be applicable to the site. Hence, these ecological criteria are considered overly conservative screening criteria for the Shepley's Hill Landfill site. Instead, less conservative values were used, called "Limit of Tolerance Levels," which are concentrations considered potentially toxic to most benthic invertebrates (Persaud 1989). The benthic invertebrate Limit of Tolerance Levels are of the same magnitude as the Upper Tolerance Limits on local soil concentrations (see Table 9-4). Exceedances of both the benthic invertebrate Limit of Tolerance levels and the background soil concentrations would indicate potential site-related risks to benthic aquatic biota.

Contaminant concentrations in sediments were determined for the three areas of concern identified above for surface water (Areas 1, 2, and 3). A comparison of metals concentrations in the three areas to background levels and ecological screening criteria is shown in Table 9-4.

In Area 2, concentrations of arsenic, barium, cadmium, and manganese were elevated relative to background and ecological screening levels at four or more sample locations (Table 9-4). Therefore, all four metals were identified as COPCs in Area 2. None of the metals were detected at levels exceeding background or the ecological screening levels for Area 3 sediments. Therefore, metals are not considered COPCs for sediments from Area 3 (Table 9-4).

Organic Substances

Organic contaminants were not detected at levels above detection in Area 2 sediment samples except at SE-SHL-02, which contained low levels

Table 9-3

COMPARATIVE SEDIMENT CRITERIA FOR METALS (mg/kg)

Metal	EPA Region V Guidelines[a]	Ontario Ministry of Environment Proposed Sediment Quality Criteria[b]	EPA Threshold Values[c]	Wisconsin Department of Natural Resources Sediment Quality Criteria[d]	New York State Department of Environmental Conservation[e]
Arsenic	3	4.0	33	10	5
Barium	20	NA	NA	500	NA
Cadmium	6	0.6	31	1.0	0.8
Manganese	300	400	NA	NA	428

RC424

[a]USEPA 1977. Levels above those provided in the table are considered moderately polluted, levels below are considered nonpolluted. For cadmium, lower limits are not established; levels above 6 mg/kg are considered heavily polluted.
[b]Persaud et al. (1989). No observed effect level for toxicity to benthic invertebrates.
[c]Bolton et al. (1985), reported in Lyman et al. (1987). Levels are calculated based on the equilibrium partioning approach: sediments with these concentrations of total metal are predicted to have concentrations of metal in the interstitial water that exceed established water quality criteria. Total organic carbon of 4 percent is assumed.
[d]Sullivan et al. 1985, reported in Fitchko 1989.
[e]New York State 1989. Criteria are derived from Persaud et al. 1989.

Key:

NA = Not available.

Source: Ecology and Environment, Inc. 1992.

Table 9-4

COMPARISON OF METALS IN PLOW SHOP POND SEDIMENTS TO BACKGROUND AND CRITERIA

Parameter	Upper Tolerance Limit (UTL) on Local Soil Concentrations[a]	Limit of Tolerance Level for Benthic Inverte-brates (LTL)	Area 1 (Plow Shop Pond - Eastern Edge) Range Minimum	Range Maximum	Elevation Frequency UTL	Elevation Frequency LTL
Arsenic	66	33	200 -	380	4/4	4/4
Barium	91	NA	76.3 -	310	3/4	NA
Cadmium	5.5	10	4.93 -	23.7	3/4	3/4
Manganese	590	1,100	310 -	3,400	3/4	3/4

Parameter	Area 2 (Plow Shop Pond - Western Edge) Range Minimum	Range Maximum	Elevation Frequency UTL	Elevation Frequency LTL	Area 3 (Nonacoicus Brook) Range Minimum	Range Maximum	Elevation Frequency UTL	Elevation Frequency LTL
Arsenic	36 -	3,200	8/9	9/9	17 -	22	0/2	0/2
Barium	10.3 -	280	7/9	NA	9.68 -	29.0	0/2	NA
Cadmium	<0.424 -	60.2	7/9	7/9		<0.424	0/2	0/2
Manganese	<84.0 -	8,880	4/9	4/9	84 -	280	0/2	0/2

RC424

[a]See Human Health Risk Assessment, Section 8

Key:

NA = Not available.

Source: Ecology and Environment, Inc. 1992.

of acetone, methylene chloride, methyl ethyl ketone, 4,4'-DDE, and heptachlor. These organic contaminants are either attributable to laboratory contamination or do not appear to be related to the landfill, or they can be eliminated due to the low levels observed and their restriction to a single location (see Section 8.1.2).

Polynuclear aromatic hydrocarbons (PAHs) were detected in Area 1 at sampling locations SE-SHL-09, SE-SHL-11, and SE-SHL-12. The sediment samples containing PAHs are all on the opposite side of the pond and seem related to Grove Pond discharge or the railroad (see Section 8.1.2).

No organic contaminants were found in Area 3 sediments.

9.3.1.3 Other Media

Elevated levels of metals and low levels of organic chemicals in groundwater are not considered to be COPCs for ecological receptors at the site, except indirectly as indicators of potential soil contamination in the root zone of plants or as a source of continuing contamination to Area 2 or Area 3 sediments or surface water. Metals in groundwater were selected as "indicator" COPCs because soil data were unavailable to evaluate effects of contaminants on plants growing on the landfill's edge. Organic contaminants in groundwater were not evaluated because levels were generally low.

Air and seep area sediment samples did not contain levels of any chemicals that might pose a significant risk to human or ecological receptors (see Section 8.1.2). Because of the lack of seep area contamination, potential exposure of mammals and birds to contaminants in drinking water at groundwater seeps was not evaluated.

9.3.1.4 Summary

The following four metals were selected as COPCs in environmental media (Plow Shop Pond sediments) potentially affected by the Shepley's Hill Landfill site: arsenic, barium, cadmium, and manganese. Metals in groundwater were chosen as "indicator" COPCs for soils. No other contaminants in sediments or other media were selected as COPCs for this ecological risk assessment. Risks associated with additional contaminants which are present in Plow Shop Pond sediments but are not related to the site are summarized in Section 9.3.5.

9.3.2 Ecological Receptors and Endpoints

This section identifies the potential ecological receptors and endpoints of concern at the Shepley's Hill Landfill site. Features of the terrestrial, wetland, and aquatic ecosystems are summarized in Section 9.3.2.1. This summary is based on the ecological characterization studies that were conducted as a part of the RI field investigations. Potential exposure pathways for ecological receptors occurring at the site are identified in Section 9.3.2.2. The ecological endpoints that will serve as the focal point of the ecological risk assessment are then identified in Section 9.3.2.3.

9.3.2.1 Summary of Existing Environment

In conjunction with the RI report, field studies were conducted and an ecological characterization of the landfill and surrounding areas was compiled. This characterization involved the identification of the plant and animal communities as well as observations of any actual or potential effects of site contaminants on these biological resources. The entire ecological characterization of the Shepley's Hill Landfill site is presented in Section 3.1.1. of the RI report. However, a summary of the major cover types and principal habitats located in the general vicinity of the landfill follows (see Table 9-5).

Coniferous Forest

This cover type is located in four different areas upgradient from the landfill. Two of the areas are red pine plantations, one is a white pine-red pine plantation, and the remaining one is a mature white pine forest. The understory in the natural forest consists of red maple and white pine saplings, while in the planted areas it is relatively open except for some regeneration.

Overall, these coniferous forests provide excellent year-round protective cover for a variety of animals including songbirds, upland game birds, raptors, and whitetail deer. In addition, the young trees (in the plantations) produce seed, which is a valuable food source for a variety of birds and mammals.

Mixed Forest

This cover type is located in five different areas around the landfill. Four of these areas, located on the west and south sides of the landfill, are upgradient of the landfill. The fifth area is located on the northwestern boundary of the landfill and extends toward the east. According to groundwater flow directions, this area is downgradient of the landfill; however, no signs of stressed vegetation were observed during the field survey. The dominant species in the overstory of this cover type include red pine, scarlet oak, red maple, and white pine. The understory consists primarily of the same species as well as dwarf blueberry and sweetfern.

The abundance of oaks in these areas results in high-quality wildlife areas. Oak acorns are a valuable fall and winter food source for a variety of species. In addition, the pines provide excellent cover and a valuable food item (seed). Overall, these areas can support a diverse group of species including whitetail deer, blue jay, common flicker, black bear, gray squirrel, ruffed grouse, gray catbird, chipmunk, and coyote.

Table 9-5

MAJOR COVER TYPES AND PRINCIPAL HABITATS LOCATED AT SHEPLEY'S HILL LANDFILL

Major Cover Type/Habitat	Dominant Species	Relation to Source/Contamination	Cover Type Numbers[a]
Coniferous Forest	Red pine, white pine	Located upgradient from landfill; two small pine plantations down-gradient	1, 4, and 16
Mixed Forest	Red pine-scarlet oak, white pine-scarlet oak	Located upgradient of landfill (south and west sides); one area is located downgradient of landfill (north side)	2, 11, and 12
Deciduous Forest	Scarlet oak, white oak, aspen, red maple,	Located downgradient of landfill (east and north sides); two areas located upgradient on west side	7, 13, 14, 15, 17, and 18
Open (includes old field, sand barren, and grassland)	Sweetfern, aspen (saplings), bluegrass	Covering landfill and downgradient; three areas located south of site are upgradient	3, 5, 6, 8, and 9
Forested Wetland	Red maple, silky dogwood, nannyberry	Located downgradient of landfill on the northern edge; borders pond	19 and 20
Emergent/Open Water Wetland	Water marigold, smartweed, sweet water lily	Located on landfill downgradient; Plow Shop Pond and bordering vegetation	10 and 21

RC424

[a]Listed in the Remedial Investigations Report, Table 3-5.

Source: Remedial Investigation Report for Shepley's Hill Landfill, Ecology and Environment, Inc. 1992.

Deciduous Forest

This cover type is located in four different areas around the landfill, and, according to the groundwater flow direction, only one of these four areas is located upgradient of the landfill. The other three areas are located downgradient and to the north and east of the landfill. Two of these areas contain small areas of dead trees (see Section 9.3.4.3).

Dominant species in the overstory of this cover type include scarlet oak, white oak, red maple, and quaking aspen. The understory consists primarily of scarlet oak and red maple.

These areas provide a variety of food items to a large number of species. Overall, these deciduous forests are considered high-quality wildlife habitats; the oaks provide an important food staple, and red maple provides browse for deer and spring fruits for birds and mammals. A few of the species likely to occur in these areas include whitetail deer, robin, rose-breasted grosbeak, cottontail, and squirrel.

Open Area

This cover type includes a number of different habitats such as grasslands, sand barrens, and old fields. These areas are located on the landfill as well as upgradient and downgradient of the groundwater flow. Two old field areas, situated on the southern boundary of the landfill, are upgradient of the landfill. The one large grassland area occurs on the capped landfill, while the two sand barren areas are located in the southeast corner and are downgradient of the landfill.

The old field areas consist of some scattered quaking aspen saplings and tartarian honeysuckle shrubs but are dominated by herbaceous species such as panic grass, goldenrods, and fescue. These old fields serve as small wildlife openings that provide edge and food. Panic grass produces seed, which is eaten by a variety of songbirds, and the shrubs are also an important food source. Some of the species likely to utilize these old field areas include the song sparrow, cottontail, field sparrow, thrasher, and catbird.

The sand barren areas support a few red pine saplings but are dominated by sweetfern. Because of the limited availability of food and cover, these areas provide low-quality wildlife habitats.

The large grassland area that covers the landfill is dominated by bluegrass, orchard grass, and path rush. Although this area is maintained (mowed), it is considered a valuable wildlife resource. Due to its large size, dense grass cover, and assortment of grass heights, this area attracts a variety of grassland birds and mammals. Some of the birds observed during the field survey include savannah sparrow, grasshopper sparrow, red-tailed hawk, American kestrel, and Cooper's hawk. Mammals likely to use this area include meadow voles, woodchucks, and coyotes (coyote tracks were observed).

Forested Wetland

Two forested wetlands are located on the northeast boundary of the landfill, and, according to groundwater flow directions, both of these wetlands are downgradient of the landfill. One wetland is located at the confluence of Nonacoicus Brook and Plow Shop Pond, while the other consists of a narrow strip of wetland that borders Plow Shop Pond. Both of these wetlands are dominated by red maple, with some nannyberry and silky dogwood in the understories.

These two wetland areas provide a valuable source of cover for a variety of species. In addition to the birds and mammals that frequent forested wetland areas, the moist soil conditions are capable of supporting a variety of amphibians such as the spring peeper and two-lined salamander.

Emergent/Open Water Wetland

One small wet meadow/emergent wetland is located in a small depression on the landfill. The dominant plants in this wetland are smartweed, broom-like sedge, and panic grass. Due to the very small size of this wet meadow, its wildlife value is limited. Species using the surrounding grassland area may forage and water within this wet meadow, and amphibians such as the American toad and leopard frog may use this area for breeding.

Plow Shop Pond is classified as a floating-leaved deep marsh and is located downgradient of the landfill. This pond is shallow, eutrophic, and dominated by water marigold, sweet water lily, and water shield. Due to its large size and abundance of floating-leaved and submergent vegetation, this pond is a valuable wildlife resource. Several species of toads and frogs are likely to use the pond for breeding. Waterfowl use the pond for feeding and resting. Herons and belted kingfishers feed on fish and frogs, and insectivorous birds forage over the pond's surface. Mammals such as the muskrat and beaver are expected to occur in the pond.

9.3.2.2 Potential Exposure Pathways

Under existing and future site conditions, five general categories of ecological receptors might be exposed to COPCs at the Shepley's Hill Landfill site. Potentially exposed receptors include:

- o Aquatic biota in Plow Shop Pond;
- o Aquatic biota in Nonacoicus Brook;
- o Semi-aquatic wildlife and terrestrial wildlife that depend on the aquatic environment for a fraction of their food or habitat needs;

- o Strictly upland terrestrial wildlife; and
- o Plants growing along the edge of or downgradient from the landfill.

The potential exposure pathways for these receptors vary among receptor types.

- o Benthic invertebrates and some fish would be expected to have direct contact with contaminated sediment particles and sediment interstitial water through contact and absorption, direct ingestion, and feeding on contaminated food. Uptake of contaminants from the sediments (via interstitial water) by aquatic plants could also occur.
- o Bioconcentration from media by aquatic species and subsequent bioaccumulation in the food chain could expose some herbivores, omnivores, predators, and piscivorous wildlife to COPCs (see Figure 9-1). Semi-aquatic wildlife and some terrestrial species could be exposed via the food chain. Some of these receptors could also be exposed through contact and absorption and direct ingestion of sediments.
- o Plants growing along the edge of the landfill could be exposed through uptake by roots. Upland terrestrial wildlife could be exposed through contact with contaminated soil, seep discharges, or exposure through the terrestrial food chain.

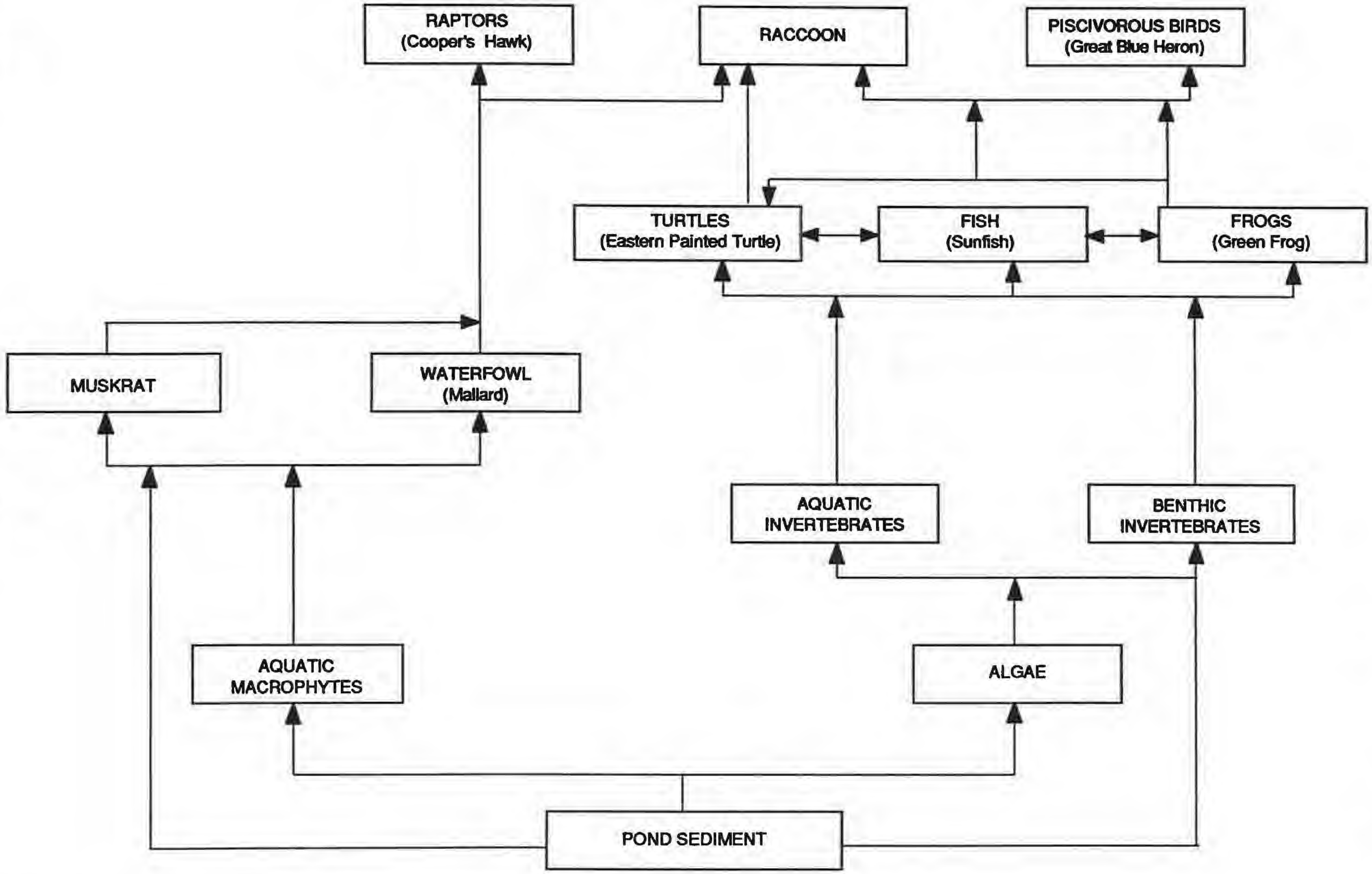
Pathways Chosen for Evaluation

Ecological receptors and potential exposure pathways were screened for inclusion in the risk assessment on the basis of the COPCs and the affected media identified in Section 9.3.1 and the characteristics of receptors found at the site as discussed in Section 9.3.2.1. The following receptors and exposure pathways were chosen for evaluation in the risk assessment.

- o Aquatic biota in Plow Shop Pond and semi-aquatic and some terrestrial wildlife species were chosen due to their potential exposure to elevated metals concentrations in sediments of Plow Shop Pond.
- o Plants growing along the edge of the landfill were chosen due to the observation of stressed vegetation in some areas.

Pathways Excluded from Evaluation

Similarly, the following receptors and exposure pathways were excluded from evaluation in the risk assessment based on the field sampling data.



SOURCE: Ecology and Environment, Inc. 1992

Figure 9-1 SIMPLIFIED HYPOTHETICAL FOOD WEB FOR TRANSPORT OF POND CONTAMINANTS IN PLOW SHOP POND AND COLD SPRING BROOK POND

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- o Aquatic biota in Nonacoicus Brook were excluded due to the low levels of contaminants found in surface water and sediments in that area.

- o Upland terrestrial wildlife were excluded due to the lack of any apparent soil or air contamination. The observation of stressed vegetation indicates the possibility that soils may be contaminated in some areas, however, and further sampling may be required in the areas of stressed vegetation to evaluate this pathway.

9.3.2.3 Assessment Endpoints

National EPA guidance describes ecological endpoints of two general types: assessment endpoints and measurement endpoints. Assessment endpoints are "formal expressions of the environmental values that are to be protected" from impacts of site contaminants; measurement endpoints are "measurable environmental characteristic(s) ... related to the valued characteristic(s) chosen as ... assessment endpoint(s) ... a quantitative expression of an observed or measured effect of the hazard" (Suter, Chapter 2 in EPA 1989b). The concept of measurement endpoints is not generally applicable to a screening-level assessment because quantitative ecological studies are usually not conducted. Hence, assessment endpoints are evaluated indirectly through the use of literature values of chronic and acute toxicity, bioaccumulation, and other effects. These may be loosely considered as measurement endpoints.

Since it is impossible to evaluate the effects of contamination on all of the potentially exposed ecological receptors occurring at the Shepley's Hill Landfill site, endpoints must be limited to a carefully selected set of potential effects on a few indicator species. Criteria for selection of assessment endpoints for site investigations include the following: social relevance; biological relevance; unambiguous definition; amenability to measurement or prediction; susceptibility to the hazard; and logical relationship to cleanup alternatives (Suter, Chapter 2 in EPA 1989b).

Potential endpoints may be evaluated at the individual, population, community, or ecosystem level. In practical terms, however, good methods and data are available only for endpoints at the individual, population, or community levels, and effects on ecosystems are not normally included as assessment endpoints.

Based on these considerations, and on the potential exposure pathways and receptors identified in the previous section, indicator species and assessment endpoints were selected. The indicator species include the following:

- o Representatives of aquatic biota expected to occur in Plow Shop Pond:

- Bluegill (Lepomis macrochirus),
- Water marigold (Megalodonta beckii),
- Dragonfly (Order: Odonata);

- o Representatives of semi-aquatic and terrestrial wildlife that are expected to occur in the area and that may depend on the pond for a fraction of their food or habitat needs:

  - Green frog (Rana clamitans melanota),
  - Painted turtle (Chrysemys picta picta),
  - Muskrat (Ondatra zibethicus),
  - Raccoon (Procyon lotor),
  - Mallard (Anas platyrhynchos),
  - Great blue heron (Ardea herodias),
  - Cooper's hawk (Accipiter cooperii);

- o A representative tree species expected to border the landfill:

  - red maple (Acer rubrum).

Assessment endpoints for the indicator species are the estimated effects of COPCs on survival, reproduction, and growth of individual organisms, or other critical effects. These potential adverse effects are primarily focused at the individual level and do not allow a quantitative evaluation to be made of effects at higher levels of biological organization, such as population or community levels. Such quantification of assessment endpoints is not necessary for the purposes of this screening-level assessment, but risks identified at the individual level could have potential adverse effects on higher levels of biological organization. Further phases of investigation and quantification of assessment endpoints might be required, however, to evaluate the ecological significance of any risks at the population, community, or ecosystem levels identified in this preliminary screening process.

Due to the numerous wildlife species (aquatic and terrestrial) found in the project area and the lack of published species-specific toxicity data/effects, it was necessary to select a few indicator species that are thought to be representative of the local wildlife populations. Selection of the indicator species involved determining the basic trophic structure of the community (as shown in Figure 9-1), and listing various species in each trophic level: primary producers (plants), primary consumers (herbivores), and secondary and tertiary consumers (omnivores and carnivores). These trophic level groups were then divided into groups of species that have similar prey and predators and a representative "indicator" species was selected. The indicator species and assessment endpoints were chosen based on their importance ecologically and their potential exposure and susceptibility to adverse effects of the COPCs. Some of these indicator species are also directly relevant to humans for consumptive (bluegill, mallard) or nonconsumptive uses (e.g., Cooper's hawk). The Cooper's hawk is a State-listed species of concern. Although its distribution is primarily upland, it was chosen as an indicator species because of possible exposure through the food chain. A brief summary of the feeding habits and ecology of the Cooper's hawk and the two other State-listed species of concern--the upland sandpiper and the grasshopper sparrow--are provided below.

Species of Concern

Based on the agency correspondence received during the preparation of the RI report, several species of concern have been identified in the general vicinity of the Shepley's Hill Landfill site. However, the majority of these are transient species that only visit the area on occasion and/or are not located within 1.5 miles of the landfill. Only three species of concern are known to occur on or around the landfill: the Cooper's hawk, the upland sandpiper, and the grasshopper sparrow. A brief description of the specific habitat and food requirements of each of these three birds, and a discussion of whether or not they are considered potential receptors of contaminants from the landfill, follows.

Cooper's Hawk (*Accipiter cooperii*)

Habitat requirements for the Cooper's hawk include a variety of different vegetative communities. This hawk prefers a mature stand of broad-leaved/deciduous trees to nest in but may occasionally use coniferous stands. Cooper's hawk nests consist of a bulky platform of crooked sticks lined with grass and feathers and are usually located in forks or side branches of large trees. The nests are located in the interior of a forest stand. The male will not hunt within 0.5 mile of the nest (Brown et al. 1989). However, Cooper's hawks will travel up to 2 miles from the nest to hunt over open fields and along woodland margins (Brown et al. 1983). In general, since the Cooper's hawk requires numerous prey items to sustain itself as well as any young, its large range will usually include a mixture of habitat types.

Food requirements for Cooper's hawks consist of a number of medium-sized vertebrates. It will prey upon chicken as well as some gamebirds (i.e., quail, grouse, and doves). Other favored prey include robins, starlings, meadowlarks, flickers, and blackbirds. The Cooper's hawk will also feed on chipmunks, squirrels, young rabbits, and bats (Audubon Society of New Hampshire undated).

The Cooper's hawk is listed as a species of concern in the Commonwealth of Massachusetts but is not identified by the USFWS as a species in need of protection. A single Cooper's hawk was observed flying over the open field at the Shepley's Hill Landfill site during the August field surveys in 1991. Since an abundance of food items and a variety of different cover types exist in the immediate vicinity of the landfill, a resident pair could be nesting in the area, although this was not confirmed during the field survey. Based on the food and habitat requirements of this hawk, there may be a potential exposure pathway for landfill contaminants found in the sediments of Plow Shop Pond to enter the food chain of the Cooper's hawk.

Upland Sandpiper (Bartramia longicauda)

Habitat requirements for the upland sandpiper include relatively level open pasture or grassy fields. As its name implies, this sandpiper is seldom found near water, but rather prefers upland grasslands (Andrle et al. 1988). Considered a ground gleaner (i.e., feeding from the ground surface), the upland sandpiper feeds in short grasses and weeds, which provide an excellent supply of food items. The upland sandpiper is omnivorous, feeding on insects such as grasshoppers, crickets, weevils, flies, and ticks, but it also utilizes the seeds of various grasses and weeds (Nature Conservancy 1989). In addition to the areas of short grass required for feeding, the upland sandpiper requires tall grass areas for nesting.

The upland sandpiper is listed by the Commonwealth of Massachusetts as an endangered species, but it is not federally listed. An upland sandpiper has been seen feeding on the maintained grass area of the Shepley's Hill Landfill, but no evidence exists of any nesting pairs in the area. Since this bird is considered an upland species with little or no food chain connections to the sediments and surface waters of Plow Shop Pond, it is considered unlikely that this species is exposed to landfill contaminants.

Grasshopper Sparrow (Ammodramus savannarum)

Habitat requirements for the grasshopper sparrow include weedy fallow fields with some scattered shrubs for display and singing. Upland areas with various densities of tall herbaceous cover and some conspicuous perches are highly favored by this bird (Andrle et al. 1988). Although the grasshopper sparrow is a ground gleaner, it will perch on tall grasses or shrubs for singing. As its name indicates, the major food item of this bird is grasshoppers, although other food items include caterpillars, ants, spiders, and other terrestrial invertebrates as well as some plant seeds (Martin et al. 1961).

The grasshopper sparrow is listed as an endangered species by the Commonwealth of Massachusetts but is not considered a species of concern by the USFWS. Grasshopper sparrows were observed on the Shepley's Hill Landfill site during the field surveys conducted in August of 1991. Based on the presence of these individual birds and the availability of suitable habitat, it is very likely that grasshopper sparrows are nesting in the immediate area of the landfill. However, based on the food and habitat requirements of this particular species, it is considered unlikely that the grasshopper sparrow is exposed to landfill contaminants.

9.3.3 <u>Exposure Assessment</u>

This section evaluates the exposure of ecological receptors to contaminants of concern at Shepley's Hill Landfill. The exposure assessment is restricted to the four metals identified as COPCs in Plow Shop Pond sediments: arsenic, barium, cadmium, and manganese; and to metals in groundwater identified as "indicator" COPCs for soils. The release, migration, and fate of these metals in sediments is discussed in Section 9.3.3.1, and exposure point concentrations (EPCs) for metals in sediments and soil are estimated in Section 9.3.3.2. EPCs are estimated for both the average and maximum exposure cases for each metal. In Section 9.3.3.3, exposure scenarios and pathways are developed for the indicator species, and quantitative estimates of exposure are derived for average and maximum exposure cases.

9.3.3.1 Contaminant Release, Migration, and Fate

This section summarizes the fate of contaminants of concern in the sediment and sediment-water interface, as affected by a variety of chemical, physical, and biological processes. The factors affecting bioavailability of COPCs are also discussed.

Cadmium

In aquatic systems, cadmium is relatively mobile as compared to other heavy metals and may exist as a hydroxyion; as a metal-inorganic complex with carbonate, chlorine, or sulfate ions; or as a metal-organic complex with humic acids. Cadmium is always found in the +2 valence state, which is a readily bioavailable form in solution. The pH has a marked effect on cadmium speciation. For example, cadmium bioavailability increases dramatically in acid lakes. However, the redox potential of the system has little direct effect on the speciation of cadmium.

Cadmium forms moderately stable complexes with a variety of organic compounds. It interacts strongly with organic matter and humic substances. Sorption processes significantly affect the mobility of cadmium in the sediment-water interface. In polluted or organic-rich waters, the sorption of cadmium by humic substances will be the controlling factor in determining release, migration, and fate (Bodek et al. 1988; Fu et al. 1992). In Plow Shop Pond sediments, organic carbon levels were relatively high (mean Total Organic Carbon = 12.9 percent). Given the tendency of cadmium to form complexes with organic matter, the mobility and bioavailability of cadmium in Plow Shop Pond is probably limited.

Recent studies have indicated that acid volatile sulfide (AVS) is a major pool for cadmium and other toxic metals in sediments (Di Toro et al. 1990). AVS normalization of contaminant concentrations was mentioned by agency representatives during project scoping as a likely approach for subsequent investigations, but was not considered necessary for this screening-level study.

In addition, cadmium concentrations in surface water were low, and the pH of surface water was neutral (mean pH = 7.2). Together, the high organic carbon content in sediments, neutral pH, and low cadmium concentrations in surface water suggest that cadmium in Plow Shop Pond sediments is relatively unavailable for uptake by aquatic biota.

Arsenic

In sediments and natural waters, arsenic is subject to a variety of chemically and/or microbiologically mediated oxidation-reduction reactions; ligand exchange; and biotransformation, precipitation, and sorption processes.

The chemical speciation of arsenic is particularly important in the sediment-water interface. In this interface, arsenic can exist in (+5), (+3), (0), and (-3) oxidation states (Masscheleyn et al. 1991; USEPA 1979). The metal arsenic (0) is extremely rare, whereas arsenic (-3) is found only at extremely low redox potentials (i.e., in highly reducing environments). The arsenate (+5) species predominates at high Eh values encountered in aerobic conditions; the arsenites (+3) are the predominant species in slightly reduced conditions; and the methylated arsenicals predominate in very reduced conditions (e.g., swamps and bogs).

The cycling of arsenic in the aquatic environment is dominated by sorption onto sediments. Sorption onto clays, iron oxides, manganese compounds, and organic matter are important fate mechanisms in surface water, with sediment serving as a reservoir for most arsenic entering surface water. Under most conditions, coprecipitation or sorption of arsenic with hydrous oxides of iron is probably the prevalent process in the removal of dissolved arsenic. In addition, arsenic has been shown to undergo a number of biologically mediated transformations in aquatic environments, most of which involve methylation to derivatives of arsenic (National Academy of Sciences 1977).

In the sediments of Plow Shop Pond, iron concentrations were elevated in the areas with the highest arsenic contamination. The spatial correlation of the highest iron levels with the highest arsenic levels suggests that the mobility and bioavailability of arsenic may be limited due to the high iron content of the sediment. Manganese levels were also high in such parts of the pond. In addition, arsenic concentrations in surface water were relatively low. Together, the high iron and manganese concentrations in sediments and the low arsenic concentrations in surface water suggest that arsenic is relatively unavailable for uptake by aquatic biota in Plow Shop Pond sediments.

Manganese

Manganese is a multivalent element; it can exist in the +2, +3, +4, +6, and +7 oxidation states. Manganous ion (Mn^{+2}) is the most thermodynamically stable aqueous oxidation state (Bodek et al. 1988).

In aquatic systems, the fate of manganese is influenced by chemical and microbiological reactions and is predominantly sorbed to sediments and suspended particulates in the form of MnO_2 and/or Mn_3O_4. Although manganese may undergo chemical speciation due to chemical and microbiological reactions, the residence time of aquatic manganese may be a few hundred years (USEPA 1984).

Manganese speciation may occur through chemical and microbiological interactions. The pH of the system and redox potential will influence speciation and solubility (USEPA 1982). Acidic lakes sometimes show high levels of manganese, for example.

Sorption of manganese is complicated by redox reactions that produce aqueous compounds of different oxidation states. Specific adsorption, ion exchange, and organic complexation all affect the retention of manganese by sediments and soils, but it is not clear which of these processes is most important (Bodek et al. 1988).

Given the neutral pH and rich nutrient and organic content of Plow Shop Pond, manganese in the sediments is not expected to be present in a readily bioavailable form.

Barium

In aquatic systems, barium is not very mobile because it forms water-insoluble salts and does not form soluble complexes with humic and fulvic materials (USEPA 1985a). Under acid conditions, however, some of the water-insoluble barium compounds may become more soluble, and partitioning to the water phase may occur.

Both specific and nonspecific sorption of barium onto oxides, soils, and sediments has been observed. Specific sorption occurs onto metal oxides and hydroxides. Adsorption onto metal oxides probably controls the concentration of barium in natural waters (Bodek et al. 1988). Given the neutral pH and rich nutrient and organic content of Plow Shop Pond, barium in the sediments is not expected to occur in a readily bioavailable form.

9.3.3.2 Exposure Point Concentrations

Sediments

A number of environmental factors affect the bioavailability of metals in sediments, as discussed in the previous section. However, for the purposes of this screening-level risk assessment, the bulk metal concentrations measured in pond sediment samples will serve as simple, first-order estimates of exposure concentrations.

As in the human health risk assessment, two cases of exposure are considered: the average exposure case and the reasonable maximum exposure (RME) case. EPCs used for the average exposure case are the average sediment concentrations of metals in Plow Shop Pond. For the RME case, the maximum sediment concentrations of metals in Plow Shop Pond were used. These values are provided in Table 9-6. In addition, average and maximum levels of other parameters detected in sediments are provided.

The pond ecosystem as a whole was considered the affected environment for the risk assessment. Therefore, all of the sediment samples taken from locations throughout Plow Shop Pond were used to calculate EPCs. The EPCs calculated in this way would apply to exposures for any ecological receptor located anywhere in the pond. The average case would apply to those receptors ranging throughout the pond or randomly placed within the pond. The RME case would apply to organisms ranging within the most highly contaminated part of the pond.

Soils

As for metals in the root-zone of plants, soil data were not available, therefore groundwater concentrations were used as estimates of exposure concentrations. EPCs used for the average exposure case are the average groundwater concentrations of metals in the Shepley's Hill Landfill zone of influence (see Section 8). For the RME case, the maximum concentrations of metals in groundwater were used. These values are provided in Table 9-6.

The Shepley's Hill Landfill zone of influence was considered the affected environment for the risk assessment. Therefore, all of the groundwater monitoring well data used to calculate human exposures were used to calculate ecological EPCs. The "unadjusted" values for metals estimated in the human health risk assessment (i.e., total metal concentrations unadjusted for suspended sediment) are the values summarized in Table 9-6. The approach of using total metal concentrations is likely to overestimate exposure. The EPCs calculated in this way would apply to any plant growing anywhere on the landfill's edge. The average case would apply to plants placed randomly on the landfill's edge. The RME case would apply to plants growing in the areas of highest groundwater contamination.

9.3.3.3 Exposure Scenarios and Pathways

For aquatic biota, the principal route of uptake for arsenic and cadmium is from water and sediment, although bioaccumulation through the food chain may also occur. Relatively little is known about the uptake of barium and manganese from water and sediments.

Since the levels of surface water metals were low in comparison to the levels in sediments, the transfer of COPCs from sediments to benthic animals and rooted aquatic macrophytes were considered to be the primary pathways for COPCs to enter the food chain.

Exposure of benthic invertebrates and macrophytes to sediment-bound metals occurs mainly through partitioning of metals between particulate

Table 9-6

EXPOSURE POINT CONCENTRATIONS

PLOW SHOP POND SEDIMENTS

Parameter	Average Sediment Concentration (mg/kg)	Maximum Sediment Concentration (mg/kg)
Landfill Contaminants		
Metals		
Arsenic	1,000	3,200
Cadmium	28.8	60.2
Barium	175	310
Manganese	1,950	8,800
Other Parameters		
Metals		
Chromium	3,248.4	10,000
Copper	62.7	132
Lead	241.4	632
Mercury	30.8	130
Nickel	38	79.3
Zinc	40.2	42.8
Pesticides		
DDE	0.032	0.172
PAHs		
Benzo(a)anthracene	0.222	1.09
Fluoranthene	0.502	3.41
Phenanthrene	0.382	2.51
Pyrene	0.969	4.35
Chrysene	0.326	1.54
Naphthalene	0.317	1.60

RC424

Table 9-6 (Cont.)

SHEPLEY'S HILL LANDFILL GROUNDWATER (SOILS)

Metal	Average Groundwater Concentration ($\mu g/L$)	Maximum Groundwater Concentration ($\mu g/L$)
Arsenic	130	710
Barium	102	710
Beryllium	<1	4
Cadmium	8	150
Chromium (VI)	28	240
Copper	36	250
Manganese	2,320	7,600
Nickel (soluble salts)	26	290
Vanadium	15	160
Zinc	105	570

RC424

Source: Ecology and Environment, Inc. 1992.

sediment and dissolved (interstitial water) phases and subsequent uptake of bioavailable forms of metal from the dissolved phase. Therefore, the development of quantitative estimates of exposure to COPCs for ecological receptors in Plow Shop Pond was based on the application of a simple partitioning model. This model provides a predictive method for evaluating bioaccumulation of contaminants at the site. The model involves the derivation of a bioaccumulation factor (BAF) from published values of metals concentrations in aquatic plants, invertebrates, fish, and sediments (Lee 1992):

BAF = metal (tissue)/metal (sediment)

Published BAF values for most metals are highly variable. Thus, an average or median BAF was computed for each metal from the available published studies. Extremely high or extremely low values were not used. For example, the data for cadmium in plants from Miller et al. (1983) were excluded because these BAFs are thought to be unrepresentative of Plow Shop Pond.

The data used to derive the plant and invertebrate BAFs for cadmium, arsenic, and manganese are provided in Table 9-7. No data were available for the calculation of BAFs for barium.

Few data are available for calculating site-specific BAFs for fish, and BAFs from different sites are highly variable. For this reason, to calculate BAFs for fish, data was combined from two separate nationwide monitoring programs. Mean levels of trace metals in fish were taken from Lowe et al. (1985) and median levels of contaminants in sediments were taken from Bolton et al. (1985; in Lyman et al. 1987). Although these studies were done separately at different locations around the United States, the levels reported in both studies were based on a large number of samples and are considered likely to be representative of background conditions. The mean levels in fish (whole body, fresh weight) reported in Lowe et al. (1985) for arsenic are 0.15 mg/kg, and the mean levels for cadmium are 0.035 mg/kg. Barium and manganese levels were not measured or reported by Lowe et al. (1985). In sediment, Bolton et al. report median arsenic of 4.0 mg/kg and median cadmium of 1.0 mg/kg. Based on these values, the arsenic fish BAF is 0.038, and the cadmium fish BAF is 0.035.

In addition to the food chain pathway, direct ingestion and dermal contact with sediment are potential pathways for exposure to COPCs in Plow Shop Pond. It was not considered necessary to evaluate this pathway separately for fish and benthic invertebrates because ingestion and contact with sediment by benthic invertebrates and fish are incorporated into the BAFs for those receptors.

The direct ingestion and dermal contact pathways were not quantitatively evaluated for mammals and birds because the majority of the risks for these receptors are presumed to be accounted for through the food chain pathway, and data are not readily available for calculating exposures for wildlife through sediment ingestion and dermal

Table 9-7

SEDIMENT BIOACCUMULATION FACTORS FOR METALS IN AQUATIC PLANTS, INVERTEBRATES, AND FISH

Species Name	Common Name	Organism Metal Concentration (mg/kg)	Tissue	Sediment Metal Concentration (mg/kg)	Bioaccumulation Factor (BAF)	Reference
CADMIUM						
Plants						
Ceratophyllum demersum	Coontail	0.164	Stems and roots	1.85	0.089	Mathis and Kevern 1975
Nuphar sp.	Pond-lily	0.072	Stems and roots	1.85	0.039	Mathis and Kevern 1975
Eriocaulon septangulare	Pipewort	2.7	Roots	0.4	6.75	Miller et al. 1983[b]
Septangulare	Pipewort	8.2	Roots	0.4	20.5	Miller et al. 1983[b]
Selected median value (data from Miller et al. 1983 excluded)					0.064	
Invertebrates						
NA	Zooplankton	0.397	Whole body	1.85	0.215	Mathis and Kevern 1975
Chaoborus sp.	Phantom midge	0.06	Larvae	1.75	0.034	Andersson and Borg 1988
Chironomus sp.	Midge	0.20	Larvae	1.75	0.114	Andersson and Borg 1988
Selected median value					0.114	

Key at end of table.

Table 9-7 (Cont.)

Species Name	Common Name	Organism Metal Concentration (mg/kg)	Tissue	Sediment Metal Concentration (mg/kg)	Bioaccumulation Factor (BAF)	Reference
ARSENIC						
Plants						
NA	NA	4.2	NA	20	0.210	Cherry and Guthrie 1977[a]
Selected median value					0.210	
Invertebrates						
NA	NA	2.1	NA	20	0.105	Cherry and Guthrie 1977[a]
Selected median value					0.105	
MANGANESE						
Invertebrates						
Physa sp.	Snail	132	NA	302	0.437	Mathis et al. 1979
Fish						
Lepomis cyanellus	Green sunfish	0.64	Muscle	302	0.002	Mathis et al. 1979
Ictalurus punctatus	Channel catfish	0.63	Muscle	302	0.002	Mathis et al. 1979

RC424

Key:

NA = Not available.

Sources:

[a]Reported in Kay 1984.
[b]Reported in McCracken 1987.
[c]Reported in Eisler 1988.

contact pathways. However, direct ingestion and dermal contact were evaluated for the human health risk assessment, and those results were used to qualitatively evaluate potential risks to wildlife.

Quantitative food chain exposure scenarios were developed for the seven semi-aquatic and terrestrial animal indicator species: green frog, painted turtle, muskrat, raccoon, great blue heron, mallard, and Cooper's hawk.

Based on the habitat and food requirements of the seven semi-aquatic and terrestrial indicator species that have been selected, each species will exhibit a different exposure scenario. The semi-aquatic muskrat requires a wetland ecosystem with a permanent supply of water and aquatic vegetation. Since Plow Shop Pond provides both these habitat requirements, a resident muskrat's exposure to contaminants from the landfill may be considerable. Similarly, the green frog, painted turtle, and mallard duck will use the pond and surrounding vegetation for all their food and habitat requirements. Because the raccoon has a large range that includes a variety of habitats and food items that are not limited to Plow Shop Pond, its exposure to the contaminants associated with Shepley's Hill Landfill will be comparatively less. The Cooper's hawk, which is discussed in more detail in Section 9.3.2.3, is considered primarily an upland species. However, like the raccoon, the Cooper's hawk does have some direct connections to Plow Shop Pond through its food chain (i.e., it might consume mallard ducklings, fish, and some reptiles and amphibians), and therefore it may be exposed to the contaminants from the landfill. The great blue heron is a mobile species that feeds around pond shorelines. Since a number of ponds exist in the general vicinity of the landfill and only Plow Shop Pond is directly impacted by the landfill, the herons' exposure to the contaminants will be related to the amount of time spent foraging at Plow Shop Pond.

To calculate chemical intake rates through the food chain pathway for each of the indicator species, E & E developed simple exposure scenarios based on the food consumption habits of each species and other information. The exposure scenarios are provided in Table 9-8, including the values used as input for each variable.

Values for input variables were derived as follows. Food consumption profiles for each of the indicator species were developed based on available natural history information. The food consumption habits are summarized in Table 9-9, and this information was used to derive the percentage of food items making up each species' diet as listed in Table 9-8. If a food item was indicated as "present" in the diet of a given indicator species, a percentage of that food item in the diet was estimated based on best professional judgement. Body weights used in the exposure scenarios were obtained from published sources, as listed in Table 9-10. The daily food consumption rates used were based on the allometric relationships between body weight and food intake provided in USEPA (1988g) and listed in Table 9-10. The percentage use of the site by each species, termed the site use factor, was derived

Table 9-8

EXPOSURE SCENARIOS FOR INDICATOR SPECIES, FOOD CHAIN PATHWAY

MALLARD

Equation:

$$\text{Intake (mg/kg - day)} = \frac{\sum_{i=1}^{n} (C \times IR \times DC_i \times SF \times BAF_i)}{BW}$$

where:

C = Contaminant concentration in sediment (mg/kg)
IR = Total daily food consumption for indicator species (g/day)
DC_i = Diet component i, where i =

(1) Plants
(2) Fish
(3) Invertebrates
(4) Reptiles and amphibians
(5) Mammals
(6) Birds

SF = Site use factor for species diet
BAF_i = Bioaccumulation factor for each diet component
BW = Body weight of indicator species

Variable	Receptor	Case	Value (Rationale/Source)
C	Adult	Average	See Table 9-6
		RME	See Table 9-6
IR	Adult	Average/RME	86 grams (Table 9-10)
DC1	Adult	Average/RME	89% (Table 9-9)
2	Adult	Average/RME	--
3	Adult	Average/RME	11% (Table 9-9)
4	Adult	Average/RME	--
5	Adult	Average/RME	--
6	Adult	Average/RME	--
SF	Adult	Average/RME	Assume 75% (seasonal use)
BAF1	Adult	Average/RME	See Table 9-7 (median value)
2	Adult	Average/RME	--
3	Adult	Average/RME	See Table 9-7 (median value)
4	Adult	Average/RME	--
5	Adult	Average/RME	--
6	Adult	Average/RME	--
BW	Adult	Average/RME	1,177 grams (Bellrose 1978)

RC424

RME = Reasonable Maximum Exposure.

Source: Compiled by Ecology and Environment, Inc. 1992.

from published sources or professional judgment concerning the home range and seasonal usage of each indicator species relative to the size of the site (130 acres). The median BAFs calculated from the values provided in Table 9-7 and in the text were used to calculate the expected concentration of COPCs in the diet components of each species. For reptiles, birds, and mammals, fish values were used as the arsenic and cadmium BAFs to estimate dietary exposure for higher trophic level consumers. This approach is conservative, since arsenic and cadmium do not biomagnify significantly and therefore concentrations in reptiles, birds, and mammals are not expected to be higher than concentrations in fish.

The estimated average and maximum exposures based on these scenarios are provided in Table 9-11 for arsenic and Table 9-12 for cadmium. Insufficient data were available to calculate reliable values for manganese, and no data were available for barium. The tissue residue values for the bluegill and water marigold in Tables 9-11 and 9-12 were calculated using the BAFs provided in Table 9-7 or in the text. Sediment exposure values provided for the water marigold and dragonfly were based on the average and maximum contaminant concentrations.

The average and maximum groundwater concentrations of metals provided in Table 9-6 were taken as estimated exposure values for red maple trees growing on the edge of the landfill. These groundwater concentrations should provide a worst-case estimate of the soil concentrations of metals available for uptake by plants.

9.3.4 Ecological Effects Assessment

In this section, the potential adverse effects of the COPCs at the Shepley's Hill Landfill site are identified and endpoint concentrations for indicator species are tabulated. The known effects of COPCs are generally described in Section 9.3.4.1. Toxicity values for critical effects of COPCs on indicator species are then identified from published sources and tabulated in Section 9.3.4.2. Observations of stressed vegetation made in the ecological field survey are discussed with regard to their possible relationship to COPCs in Section 9.3.4.3.

9.3.4.1 Ecological Effects Summaries

This section discusses the acute and chronic toxicity of contaminants of concern in the sediment to freshwater invertebrates, fish, and plants. The tendency of COPCs to bioconcentrate or bioaccumulate and their effect on higher trophic levels are also discussed.

For the purpose of this report, salient toxicity information for each of the contaminants of concern is summarized below.

Table 9-11

**ESTIMATED EXPOSURES TO ARSENIC FOR SELECTED INDICATOR SPECIES
PLOW SHOP POND**

Indicator Species	Receptor	Case	Diet (mg/kg Diet/day)	Body Weight (mg/kg BW/day)	Tissue Residue (mg/kg BW)	Sediment (mg/kg)
Bluegill	Adult/Juvenile	RME	--	--	64.0	--
		Average	--	--	20.0	--
Water marigold	--	RME	--	--	672	3,200
		Average	--	--	210	1,000
Dragonfly	Larval	RME	--	--	--	3,200
		Average	--	--	--	1,000
Green frog	Adult	RME	327	44.2	--	--
		Average	102	13.8	--	--
Painted turtle	Adult	RME	438	29.4	--	--
		Average	137	9.2	--	--
Muskrat	Adult	RME	625	32.5	--	--
		Average	196	10.2	--	--
Raccoon	Adult	RME	69.1	1.92	--	--
		Average	21.6	0.60	--	--
Mallard	Adult	RME	355.7	36.0	--	--
		Average	107.7	10.9	--	--
Great blue heron	Adult	RME	77.3	4.3	--	--
		Average	23.7	1.5	--	--
Cooper's hawk	Adult	RME	12.2	1.03	--	--
		Average	3.8	0.32	--	--

RC424

Source: Ecology and Environment, Inc. 1992.

Table 9-12

ESTIMATED EXPOSURES TO CADMIUM FOR SELECTED INDICATOR SPECIES PLOW SHOP POND

Indicator Species	Receptor	Case	Diet (mg/kg Diet/day)	Body Weight (mg/kg BW/day)	Tissue Residue (mg/kg BW)	Sediment (mg/kg)
Bluegill	Adult/Juvenile	RME	--	--	1.3	--
		Average	--	--	0.6	--
Water marigold	--	RME	--	--	3.9	60.2
		Average	--	--	1.8	28.8
Dragonfly	Larval	RME	--	--	--	60.2
		Average	--	--	--	28.8
Green frog	Adult	RME	5.6	0.76	--	--
		Average	2.6	0.36	--	--
Painted turtle	Adult	RME	5.0	0.33	--	--
		Average	2.4	0.16	--	--
Muskrat	Adult	RME	4.04	0.21	--	--
		Average	1.92	0.10	--	--
Raccoon	Adult	RME	0.72	0.02	--	--
		Average	0.36	0.01	--	--
Mallard	Adult	RME	3.15	0.23	--	--
		Average	1.51	0.11	--	--
Great blue heron	Adult	RME	1.4	0.09	--	--
		Average	0.68	0.04	--	--
Cooper's hawk	Adult	RME	0.11	0.009	--	--
		Average	0.21	0.018	--	--

RC424

Source: Ecology and Environment, Inc. 1992.

Cadmium

Cadmium, a relatively rare heavy metal, is not biologically essential or beneficial; on the contrary, as reported by Eisler (1985), cadmium is a known teratogen and carcinogen for fish and wildlife. The freshwater biota is especially sensitive to elevated cadmium concentrations. Cadmium concentrations of 0.8 to 9.9 µg/l in water were reported to be lethal to several species of aquatic insects, crustaceans, and fish, and concentrations of 0.7 to 5.0 µg/l were associated with sublethal effects.

Mammals and birds are comparatively resistant to the toxic properties of cadmium. Sublethal effects of cadmium in birds, which are similar to those in other animals, include growth retardation, anemia, and testicular damage; however, these effects occur at higher concentrations than in similarly affected aquatic biota.

It is conservatively estimated that adverse effects on fish or wildlife are either pronounced or probable when cadmium concentrations exceed 3 µg/l in freshwater.

Growth of freshwater aquatic plants is reduced by cadmium at concentrations ranging from 2 to 7,400 µg/l. These values are in the same range as the acute toxicity values for fish and invertebrate species and are considerably above the chronic values. Bioconcentration factors (BCFs) for cadmium in freshwater range from 164 to 4,190 for invertebrates and from 3 to 2,213 for fishes (USEPA 1985).

Cadmium may bioaccumulate through food or media, but it does not significantly biomagnify in food chains. For example, in a review of field and experimental studies of food chain transfer of metals from sediments, cadmium concentrations generally decreased in higher trophic levels or showed no consistent pattern (Campbell et al. 1988).

Arsenic

As summarized by Eisler (1987), arsenic is a teratogen and carcinogen to fish and wildlife and can traverse placental barriers and produce fetal death and malformations in many species of mammals. Adverse effects of arsenic on aquatic organisms have been reported at concentrations above 19 µg/l in water. Acute tests showed effects in developing embryos of toads and the reduction in growth of freshwater algae. Chronic studies with mass cultures of phytoplankton communities exposed to low levels of arsenate (1.0 to 15.2 µg/l) showed that arsenate differentially inhibits certain plants, causing a marked change in species composition and succession.

The lethal effects of acute toxicity of inorganic arsenic to birds are related to the destruction of blood vessels lining the gut and subsequent shock. These effects were attributed to osmotic imbalance.

According to freshwater residue data, arsenic does not bioconcentrate to a high degree, but lower forms of aquatic life may accumulate higher arsenic residues than fish. The low bioconcentration factor and short half-life of arsenic in fish tissue suggest that residues should not normally be a problem to predators of aquatic life.

Manganese

Manganese is an essential element and a cofactor for a number of enzymatic reactions. It is not highly toxic to aquatic organisms. Tolerance concentrations reported for manganese range from 1.5 mg/l to over 1,000 mg/l, and it is not considered to be a problem in the freshwater environment.

A few reports are available on the relationship between manganese and environmental media and manganese levels in tissues of aquatic organisms. Mathis (1979) has reported that the manganese content of several species of rooted aquatic plants was proportional to the dissolved manganese concentrations in water, while several species of fishes maintained relatively constant manganese levels regardless of concentrations in water. Laboratory exposure of water weeds to manganese at elevated levels indicates that photosynthesis can be inhibited.

In mammals, very large doses of ingested manganese can cause liver, lung, and central nervous system damage.

Although studies have shown that manganese can bioconcentrate in plants and animals, no bioconcentration factors have been reported.

Barium

Acute overexposure of animals to barium results in a variety of cardiac, gastrointestinal, and neuromuscular effects. However, experimental data indicate that the soluble barium concentration in fresh water generally would have to exceed 50 mg/l before toxicity to aquatic life would be expected (USEPA 1986b). In most natural waters, sufficient sulfate or carbonate exists to precipitate the barium present in the water as a virtually insoluble, nontoxic compound.

9.3.4.2 Toxicity Benchmark Values

Toxicity benchmark values for the indicator species at the Shepley's Hill Landfill site are of four general types:

- o Diet residue values for COPC concentrations in food items causing adverse chronic effects, expressed in units of mg chemical/kg diet/day;
- o Dose levels in food causing adverse chronic effects, expressed in units of mg chemical/kg body weight/day;

- o Tissue residues associated with adverse chronic effects, expressed in units of mg chemical/kg tissue; and

- o Sediment values associated with adverse chronic effects, expressed in units of mg chemical/kg sediment.

The toxicity values for each indicator species are provided for arsenic in Table 9-13 and for cadmium in Table 9-14. Reliable wildlife toxicity values for barium and manganese in food and tissues were not available, but sediment toxicity was considered for these COPCs by reference to the ecological criteria provided in Table 9-4.

Toxicity values were generally derived in a conservative fashion by considering less than the lowest observed effect levels (LOELs) for effects of chronic exposure on species of concern. Values for the most sensitive surrogate species were used if values were unavailable for the indicator species. The selection process for these surrogate species examined the taxonomic group (i.e., class, order, family, and genus); feeding niche (i.e., food items); physical characteristics (i.e., size, sex); life stage (i.e., larval, juvenile, adult); and habitat requirements (i.e., aquatic, terrestrial) of the indicator species, and matched them with the most similar species for which toxicity values were available. The fact that effects data are rarely specific to the indicator species is a limitation of the available literature. In some cases, safety factors were used as indicated in Tables 9-13 and 9-14. The use of these factors and their numerical values were based on best professional judgment and the general guidelines provided by the USEPA (1986f). For example, since the Cooper's hawk is a State-listed species, the toxicity values for the effects of arsenic and cadmium on mallards and other birds were multiplied by a safety factor of 0.1 to derive values for the Cooper's hawk (USEPA 1986f).

Despite a thorough literature review, few reliable values for arsenic and cadmium were found. Nevertheless, the values given in Tables 9-13 and 9-14 are considered sufficiently authoritative for use in this screening-level risk assessment.

For completeness, additional toxicity benchmark values for sediments are provided in Table 9-15 (Long and Morgan 1990). These values are derived from a database of contaminant effects on benthic invertebrates in both freshwater and marine sediments and may not be indicative of effects of contaminants in Plow Shop Pond. The benchmark values are provided for COPCs as well as for additional parameters detected in the sediments, but not selected as COPCs.

Toxicity benchmark values for soil COPCs are discussed in the next section.

9.3.4.3 Field Observations of Stress

Evidence of physically stressed vegetation in the form of dead or dying trees was observed during the field survey conducted in August of

Table 9-13

TOXICITY BENCHMARK VALUES FOR SELECTED INDICATOR SPECIES - ARSENIC

Indicator Species	Receptor	Diet Residue (mg/kg Diet)	Dose (mg/kg BW)	Tissue Residue (mg/kg BW)	Sediment (mg/kg)	Critical Effects	Reference
Bluegill	Adult	—	—	5.0	—	Diminished growth and survival	NRCC 1978[a]
	Juvenile	—	—	1.3	—	Diminished growth and survival	NRCC 1978[a]
Water marigold	—	—	—	20	—	Critical level in tops of rice	Chino 1981[b]
Dragonfly	Larval	—	—	—	33	Limit of tolerance	See Table 9-4
Green frog/ Painted turtle	Adult	60	—	—	—	Growth depression, impaired feeding in rainbow trout, multiplied by Safety Factor = 0.5	Cockell and Hilton 1985[a]
Muskrat/Raccoon	Adult	5	1	—	—	Death or malformations in mammals, various species, chronic exposure	Eisler 1988
Mallard/Great blue heron	Adult	180	—	—	—	Maximum safe level in diets, domestic poultry, arsenic feed additives	NAS 1977[a]
		—	64.6	—	—	Mallard LD-50, multiplied by Safety Factor = 0.2	Eisler 1988
		—	—	10	—	Resides in liver or kidney; considered indicative of poisoning	Goede 1985[a]
Cooper's hawk	Adult	18	32.3	1.0	—	Values for mallard, multiplied by Safety Factor = 0.1	

Key:

[a]Eisler 1988.
[b]Adriano 1986.

Table 9-14

TOXICITY BENCHMARK VALUES FOR SELECTED INDICATOR SPECIES - CADMIUM

Indicator Species	Receptor	Diet Residue (mg/kg Diet)	Dose (mg/kg BW)	Tissue Residue (mg/kg BW)	Sediment (mg/kg)	Critical Effects	Reference
Bluegill	—	—	—	32.5	—	Liver concentration associated with sublethal effects; divided by 10 (estimated liver to whole body ratio)	Eaton 1974[a]
Water marigold	—	—	—	5	—	Critical level in tops of rice	Chino 1981[b]
Dragonfly	Larval	—	—	—	10	Limit of tolerance	See Table 9-4
Green frog/ Painted turtle/ Muskrat/Raccoon/ Mallard/Great blue heron/	Adult	100	—	—	—	Wildlife dietary levels exceeding 100 mg/kg, should be "viewed with caution."	Eisler 1985
Cooper's hawk	Adult	10.0	—	—	—	Values for wildlife, multiplied by 0.1	

RC424

Key:

[a]Sprague 1987.
[b]Adriano 1986.

Table 9-15

TOXICITY BENCHMARK VALUES FOR BENTHIC INVERTEBRATES PLOW SHOP SEDIMENTS

Parameter	Sediment ER-L[a] (mg/kg)	Sediment ER-M[b] (mg/kg)
Landfill Contaminants		
Metals		
Arsenic	33	35
Barium	NA	NA
Cadmium	5	9
Manganese	NA	NA
Other Parameters		
Metals		
Chromium	80	145
Copper	70	390
Lead	35	110
Mercury	0.15	1.3
Nickel	30	50
Zinc	120	270
Pesticides		
DDE	0.002	0.015
PAHs		
Benzo(a)anthracene	0.23	1.6
Chrysene	0.4	2.8
Fluoranthene	0.6	3.6
Naphthalene	0.34	2.1
Phenanthrene	0.225	1.38
Pyrene	0.35	2.2

RC424

[a]ER-L is the Effects Range-Low, a concentration at the low end of the range where effects are observed.

[b]ER-M is the Effects Range-Median, a concentration approximately midway in the range of reported values associated with biological effects.

Key:

NA = Not available.

Source: Long and Morgan 1990.

1991. This stressed vegetation occurs in two separate areas located in the deciduous forest cover type (areas 13 and 17). One of these areas is located on the eastern edge of the landfill near Plow Shop Pond, while the other area is located north of the landfill toward Nonacoicus Brook. In the area located to the east of the landfill, field observations identified several mature trees devoid of leaves and with only small patches of bark remaining. The area located near Nonacoicus Brook had a few mature trees that showed signs of stress (i.e., brown wilted leaves, some bark loss, and lack of buds on some branches). Shrubs and herbs in both of these areas appeared relatively healthy at the time of the survey, possibly due to the shallow roots of these plants.

The observation of dead trees in a confined area indicates that exposure is limited to areas where roots may penetrate a groundwater plume. According to the groundwater contours and the sampling of contaminants during the RI, there is evidence that a groundwater plume of arsenic and other metals occurs in the area of stressed vegetation located on the eastern edge of the landfill. Although the concentrations of metals in the soil are not available for this area, studies indicate that some metals are phytotoxic. For example, depending on the soil texture and the plants' sensitivity, arsenic concentrations in the soil will have variable adverse effects on plant growth. Woolson (1973) indicated that no plants grew when the total arsenic concentration was 500 mg/kg, but that at 10, 50, and 100 mg/kg the plants survived and their growth was proportional to the arsenic concentration of the soil.

To allow a comparison to be made between groundwater concentrations of metals and levels in the soil likely to be phytotoxic, toxicity values for metals were selected based on published criteria for irrigation water. These values are provided in Table 9-16. The most conservative values were chosen from among the available irrigation water criteria.

At present, it is uncertain whether the stressed vegetation located near Nonacoicus Brook is affected by groundwater or surface water flow from the landfill. This area of stress is not as severe as the other area, and it may be due to root damage caused during groundwater well installation. Additional information is required before the cause of the stress can be determined.

9.3.5 Risk Characterization

In this section, the ecological risks posed by COPCs at the Shepley's Hill Landfill site are identified and summarized. In Section 9.3.5.1, risks are quantified using hazard index (HI) ratios calculated from estimated exposure and toxicity benchmark values for each receptor. The risks are then summarized and the principal uncertainties of the risk assessment are discussed in Section 9.3.5.2. The ecological significance of the findings is discussed in Section 9.3.5.3.

Table 9-16

TOXICITY BENCHMARK VALUES FOR RED MAPLE - METALS

Metal	Groundwater ($\mu g/L$)	Critical Effects[a]
Arsenic	100	Recommended maximum continuous use concentrations of trace elements in irrigation waters used for sensitive crops on soils with low capacities to retain these elements in unavailable forms.
Barium	--	See Arsenic.
Beryllium	--	See Arsenic.
Cadmium	10	See Arsenic.
Chromium	100	See Arsenic.
Copper	200	See Arsenic.
Manganese	200	See Arsenic.
Nickel	200	See Arsenic.
Vanadium	100	See Arsenic.
Zinc	2,000	See Arsenic.

RC424

[a]National Academy of Sciences - National Academy of Engineering (1973) - reported in Adriano (1986).

9.3.5.1 Hazard Index Ratios

The risks of site contamination were quantified by calculating an HI ratio for each COPC, pathway, receptor, and case that could be quantitatively evaluated. In addition, HIs were calculated for each critical effect that could be quantitatively evaluated on a dietary, body, weight, tissue residue, sediment, or soil concentration basis. The HIs were calculated as follows:

$$HI = EE/TB,$$

where:

HI = hazard index,
TB = toxicity benchmark value, and
EE = estimated exposure.

Toxicity benchmark values were derived in the toxicity assessment. Estimated exposures were derived in the exposure assessment. The HIs for arsenic are provided in Table 9-17, and the HIs for cadmium are provided in Table 9-18. The HIs for benthic invertebrates, calculated using the Long and Morgan benchmarks, are provided in Table 9-19. The HIs for soil metals are provided in Table 9-20.

An HI greater than 1 would be considered presumptive evidence for a risk of adverse chronic effects of a chemical on a given ecological receptor for a given case, a given pathway, and a given critical effect.

9.3.5.2 Summary of Risks and Uncertainties

HIs greater than 1 for arsenic are summarized in Table 9-21, and HIs greater than 1 for cadmium are summarized in Table 9-22. These and other risks are summarized as follows:

- For arsenic in pond sediments or soil on the edge of the landfill, food chain or direct exposures presumed to result in adverse effects are evident for bluegill, water marigold, dragonfly, green frog, painted turtle, muskrat, raccoon, mallard (for RME case only), and red maple. No risks from arsenic are presumed for the great blue heron and Cooper's hawk.

- For cadmium in pond sediments or soil on the edge of the landfill, exposures presumed to result in adverse effects are evident for dragonfly and red maple (RME case only). No risks from cadmium are presumed for any of the other indicator species or pathways.

- For manganese and barium in pond sediments, exposures resulting in adverse effects are presumed for the dragonfly. Risks from manganese and barium in pond sediments cannot be evaluated for other indicator species using currently available information.

Table 9-17

HAZARD INDEX RATIO VALUES FOR INDICATOR SPECIES - ARSENIC PLOW SHOP POND

			Basis			
Indicator Species	Receptor	Case	Diet	Body Weight	Tissue Residue	Sediment
Bluegill	Adult	RME	--	--	12.8	--
		Average	--	--	4.0	--
	Juvenile	RME	--	--	49.2	--
		Average	--	--	15.4	--
Water marigold	--	RME	--	--	33.6	--
		Average	--	--	10.5	--
Dragonfly	Larval	RME	--	--	--	97.0
		Average	--	--	--	30.3
Green frog	Adult	RME	5.5	--	--	--
		Average	1.7	--	--	--
Painted turtle	Adult	RME	7.3	--	--	--
		Average	2.3	--	--	--
Muskrat	Adult	RME	125	32.5	--	--
		Average	39.2	10.2	--	--
Raccoon	Adult	RME	13.8	1.9	--	--
		Average	4.3	0.6	--	--
Mallard	Adult	RME	2.0	0.6	--	--
		Average	0.6	0.2	--	--
Great blue heron	Adult	RME	0.4	0.03	--	--
		Average	0.1	0.02	--	--
Cooper's hawk	Adult	RME	0.7	0.03	--	--
		Average	0.2	0.01	--	--

RC424

Note: Hazard index ratio values are unitless.

Source: Ecology and Environment, Inc. 1992.

Table 9-18

HAZARD INDEX RATIO VALUES FOR INDICATOR SPECIES - CADMIUM
PLOW SHOP POND

Indicator Species	Receptor	Case	Basis: Diet	Basis: Body Weight	Basis: Tissue Residue	Basis: Sediment
Bluegill	Adult (assumed)	RME	--	--	0.04	--
		Average	--	--	0.02	--
Water marigold	--	RME	--	--	0.8	--
		Average	--	--	0.4	--
Dragonfly	Larval	RME	--	--	--	6.0
		Average	--	--	--	2.9
Green frog	Adult	RME	0.06	--	--	--
		Average	0.03	--	--	--
Painted turtle	Adult	RME	0.05	--	--	--
		Average	0.02	--	--	--
Muskrat	Adult	RME	0.04	--	--	--
		Average	0.02	--	--	--
Raccoon	Adult	RME	0.007	--	--	--
		Average	0.003	--	--	--
Mallard	Adult	RME	0.03	--	--	--
		Average	0.01	--	--	--
Great blue heron	Adult	RME	0.01	--	--	--
		Average	0.007	--	--	--
Cooper's hawk	Adult	RME	0.01	--	--	--
		Average	0.02	--	--	--

RC424

Note: Hazard index ratio values are unitless.

Source: Ecology and Environment, Inc. 1992.

Table 9-19

HAZARD INDEX RATIO VALUES FOR BENTHIC INVERTEBRATES PLOW SHOP POND

Parameter	Average	ER-L Ratio	ER-M Ratio
Landfill Contaminants			
Arsenic	RME	97.0	91.4
	Average	30.3	28.5
Barium	RME	NA	NA
	Average	NA	NA
Cadmium	RME	12.0	6.7
	Average	5.8	3.2
Manganese	RME	NA	NA
	Average	NA	NA
Other Parameters			
Metals			
Chromium	RME	303.0	285.7
	Average	98.4	92.8
Copper	RME	1.89	0.34
	Average	0.90	0.16
Lead	RME	18.06	1.20
	Average	6.90	2.19
Mercury	RME	866.67	100.0
	Average	205.3	23.69
Nickel	RME	2.64	1.59
	Average	1.27	0.76
Zinc	RME	0.36	0.16
	Average	0.34	0.15
Pesticides			
DDE	RME	86.0	11.43
	Average	16.0	2.13
PAHs			
Benzo(a)anthracene	RME	4.74	0.68
	Average	0.97	0.14
Chrysene	RME	3.85	0.55
	Average	0.82	0.12
Fluoranthene	RME	5.68	0.95
	Average	0.84	0.14
Naphthalene	RME	4.71	0.76
	Average	0.93	0.15
Phenanthrene	RME	11.16	1.82
	Average	1.70	0.28
Pyrene	RME	12.43	1.98
	Average	2.77	0.44

RC424

Source: Compiled by Ecology and Environment, Inc., 1992

Table 9-20

**HAZARD INDEX RATIO VALUES FOR RED MAPLE - METALS
SHEPLEY'S HILL LANDFILL**

Metal	Case	Groundwater (Soil) Basis
Arsenic	RME	7.1
	Average	1.3
Barium	RME	--
	Average	
Beryllium	RME	--
	Average	
Cadmium	RME	15
	Average	0.8
Chromium	RME	2.4
	Average	0.3
Copper	RME	1.3
	Average	0.2
Manganese	RME	38
	Average	12
Nickel	RME	1.5
	Average	0.1
Vanadium	RME	1.6
	Average	0.2
Zinc	RME	0.3
	Average	0.1

RC424

Source: Ecology and Environment, Inc. 1992.

Table 9-21

SUMMARY OF RISKS FOR INDICATOR SPECIES - ARSENIC
SHEPLEY'S HILL LANDFILL

Indicator Species/ Receptor	Case	Pathway: Food Ingestion		Sediment - Dermal Contact	Sediment - Ingestion	All Pathways		Root Uptake
	Basis:	Diet Residue	Body Weight	Human Risk	Human Risk	Tissue Residue	Sediment	Groundwater
Bluegill/Adult	RME	-	-	-	-	+	-	-
	Average	-	-	-	-	+	-	-
Bluegill/Juvenile	RME	-	-	-	-	+	-	-
	Average	-	-	-	-	+	-	-
Water Marigold	RME	-	-	-	-	+	-	-
	Average	-	-	-	-	+	-	-
Dragonfly/Larval	RME	-	-	-	-	-	+	-
	Average	-	-	-	-	-	+	-
Greenfrog/Adult	RME	+	-	-	-	-	-	-
	Average	+	-	-	-	-	-	-
Painted Turtle/Adult	RME	+	-	-	-	-	-	-
	Average	+	-	-	-	-	-	-
Muskrat/Adult	RME	+	+	+	+	-	-	-
	Average	+	+	+	+	-	-	-
Raccoon/Adult	RME	+	+	+	+	-	-	-
	Average	+	0	+	+	-	-	-
Mallard/Adult	RME	+	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-
Great Blue Heron/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-
Coopers Hawk/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-

RC424

Key at end of table.

Table 9-21 (Cont.)

Indicator Species/ Receptor	Case	Pathway: Basis:	Food Ingestion: Diet Residue	Food Ingestion: Body Weight	Sediment - Dermal Contact: Human Risk	Sediment - Ingestion: Human Risk	All Pathways: Tissue Residue	All Pathways: Sediment	Root Uptake: Groundwater
Red Maple	RME		-	-	-	-	-	-	+
	Average		-	-	-	-	-	-	+

RC424

Key:

+ = Risks of adverse effects are presumed.
0 = No risks presumed.
- = Pathway not evaluated.

Table 9-22

SUMMARY OF RISKS FOR INDICATOR SPECIES - CADMIUM
SHEPLEY'S HILL LANDFILL

Indicator Species/ Receptor	Case	Pathway: Food Ingestion		Sediment - Dermal Contact	Sediment - Ingestion	All Pathways		Root Uptake
	Basis:	Diet Residue	Body Weight	Human Risk	Human Risk	Tissue Residue	Sediment	Groundwater
Bluegill/Adult	RME	-	-	-	-	0	-	-
	Average	-	-	-	-	0	-	-
Water Marigold	RME	-	-	-	-	0	-	-
	Average	-	-	-	-	0	-	-
Dragonfly/Larval	RME	-	-	-	-	-	+	-
	Average	-	-	-	-	-	+	-
Greenfrog/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-
Painted Turtle/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-
Muskrat/Adult	RME	0	-	0	0	-	-	-
	Average	0	-	0	0	-	-	-
Raccoon/Adult	RME	0	-	0	0	-	-	-
	Average	0	-	0	0	-	-	-
Mallard/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-
Great Blue Heron/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-
Coopers Hawk/Adult	RME	0	-	-	-	-	-	-
	Average	0	-	-	-	-	-	-

RC424

Key at end of table.

Table 9-22 (Cont.)

Indicator Species/ Receptor	Case	Pathway: / Basis:	Food Ingestion		Sediment - Dermal Contact	Sediment - Ingestion	All Pathways		Root Uptake
			Diet Residue	Body Weight	Human Risk	Human Risk	Tissue Residue	Sediment	Groundwater
Red Maple	RME		-	-	-	-	-	-	+
	Average		-	-	-	-	-	-	0

RC424

Key:

+ = Risks of adverse effects are presumed.
0 = No risks presumed.
- = Pathway not elevated.

- o Additional metals other than arsenic and cadmium in the groundwater or root zone of trees, including chromium, copper, manganese, nickel, and vanadium, are suspected of adversely affecting trees occurring in some areas on the edge of the landfill.

The principal uncertainties of the ecological risk assessment are associated with the identification of COPCs and the exposure assessment, toxicity assessment, and risk characterization.

The relationship of COPCs to the site is uncertain due to the presence of another apparent source of contamination coming from Grove Pond. Nevertheless, the spatial distribution of sediment COPCs and groundwater data showing areas of elevated metals seem to indicate that arsenic and manganese in the pond sediments on the western edge of the pond are clearly derived from Shepley's Hill Landfill. Cadmium and barium are less clearly derived from the landfill, and other metals occurring at elevated levels in the pond sediments appear to be derived from another source.

The principal uncertainty in the exposure assessment has to do with estimating the bioavailable fraction of metals in sediments. The estimates provided are based on BAF values calculated from published information, which vary considerably and may not accurately represent conditions in Plow Shop Pond. Additional uncertainties arise from a lack of information about direct ingestion and dermal pathways for wildlife. Moreover, each of the input variables used to derive estimated exposures for the food chain pathway were subject to uncertainty. Generally, the reasonable worst case was assumed to provide a conservative estimate.

Few reliable toxicity values were available for sediments and for the effects of the COPCs on wildlife. Considerable uncertainties are inherent in the extrapolation of toxicity values derived from laboratory studies to field situations and from the extrapolation of values from surrogate species to species of concern. As with the exposure assessment, reasonable worst case assumptions were made to provide a conservative estimate.

In general, because of the conservative nature of the assumptions used, the risk assessment is likely to overestimate rather than underestimate the risks of adverse ecological effects at the site.

9.3.5.3 Ecological Significance

The sediments of Plow Shop Pond are contaminated with elevated levels of arsenic, barium, cadmium, and manganese. These COPCs can be related to the Shepley's Hill Landfill as a likely or possible source. Risks of adverse effects on aquatic and semi-aquatic biota are presumed from the levels of arsenic found in the pond sediments. Lesser risks to some aquatic biota, mainly plants and benthic invertebrates, are presumed from the levels of cadmium in the sediments. Barium and manganese occur at elevated levels in the sediments and may adversely affect benthic aquatic life, but their ecological significance to higher trophic levels is unclear.

The pond sediment COPCs are not of concern in terms of bioaccumulation in the terrestrial food chain. Most birds do not appear to be at risk from exposure to pond sediment COPCs. The COPCs are not known to biomagnify, and apex predators should not be adversely affected by the direct toxic effects of the pond contaminants. The potential adverse effects of COPCs on benthic invertebrates and other aquatic biota could indirectly impact higher trophic levels by degrading the abundance of their food source. These indirect effects of COPCs are not likely to be significant, but they cannot be ruled out with the present information.

Although the risk assessment identifies risks of potential adverse effects of COPCs on the Plow Shop Pond ecosystem, a variety of factors are considered likely to mitigate the toxicity of the COPCs under the prevailing environmental conditions. In particular, the high TOC, high iron, neutral pH, and rich nutrient status of the pond would be expected to decrease the bioavailability of some of the sediment-bound COPCs. The risks presented in this report are likely to represent a worst case scenario, but further investigation is warranted.

The Plow Shop Pond ecosystem is affected by high levels of a variety of metals not considered COPCs in this risk assessment. These other contaminants are not clearly related to the Shepley's Hill Landfill site and appear to have another source. Some of these contaminants could adversely affect the ecosystem (as indicated by HIs greater than 1; see Table 9-19) and should be investigated.

Finally, plants growing on the edge of the landfill may be adversely affected in some areas by elevated metals concentrations in the soil. Groundwater metals concentrations were used to evaluate risks to deeply rooted plants such as trees, some of which were observed to be stressed in an area of groundwater contamination next to Plow Shop Pond. Potential soil contamination in the root zone of plants should be investigated.

9.4 ECOLOGICAL RISK ASSESSMENT FOR COLD SPRING BROOK LANDFILL

The ecological risk assessment for the Cold Spring Brook Landfill site is provided in the following sections.

9.4.1 Contaminants of Ecological Concern

Selection of contaminants of potential concern (COPCs) for ecological receptors followed the procedures for the Shepley's Hill Landfill site, as described in Section 9.3.1.

The results of screening chemicals in sediment, surface water, and other media are provided below.

9.4.1.1 Surface Water

As described in Section 2.2.3 of the RI report, a total of 10 surface water samples were collected for chemical analysis from the Cold Spring Brook Landfill site. A total of 9 samples were taken from Cold Spring Brook Pond, and one sample was taken from the Cold Spring Brook stream channel to the east of Patton Road, downstream from Cold Spring Brook Pond. The sampling locations are shown in Figure 2-6, and analytical results are summarized in Table 5-13 of the RI report.

The metals concentrations in the surface water at the site are generally low and probably reflect background concentrations. As discussed in the human health risk assessment, however, the presence of elevated metals in pond sediments and historical evidence of contamination suggest that Cold Spring Brook Pond cannot be regarded as representative of background water quality. In addition, the upstream sample SW-CSB-01 is in an area probably influenced by groundwater flow from the landfill and cannot be assumed to be representative of background conditions. Therefore, in addition to the general screening criteria applied in the human health risk assessment, chemicals in surface water samples were compared to EPA Ambient Water Quality Criteria (AWQC) for protection of aquatic life. Chemicals not detected at concentrations approaching or exceeding AWQC would not be expected to pose a significant ecological risk and were not regarded as COPCs for the risk assessment. Chronic AWQC were used for screening if available; otherwise, acute AWQC were used. If no AWQC or LOEL was available for a given chemical, that chemical was not eliminated on the basis of these ecological criteria. The AWQC for all chemicals of potential ecological concern listed in Table 5-13 are provided in Table 9-23.

The range of chemical concentrations in surface water was determined for Cold Spring Brook Pond (Area 1) and for the one sample taken from Cold Spring Brook on the east side of Patton Road, downstream from the landfill (Area 2). Area 1 is defined by sampling stations SW-CSB-01 through SW-CSB-09, which are located on the shore of Cold Spring Brook Pond adjacent to the landfill, or in the middle of the pond. Area 2 is defined by sample SW-CSB-10, which is located downstream from the landfill. Surface water quality in Areas 1 and 2 could be related to effects from the site due to their proximity to the landfill.

The results of the screening are provided in Table 9-24.

In Area 1, chronic AWQC were exceeded for iron at all nine of the sampling stations, and for zinc at one of the nine sampling stations. These were the only exceedances of AWQC in Cold Spring Brook Pond.

In Area 2, chronic AWQC were exceeded for iron. Iron and zinc are not considered COPCs in Areas 1 and 2 for the following reasons:

Table 9-23

**EPA AMBIENT WATER QUALITY CRITERIA
PROTECTION OF AQUATIC LIFE
COLD SPRING BROOK LANDFILL**

Parameter	AWQC[a] (µg/L) or Other Criteria	Notes
Inorganic Substances		
Arsenic	190/360	(1), (3)
Barium	50,000	(6)
Chromium	158/1,322	(1), (3), (4)
Copper	8.9/13.0	(1), (4)
Iron	1,000	(5)
Manganese	1,000	(7)
Silver	0.12/2.3	(1), (4)
Zinc	80/88.3	(1), (4)
Organic Substances		
Alpha-benzenehexachloride	100	(2)

RC424

[a]Ambient Water Quality Criteria.

NOTES:

(1) Fresh Water Chronic Criterion/Fresh Water Acute Criterion or Value.
(2) Insufficient Data to Develop Criterion. Values presented are the Lowest Observed Effect Level (LOEL).
(3) Values presented are for the trivalent species.
(4) Hardness Dependent Criterion (71.7 mg/L, site-specific value of hardness in the surface water).
(5) Fresh Water Chronic Criterion.
(6) Soluble barium concentrations would have to exceed this level before toxicity would be expected (USEPA 1986b).
(7) Manganese is rarely found in surface waters at concentrations higher than this level (USEPA 1986b).

Source: Ecology and Environment, Inc. 1992.

Table 9-24

COMPARISON OF CHEMICALS IN COLD SPRING BROOK SURFACE WATER TO AWQC

	Area 1 Cold Spring Brook Pond			
	Range		Elevation Frequency	
Parameter	Minimum	Maximum	Chronic	Acute
Inorganic Substances				
Arsenic	4.51 -	17.7	0/9	--
Barium	9.71 -	13.4	0/9	--
Chromium	<4.47 -	4.76	0/9	--
Copper	<4.29 -	6.75	0/9	--
Iron	1,100 -	3,200	9/9	--
Manganese	53.3 -	400	0/9	--
Silver	<0.316 -	0.71	0[a]	0/9
Zinc	<19.4 -	86.3	1/9	0/9
Organic Substances				
Alpha-benzene-hexachloride	<.006 -	0.02	0/9	--

RC424

Table 9-24 (Cont.)

	Area 2 Cold Spring Brook Below Patton Road		
		Elevation Frequency	
Parameter	Value	Chronic	Acute
Inorganic Substances			
Arsenic	5.21	0/1	--
Barium	10.1	0/1	--
Chromium	<4.47	0/1	--
Copper	<4.29	0/1	--
Iron	1,300	1/1	--
Manganese	118	0/1	--
Silver	<0.316	0[a]	0/1
Zinc	<19.4	0/1	--
Organic Substances			
Alpha-benzene-hexachloride	0.015	0/1	--

RC424

[a]AWQC is below the detection limit.

Source: Ecology and Environment, Inc. 1992.

- o The AWQC exceedances for zinc were relatively small and isolated to one location.

- o The AWQC exceedances for iron were relatively small. Iron is an essential nutrient with relatively low toxicity to aquatic life (USEPA 1986b. Moreover, natural background concentrations of iron are frequently high in swamps due to the reducing conditions that occur in anaerobic swamp soils and sediments.

No organic substances exceeded AWQC in the surface water in Areas 1 or 2. Alpha-benzenehexachloride was found in nine samples at the detection limit but was not confirmed on a second column and does not appear to be of concern because it is present at a level below the AWQC.

Therefore, on the basis of this screening, none of the chemicals in surface water was considered a COPC, and, consequently, none was included in the ecological risk assessment.

9.4.1.2 Sediment

A total of 10 sediment samples were collected for chemical analysis from the Cold Spring Brook Landfill site. The sediment samples were collected from the same locations as the surface water samples. The sampling locations are shown in Figure 2-6, and chemical results are summarized in Table 5-14 of the RI report.

Metals

As discussed in the human health risk assessment, four metals detected in the sediments of Cold Spring Brook Pond were found at levels elevated above background at one or more sample locations. The metals are: arsenic, lead, manganese, and zinc.

In addition to the general screening criteria applied in the human health risk assessment, metals in sediments were compared to a range of published freshwater sediment quality criteria. Metals not detected at concentrations approaching or exceeding these ecological criteria would not be expected to pose a significant ecological risk and were not regarded as COPCs for the risk assessment. The proposed regulatory criteria for sediments are not consistent, however, and uniform national or Commonwealth of Massachusetts criteria have not been established. Comparative sediment criteria for the four metals of potential concern are shown in Table 9-25.

The ecological criteria shown in Table 9-25 are generally well below background concentrations for soils at the site. Hence, they are considered overly conservative screening criteria for the Cold Spring Brook Landfill site. Instead, less conservative values were used, called "Limit of Tolerance Levels," which are concentrations considered potentially toxic to most benthic invertebrates (Persaud 1989). The benthic invertebrate Limit of Tolerance levels are of the same magnitude

Table 9-25

COMPARATIVE SEDIMENT CRITERIA FOR METALS (mg/kg)

Metal	EPA Region V Guidelines[a]	Ontario Ministry of Environment Proposed Sediment Quality Criteria[b]	EPA Threshold Values[c]	Wisconsin Department of Natural Resources Sediment Quality Criteria[d]	New York State Department of Environmental Conservation[e]
Arsenic	3	4.0	33	10	5
Lead	40	23	132	50	27
Manganese	300	400	NA	NA	428
Zinc	90	65	760	100	85

RC424

[a]USEPA 1977. Levels above those provided in the table are considered moderately polluted, levels below are considered nonpolluted.
[b]Persaud et al. (1989). No observed effect level for toxicity to benthic invertebrates.
[c]Bolton et al. (1985), reported in Lyman et al. (1987). Levels are calculated based on the equilibrium partioning approach: sediments with these concentrations of total metal are predicted to have concentrations of metal in the interstitial water that exceed established water quality criteria. Total organic carbon of 4% is assumed.
[d]Sullivan et al. 1985, reported in Fitchko 1989.
[e]New York State 1989. Criteria are derived from Persaud et al. 1989.

Key:

NA = Not available.

Source: Ecology and Environment, Inc. 1992.

as the Upper Tolerance Limits on local soil concentrations (see Table 9-26). Exceedances of both the benthic invertebrate Limit of Tolerance levels and the background soil concentrations would indicate potential site-related risks to benthic aquatic biota.

Contaminant concentrations in sediments were determined for the two areas of concern identified for surface water (Areas 1 and 2). A comparison of metals concentrations in these areas to background levels and ecological screening criteria is shown in Table 9-26.

In Area 1, concentrations of arsenic, lead, manganese, and zinc were elevated in one or two locations relative to background screening levels (Table 9-26). Only arsenic was elevated at more than one location relative to the benthic invertebrate Limit of Tolerance levels. Given the sporadic occurrence of lead, manganese, and zinc at levels above background or ecological screening levels, these three metals were not considered COPCs in Cold Spring Brook Pond sediments. However, as a result of the greater frequency of exceedances of ecological screening levels (six out of nine samples), arsenic was considered a COPC in Cold Spring Brook Pond. None of the metals were detected at levels exceeding background or the ecological screening levels for Area 2 sediments. Therefore, metals are not considered COPCs for sediments from Area 2 (Table 9-26).

Organic Substances

Several polynuclear aromatic hydrocarbons (PAHs) were detected at two sampling locations in Area 1, SE-CSB-06 and SE-CSB-09. Fluoranthene was also detected at SE-CSB-02, and several PAHs were detected in Area 2 at SE-CSB-10. The chlorinated pesticides P,P'-DDD and P,P'-DDE (breakdown products of DDT) were also detected at a majority of locations in Area 1. The levels of these organic substances were generally low (<10 mg/kg), but they are considered COPCs because of their widespread occurrence, their potential for bioaccumulation and biomagnification (DDTs), or their known toxicity to benthic aquatic organisms (PAHs).

9.4.1.3 Soils

Metals were not detected at elevated levels in the three surface soil samples taken from Cold Spring Brook Landfill (see Table 5-10). However, low levels of PAHs and DDT/DDD were detected at a single location, SL-CSB-1. The low levels of these organic contaminants and their restriction to one or two locations indicates that they are of limited ecological importance in soils at the site. For example, soils typically contain up to 1 mg/kg benzo(a)pyrene (Edwards 1983, Table 3 in Eisler 1987). According to tentative soil criteria for the Netherlands, most PAHs are not considered of environmental concern under 5 to 10 mg/kg in soils (total PAHs equal to 20 mg/kg, Fitchko 1989). Likewise, low levels of DDT and related compounds are common in soils. For example, mean levels in non-cropland in the United States have been reported from 0.14 to 0.81 mg/kg in various studies, and significantly

Table 9-26

COMPARISON OF METALS IN COLD SPRING BROOK POND SEDIMENTS TO BACKGROUND AND CRITERIA

			Area 1 (Cold Spring Brook Pond)				Area 2 Cold Spring Brook		
			Range		Elevation Frequency			Elevation Frequency	
Parameter	Upper Tolerance Limit (UTL) on Local Soil Concentrations[a]	Limit of Tolerance Level (LTL) for Benthic Inverte-brates	Minimum	Maximum	UTL	LTL	Value	UTL	LTL
Arsenic	66	33	6.5 -	160	2/9	6/9	13	0/1	0/1
Lead	275	250	11.4 -	345	1/9	1/9	53.1	0/1	0/1
Manganese	590	1,100	130 -	3,000	2/9	1/9	110	0/1	0/1
Zinc	105	800	14.6 -	690	1/9	0/9	34.6	0/1	0/1

RC424

[a]See Human Health Risk Assessment, Section 8.

Source: Ecology and Environment, Inc. 1992.

higher levels may occur in agricultural or forest land as a result of past pesticidal spraying (Edwards 1973). Moreover, the levels of PAHs and DDT in Cold Spring Brook Landfill soils are comparable to levels reported in reference soils from another Superfund site in Massachusetts (Menzie et al. 1992). Therefore, the low levels of PAHs and DDT/DDD in surface soil are not considered of ecological concern at the site.

9.4.1.4 Other Media

Contaminants in groundwater were not considered to be COPCs for ecological receptors, although some groundwater contaminants were found to be elevated relative to background or human-health criteria (see Section 8). Ecological receptors are not exposed to groundwater directly; therefore, groundwater is not generally considered an exposure medium for ecological receptors. Concentrations of contaminants in groundwater may be used as an indicator of contamination in other media, such as overlying soils (as at Shepley's Hill). However, soil data were available at Cold Spring Brook Landfill to evaluate soil contamination. Therefore, groundwater values were not used as indicators of soil contamination at Cold Spring Brook landfill.

Air samples did not contain levels of any chemicals that might pose a significant risk to human or ecological receptors (see Section 8).

9.4.1.5 Summary

Arsenic, PAHs, and DDD/DDE were selected as COPCs in environmental media (Cold Spring Brook Pond sediments) potentially affected by the Cold Spring Brook Landfill site. No other contaminants in other media were selected as COPCs for this ecological risk assessment. Risks associated with additional parameters which are present in Cold Spring Brook, but not at levels exceeding background, are summarized in Section 9.4.5.

9.4.2 Ecological Receptors and Endpoints

This section identifies the potential ecological receptors and endpoints of concern at the Cold Spring Brook Landfill site. Features of the terrestrial, wetland, and aquatic ecosystems are summarized in Section 9.4.2.1. This summary is based on the ecological characterization studies that were conducted as a part of the RI field investigations. Potential exposure pathways for ecological receptors occurring at the site are identified in Section 9.4.2.2. The ecological endpoints that will serve as the focal point of the ecological risk assessment are then identified in Section 9.4.2.3.

9.4.2.1 Summary of Existing Environment

In conjunction with the RI report, field studies were conducted and an ecological characterization of the landfill and surrounding areas was compiled. This characterization involved the identification of the plant and animal communities as well as observations of any actual or potential effects of site contaminants on these biological resources. The entire ecological characterization of the Cold Spring Brook Landfill site is presented in Section 3.2.1. of this report. However, a summary of the major cover types and principal habitats located in the general vicinity of the landfill follows (see Table 9-27).

Coniferous Forest

This cover type is located in three different areas on and around the landfill. Two of the areas, a scotch pine plantation and a red pine plantation, are located on the landfill. The other area, a mature white pine forest, is located on the eastern side of Patton Road and is not in an area influenced by groundwater from the landfill. The understory in this natural forest consists of red maple and white pine saplings, while in the planted areas it is relatively open except for some regeneration.

Overall, these coniferous forests provide excellent year-round protective cover for a variety of animals including songbirds, upland game birds, raptors, and whitetail deer. In addition, the young trees (in the plantations) produce seed, which is a valuable food source for a variety of birds and mammals.

Mixed Forest

This cover type is located in one large area located at the western end of the pond. The entire area is upgradient of the landfill. The dominant species in the overstory of this cover type include white oak, scarlet oak, red maple, and white pine. The understory consists primarily of the same species as well as dwarf blueberry.

The abundance of oaks in these areas results in high-quality wildlife areas. Oak acorns are a valuable fall and winter food source for a variety of species. In addition, the pines provide excellent cover and a valuable food item (seed). Overall, these areas can support a diverse group of species including whitetail deer, blue jay, common flicker, black bear, gray squirrel, ruffed grouse, gray catbird, chipmunk, and raccoon.

Deciduous Forest

This cover type is located in four different areas around the landfill, and, according to the groundwater flow direction, only one of these areas is located downgradient. The other three areas are located to the north and south of the landfill and are upgradient.

Dominant species in the overstory of this cover type include scarlet oak, white oak, eastern cottonwood, and quaking aspen. The understory primarily consists of the same species with some red maple and white pine.

These areas provide a variety of food items to a large number of species. Overall, these deciduous forests are considered high-quality

Table 9-27

MAJOR COVER TYPES AND PRINCIPAL HABITATS LOCATED AT COLD SPRING BROOK LANDFILL

Major Cover Type/Habitat	Dominant Species	Relation to Source/Contamination	Cover Type Numbers[a]
Coniferous Forest	Scotch pine, red pine, white pine	Located on landfill; one area is east of Patton Road and upgradient of Cold Spring Brook	1, 6, and 16
Mixed Forest	White pine, scarlet oak, paper birch, red maple, white oak	Located upgradient of landfill on south and west sides; one area is across pond but upgradient	19, 20, and 22
Deciduous Forest	Scarlet oak, quaking aspen, eastern cottonwood, American hazelnut	Located on the landfill and surrounding the pond; few areas are upgradient (south of Patton Road and north of the pond)	3, 4, 17, 18, 21, 23, and 24
Reverting Field	White pine (sapling), red pine (sapling), staghorn sumac, sweetfern	Located on landfill; east end and northwest corner	2 and 5
Forested Wetland	White pine, red maple, silky dogwood, American elm, highbush blueberry	Located around pond (shoreline) and and riparian corridor of Cold Spring Brook; downgradient of landfill	10, 11, 12, 14, and 15
Emergent/Open Water Wetland	Swamp loosestrife, silky dogwood, broad-leaf cattail	Located downgradient of landfill on northern edge; pond and shoreline	13 and 9
Scrub/Shrub Wetland	Red maple, smooth alder, buttonbush, marsh fern	Located downgradient of landfill on northwestern edge; between pond and landfill	7 and 8

RC424

[a]Listed in Table 3-11 of this report.

Source: Ecology and Environment, Inc. 1992.

wildlife habitats; the oaks provide an important food staple, and red maple provides browse for deer and spring fruits for birds and mammals. A few of the species likely to occur in these areas include white-tailed deer, robin, rose-breasted grosbeak, cottontail, and squirrel.

Reverting Field

This cover type includes two different habitats that are located on the landfill: a sumac thicket and an old field. The old field area is situated on the eastern boundary of the landfill, and the sumac thicket occurs on the northwest corner of the landfill.

The old field area consists of some scattered white pine saplings and sweetfern shrubs, but herbaceous species dominate such as panic grass, goldenrods, and spotted knapweed. Old fields serve as small wildlife openings that provide edge and food. Panic grass produces seed, which is eaten by a variety of songbirds. Some of the species likely to utilize old field areas include the song sparrow, cottontail, field sparrow, thrasher, and catbird.

The small sumac thicket area is dominated by panic grass, staghorn, sumac, and black raspberry. A few red pine saplings are scattered through the area. This area does not provide choice food for wildlife, but does provide an excellent area for cover and shelter.

Forested Wetland

Three forested wetlands are located on the north shore of the pond, and according to groundwater flow directions these wetlands are downgradient of the landfill. One wetland is located along the riparian corridor of Cold Spring Brook, while the other is a small pocket of wetland located at the northeast corner of the landfill. Both of these wetlands are also downgradient of the landfill and are dominated by red maple and white pine, with some American hazelnut and silky dogwood in the understories.

These five wetland areas provide a valuable source of cover for a variety of species. In addition to the birds and mammals that frequent forested wetland areas, the moist soil conditions are capable of supporting a variety of amphibians such as the spring peeper and two-lined salamander.

Emergent/Open Water Wetland

Two small wet meadow/emergent wetlands are located downgradient of the landfill. The dominant plants in these wetlands are swamp loosestrife, broad-leaf cattail, silky dogwood, and marsh fern. Due to the very small size of these wetlands, their wildlife values are limited. Species using the surrounding areas may forage and water within these wetlands, and amphibians such as the American toad and leopard frog may use this area for breeding.

Cold Spring Brook Pond is classified as a floating-leaved deep marsh, and is located downgradient of the landfill. This pond is shallow, eutrophic, and dominated by sweet water lily, swamp loosestrife, and cattails. This pond is a valuable wildlife resource: several species of toads and frogs are likely to use the pond for breeding; waterfowl use the pond for feeding and resting; herons and belted kingfishers feed on fish and frogs; and insectivorous birds forage over the pond's surface. Mammals such as the muskrat and beaver are expected to occur in the pond.

Scrub/Shrub Wetland

Two scrub/shrub wetland areas are located at the western end of the pond and are downgradient of the landfill. Dominant species in these wetlands include red maple, smooth alder, buttonbush, meadowsweet, sedge, and marsh fern. Both of these areas had saturated soils at the time of the survey.

Overall, these two wetlands do not provide any high-quality food items, but do provide a low, dense protective cover. These areas likely serve as breeding pools for a variety of amphibians, and as a water source for the birds and mammals utilizing the surrounding areas.

9.4.2.2 Potential Exposure Pathways

Under existing and future site conditions, five general categories of ecological receptors might be exposed to COPCs at the Cold Spring Brook Landfill site. Potentially exposed receptors include:

- o Aquatic biota in Cold Spring Brook Pond;
- o Aquatic biota in Cold Spring Brook;
- o Semi-aquatic wildlife and terrestrial wildlife that depend on the aquatic environment for a fraction of their food or habitat needs;
- o Strictly upland terrestrial wildlife; and
- o Plants growing on top of, along the edge of, or downgradient from the landfill.

The potential exposure pathways for these receptors vary among receptor types.

- o Benthic invertebrates and some fish would be expected to have direct contact with contaminated sediment particles and sediment interstitial water through contact and absorption, direct ingestion, and feeding on contaminated food. Uptake of contaminants from the sediments (via interstitial water) by aquatic plants could also occur.

- o Bioconcentration from media by aquatic species and subsequent bioaccumulation in the food chain could expose some herbivores, omnivores, predators, and piscivorous wildlife to COPCs (see Figure 9-1). Semi-aquatic wildlife and some terrestrial species could be exposed via the food chain. Some of these receptors could also be exposed through contact and absorption and direct ingestion of sediments.

- o Plants growing on top of or along the edge of the landfill could be exposed through uptake by roots. Upland terrestrial wildlife could be exposed through contact with contaminated soil, seep discharges, or exposure through the terrestrial food chain.

Pathways Chosen for Evaluation

Ecological receptors and potential exposure pathways were evaluated for inclusion in the risk assessment on the basis of the COPCs and the affected media identified in Section 9.4.1 and the characteristics of receptors found at the site as discussed in Section 9.4.2.1. The following receptors and exposure pathways were chosen for evaluation in the risk assessment.

- o Aquatic biota in Cold Spring Brook Pond and semi-aquatic and some terrestrial wildlife species were chosen due to their potential exposure to elevated arsenic, PAHs, and DDD/DDE concentrations in sediments.

Pathways Excluded from Evaluation

Similarly, the following receptors and exposure pathways were excluded from evaluation in the risk assessment, based on the field sampling data.

- o Aquatic biota in Cold Spring Brook downstream from Patton Road were excluded due to the low levels of contaminants found in surface water and sediments in that area.

- o Plants and upland terrestrial wildlife were excluded due to the low levels of soil contamination and the lack of any apparent air contamination.

9.4.2.3 Assessment Endpoints

Assessment endpoints chosen for the Cold Spring Brook Landfill site are the same as those selected for Shepley's Hill Landfill (see Section 9.3.2.3), with the exception of Cooper's hawk and red maple. Cooper's hawk is excluded because it is not known to occur at or utilize the site and any contact with the site is likely to be incidental for this species. Red maple is excluded because risks to terrestrial plants are not considered of concern at Cold Spring Brook Landfill.

The indicator species selected for evaluation at Cold Spring Brook include:

- o Representatives of aquatic biota expected to occur in Cold Spring Brook Pond:

  - Bluegill (Lepomis macrochirus),
  - Water marigold (Megalodonta beckii),
  - Dragonfly (Order: Odonata);

- o Representatives of semi-aquatic and terrestrial wildlife that are expected to occur in the area and that may depend on the pond for a fraction of their food or habitat needs:

  - Green frog (Rana clamitans melanota),
  - Painted turtle (Chrysemys picta picta),
  - Muskrat (Ondatra zibethicus),
  - Raccoon (Procyon lotor),
  - Mallard (Anas platyrhynchos),
  - Great blue heron (Ardea herodias).

9.4.3 Exposure Assessment

This section evaluates the exposure of ecological receptors to contaminants of concern at Cold Spring Brook Landfill. The exposure assessment is restricted to chemicals identified as COPCs in Cold Spring Brook Pond sediments: arsenic, DDD/DDE, and PAHs. The release, migration, and fate of these metals in sediments is discussed in Section 9.4.3.1, and exposure point concentrations (EPCs) are estimated in Section 9.4.3.2. EPCs are estimated for both the average and maximum exposure cases for each COPC. In Section 9.4.3.3, exposure scenarios and pathways are developed for the indicator species, and quantitative estimates of exposure are derived for average and maximum exposure cases.

9.4.3.1 Contaminant Release, Migration, and Fate

This section summarizes the fate of contaminants of concern in the sediment and sediment-water interface, as affected by a variety of chemical, physical, and biological processes. The factors affecting bioavailability of COPCs are also discussed.

Arsenic

The migration and fate of arsenic is summarized in Section 9.3.3.1.

DDD

DDD is a pesticide extensively used in the past throughout the world for insect control. It is also recognized as a metabolite of DDT. The physical and chemical properties relevant to its environmental fate are summarized in Table 9-28.

Table 9-28

CHEMICAL AND PHYSICAL PROPERTIES OF DDD AND DDE

Parameter	DDD	DDE
Chemical name	1,1'-(2,2-dichloroethylidene)-bis(4-chlorobenzene)	1,1'-(2,2-dichloroethenylidene)-bis(4-chlorobenzene)
CAS number	72-54-8	72-55-9
Molecular weight	320	318
Melting point	112°C	88-90°C
Vapor pressure (mmHg)	10.2×10^{-7} (pp')[a] 18.9×10^{-7} (op')[a]	6.5×10^{-6} (pp')[b] 6.2×10^{-6} (op')[b]
K_{oc} (ml/g)	7.7×10^{5}	4.4×10^{6}
log K_{ow}	6.2	7.0
Half lives		
Soil (years)	15.6 (high) 2.0 (low)	15.6 (high) 2.0 (low)
Volatilization (days)	7.4	7.4
Atmospheric/Aquatic Photolysis (hours)	-- --	146 (high) 15 (low)

RC424

[a] pp'-DDD and op'-DDD isomers at 30°C.
[b] pp'-DDE and op'-DDE isomers at 20°C.

Sources: USEPA 1979; ATSDR 1989; Howard et al. 1991.

The major fate processes of DDD in the environment are bioaccumulation and sorption to sediments and/or soils. The mobility of DDD in soils and sediments has been studied by various authors and reported to be extremely low (USEPA 1988f). Therefore, migration or leaching is expected to be very low, particularly in areas where the organic carbon content is high. The humic fraction represents a major source of adsorptive capacity for DDD; the degree of sorption, however, is strongly related with the degree of humification. Soils or sediments containing large amounts of humic material may not absorb DDD as greatly as others where humification is more advanced (WHO 1989).

Volatilization is also an important process for loss of DDD from aquatic systems, with DDD half-lives on the order of a few days to several weeks. Experimental data, however, indicates that the volatilization rates of DDD are less than DDT or DDE (USEPA 1979).

DDD also photolyzes, oxidizes, and hydrolyzes from soils and aquatic environments. However, these pathways of degradation are less significant in determining its fate in the environment.

DDE

DDE in the environment is found as a degradation product of DDT and is not manufactured as a commercial product. The physical and chemical properties relevant to its environmental fate are summarized in Table 9-28.

The major fate processes of DDE in the environment are bioaccumulation and sorption to sediments and/or soils. The migration of DDE in sediments and soils has been studied by various authors and reported to be extremely low (USEPA 1988f). Therefore, as discussed for DDD, the mobility of DDE is expected to be very low and is related to the organic matter content. The organic matter humic fraction content represents a major source of adsorptive capacity for DDE (WHO 1989). Laboratory studies suggest that in aquatic environments, losses through volatilization and photolysis are also important pathways with half-lives of several days for volatilization and several hours for photolysis.

The ultimate loss of DDE may be through photolysis in water or volatilization into the atmosphere after desorption or release from biota or sediments; biotransformation may also be an ultimate transformation process, although DDE is much less susceptible to such processes than DDT (USEPA 1979).

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular, or cluster arrangements. In general, higher molecular weight PAHs can be characterized as having low vapor pressure, low water solubility, low Henry's Law constants, high octanol-water partition coefficients (log K_{ow}), and high organic carbon partition coefficients (K_{oc}).

High partition coefficients and low solubility properties suggest that PAHs in the aquatic environment are likely to be adsorbed onto sediments. Conversely, low vapor pressures, low Henry's Law constants, and low K_{oc}, indicate that most PAHs will not readily volatilize (USEPA 1982b; Jones and Leber 1979).

Studies have shown that PAHs' sorption to sediments is strongly correlated with the organic carbon content of the sediments and not related to the cation exchange capacity.

The fate of adsorbed PAHs in the water column is influenced by a number of factors; duration of PAH exposure to sunlight will largely determine the extent of photooxidation. In general, from the available literature, it appears that very little PAHs in aquatic systems will be found in solution, and can be expected to accumulate in the sediments.

Typically, although PAHs are regarded as persistent in the environment, they are degradable by microorganisms. Degradation rates and degree of degradation are influenced by environmental factors, microbial flora, and physicochemical properties of PAHs themselves. Important environmental factors influencing degradation include temperature, pH, redox potential, and microbial species. Physicochemical properties include chemical structure, concentration, and lipophilicity.

9.4.3.2 Exposure Point Concentrations

Sediments

A number of environmental factors affect the bioavailability of arsenic in sediments, as discussed in the previous section. However, for the purposes of this screening-level risk assessment, the bulk arsenic concentrations measured in pond sediment samples will serve as crude, first-order estimates of exposure concentrations.

For neutral organic compounds such as DDD/DDE and PAHs, sorption to organic carbon is the principal factor controlling bioavailability. Interim sediment criteria have been proposed based on the carbon-normalized sediment concentrations of some nonpolar contaminants, including some PAHs (USEPA 1989g). Therefore, the EPCs for DDD/DDE and PAHs are presented on a total and carbon-normalized basis in Table 9-27.

As in the human health risk assessment, two cases of exposure are considered: the average exposure case and the reasonable maximum exposure (RME) case. EPCs used for the average exposure case are the average sediment concentrations of COPCs in Cold Spring Brook Pond. For the RME case, the maximum sediment concentrations of COPCs in Cold Spring Brook Pond were used. These values are provided in Table 9-29.

Table 9-29

**EXPOSURE POINT CONCENTRATIONS
COLD SPRING BROOK POND SEDIMENTS**

Parameter	Average Sediment Concentration (mg/kg)	Carbon-Normalized Average Sediment Concentration (mg/kg C)	Maximum Sediment Concentration (mg/kg)	Carbon-Normalized Maximum Sediment Concentration (mg/kg C)
Landfill Contaminants				
Metals				
Arsenic	50.2	--	160	--
Pesticides				
DDD	0.42	6.87	1.290	12.8
DDE	0.079	1.79	0.202	4.56
PAHs				
Benzo(a)anthracene	0.68	10.7	4.31	42.7
Benzo(a)pyrene	0.93	14.5	5.96	59.0
Fluoranthene	2.48	30.5	14.7	145.6
Pyrene	2.21	29.5	15.3	151.5
Phenanthrene	0.84	13.1	5.88	58.2
Other Parameters				
Metals				
Chromium	14.9	--	38.3	--
Copper	11.1	--	34.9	--
Lead	90.0	--	345	--
Mercury	0.168	--	0.724	--
Nickel	6.62	--	26.3	--
Zinc	114.6	--	690	--

RC424

Source: Ecology and Environment, Inc., 1992

In addition, average and maximum levels of other parameters detected in sediments are provided.

The pond ecosystem as a whole was considered the affected environment for the risk assessment. Therefore, all of the sediment samples taken from locations throughout Cold Spring Brook Pond were used to calculate EPCs. The EPCs calculated in this way would apply to exposures for any ecological receptor located anywhere in the pond. The average case would apply to those receptors ranging throughout the pond or randomly placed within the pond. The RME case would apply to organisms ranging within the most highly contaminated part of the pond.

9.4.3.3 Exposure Scenarios and Pathways

For aquatic biota, the principal route of uptake for arsenic is from the water and sediment, although bioaccumulation through the food chain may also occur. For DDD/DDE bioaccumulation through food is a greater concern. PAHs are readily metabolized by fish and are not likely to bioaccumulate through the aquatic food chain.

Since the levels of surface water COPCs were low in comparison to the levels in sediments, the transfer of COPCs from sediments to benthic animals and rooted aquatic macrophytes were considered to be the primary pathways for COPCs to enter the food chain.

Exposure of benthic invertebrates and macrophytes to sediment-bound contaminants occurs mainly through partitioning of contaminants between particulate sediment and dissolved (interstitial water) phases and subsequent uptake of bioavailable forms from the dissolved phase. Therefore, the development of quantitative estimates of exposure to COPCs for ecological receptors in Cold Spring Brook Pond was based on the application of simple partitioning models. These models provide a predictive method for evaluating bioaccumulation of contaminants at the site.

For metals, as described in Section 9.3.3.3, the model involves the derivation of a bioaccumulation factor (BAF) from published values of metals concentrations in aquatic plants, invertebrates, fish, and sediments (Lee 1992):

BAF = metal (tissue)/metal (sediment)

BAF values for arsenic in Cold Spring Brook Pond were calculated as described in Section 9.3.3.3.

For PAHs, interim sediment criteria have been developed based on the equilibrium partitioning (EP) approach. The EP approach is based on the assumption that (1) partitioning of neutral organic contaminants between particulate sediment and interstitial water phases is controlled by the organic carbon content of the sediment; and (2) toxicity and accumulation of contaminants by benthic organisms is related principally to interstitial water concentrations (USEPA 1989g). The method, as applied to the protection of benthic organisms, may not account for bioaccumulation in the food chain. However, since PAHs are metabolized by fish and do not bioaccumulate to an appreciable degree, the risk assessment for PAHs is restricted to benthic invertebrates and fish that interact with sediments. Estimated exposure concentrations for five PAHs are provided in Table 9-29 (the average and maximum carbon-normalized EPCs).

An interim sediment criterion has also been developed for DDT using the EP approach. However, this value was not used as an indicator of toxicity of DDD and DDE. Rather, an EP bioaccumulation model was applied to estimate DDD/DDE tissue residues in fish and invertebrates. This was done to allow evaluation of fish consumption in the human health risk assessment. The data were also applied to evaluation of risks to fish and fish-eating wildlife using the exposure scenarios already developed for evaluation of arsenic. The exposure estimates developed using this approach should be more indicative of food chain exposures at the site than the interim sediment criterion for DDT, which is derived from water exposure only (USEPA 1989g).

The EP bioaccumulation model for estimating tissue residues of nonpolar organic contaminants is discussed by Lee (1992), Bierman (1990), and Lake et al. (1990), among other references. The model is:

$$C_t = (AF)\ (C_s/TOC)\ (L)$$

where

C_t = contaminant concentration in tissue (dry weight)
C_s = contaminant concentration in sediment (dry weight)
TOC = total organic carbon
L = fraction of lipids in tissue
AF = accumulation factor (gC/gL)

Accumulation Factors (AFs) are conversion factors that account for the equilibrium partitioning of contaminants in lipids and sediment carbon. Multiplication of the carbon-normalized contaminant concentration by the AF predicts the lipid-normalized tissue residue. AFs differ from BAFs in that the latter are not normalized for lipids or for sediment carbon. A theoretical value of AF = 1.7 has been derived from thermodynamic considerations, but experimentally-derived AFs vary somewhat among compounds (Lee 1992). AFs for DDD and DDE have been experimentally derived, and mean AF values are provided in Lee (1992) as follows: AF = 2.1 for DDD, AF = 1.3 for DDE. L was assumed equal to 2 percent, considered a representative value for forage fish and benthic invertebrates. Tissue contaminant concentrations were converted from dry weight to wet weight by assuming that dry weight is 15 percent of wet weight (Bierman 1990).

Although the published AFs were derived for benthic invertebrates, the values may also be used for fish. Forage fish and benthic invertebrates have been shown to not differ significantly in their bioaccumulation of neutral organic contaminants from sediments (Bierman 1990).

In addition to the food chain pathway, direct ingestion and dermal contact with sediment are potential pathways for exposure to COPCs in Cold Spring Brook Pond. It was not considered necessary to evaluate this pathway separately for fish and benthic invertebrates because ingestion and contact with sediment by benthic invertebrates and fish are incorporated into the BAFs and AFs for those receptors.

The direct ingestion and dermal contact pathways were not quantitatively evaluated for mammals and birds because the majority of the risks for these receptors are presumed to be accounted for through the food chain pathway, and data are not readily available for calculating exposures for wildlife through sediment ingestion and dermal contact pathways. However, direct ingestion and dermal contact were evaluated for the human health risk assessment, and those results were used to qualitatively evaluate risks to wildlife.

For arsenic, quantitative food chain exposure scenarios were developed for the six semi-aquatic and terrestrial animal indicator species: green frog, painted turtle, muskrat, raccoon, great blue heron, and mallard. For DDD/DDE, the quantitative food chain exposure scenario for great blue heron was evaluated. The risk assessment for DDD/DDE was limited to the great blue heron, a fish-eating bird, because risks of bioaccumulation from fish were considered the only pathway of concern for such low levels of DDD/DDE contamination. Fish-eating birds are known to be sensitive receptors for environmental DDT contamination (see next section).

The exposure scenarios for the indicator species were described in Section 9.3.3.3. Values for input variables were not changed with the exception of some of the site use factors (raccoon and great blue heron), which were reduced due to the smaller size of the Cold Spring Brook site. The site use factor for the raccoon was reduced from 20 percent to 15 percent, and the site use factor for the great blue heron was reduced from 50 percent to 30 percent.

The estimated average and maximum exposures based on these scenarios are provided in Table 9-30 for arsenic and Table 9-31 for DDD and DDE. The sediment EEs presented in Table 9-31 are normalized for organic carbon. Carbon-normalized values were derived by dividing the contaminant concentrations at each sample location by their respective level of Total Organic Carbon.

9.4.4 Ecological Effects Assessment

In this section, the potential adverse effects of the COPCs at the Cold Spring Brook Landfill site are identified and endpoint concentrations for indicator species are tabulated. The known effects of COPCs are generally described in Section 9.4.4.1. Toxicity values

Table 9-30

**ESTIMATED EXPOSURES TO ARSENIC FOR SELECTED INDICATOR SPECIES
COLD SPRING BROOK LANDFILL**

Indicator Species	Receptor	Case	Diet (mg/kg Diet/day)	Body Weight (mg/kg BW/day)	Tissue Residue (mg/kg BW)	Sediment (mg/kg)
Bluegill	Adult/Juvenile	RME	--	--	6.1	--
		Average	--	--	1.9	--
Water marigold	--	RME	--	--	33.6	160
		Average	--	--	10.5	50.2
Dragonfly	Larval	RME	--	--	--	160
		Average	--	--	--	50.2
Green frog	Adult	RME	16	2.2	--	--
		Average	5.1	0.69	--	--
Painted turtle	Adult	RME	22	1.5	--	--
		Average	6.9	0.46	--	--
Muskrat	Adult	RME	39	2.0	--	--
		Average	12	0.64	--	--
Raccoon	Adult	RME	2.6	0.07	--	--
		Average	0.81	0.02	--	--
Mallard	Adult	RME	24	1.7	--	--
		Average	7.5	0.55	--	--
Great blue heron	Adult	RME	2.3	0.15	--	--
		Average	0.73	0.05	--	--

RC424

Source: Ecology and Environment, Inc. 1992.

Table 9-31

**ESTIMATED EXPOSURES TO DDD AND DDE FOR SELECTED INDICATOR SPECIES
COLD SPRING BROOK LANDFILL**

Indicator Species	Receptor	Case	Diet (mg/kg Diet/day)	Body Weight (mg/kg BW/day)	Tissue Residue (mg/kg BW)	Sediment (mg/kg C)
DDD						
Bluegill	Adult/	RME	--	--	3.6	--
	Juvenile	Average	--	--	1.9	--
Dragonfly	Larval	RME	--	--	3.6	12.8
		Average	--	--	1.9	6.9
Great blue heron	Adult	RME	1.1	.07	--	--
		Average	.57	.04	--	--
DDE						
Bluegill	Adult/	RME	--	--	0.79	--
	Juvenile	Average	--	--	0.31	--
Dragonfly	Larval	RME	--	--	0.79	4.6
		Average	--	--	0.31	1.8
Great blue heron	Adult	RME	0.24	0.02	--	--
		Average	0.09	0.01	--	--

RC424

Source: Ecology and Environment, Inc. 1992.

for critical effects of COPCs on indicator species are then identified from published sources and tabulated in Section 9.4.4.2.

9.4.4.1 Ecological Effects Summaries

This section discusses the acute and chronic toxicity of contaminants of concern in the sediment to freshwater invertebrates, fish, and plants. The tendency of COPCs to bioconcentrate or bioaccumulate and their effect on higher trophic levels are also discussed.

For the purpose of this report, salient toxicity information for each of the contaminants of concern is summarized below.

Arsenic

The ecological effects of arsenic are summarized in Section 9.3.4.1.

DDD

The available information for DDD indicates that acute toxicity to freshwater aquatic life occurs at concentrations as low as 0.6 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of DDD to sensitive freshwater aquatic life (USEPA 1980; WHO 1989).

The sublethal effects of DDD to aquatic organisms include impairment of reproduction and development, cardiovascular modifications, neurological changes, changes in development and behavior, and biochemical alterations.

Information on the sensitivity of aquatic plant species, including algae, to DDD is limited. However, studies with freshwater algae have shown a wide range of sensitivity (USEPA 1980). DDT and its metabolites (e.g., DDD and DDE) have been found to reduce photosynthesis. Sublethal effects of DDD in mammals are numerous and include teratogenicity, mutagenicity, and carcinogenicity. In birds, DDD can lower the reproductive rate of birds by causing eggshell thinning and by causing embryo deaths. However, different groups of birds vary greatly in their sensitivity.

Bioaccumulation is an important fate process for DDD in aquatic systems; based on the structural similarities to DDT, bioconcentration factors (BCFs) for DDD range from 10^3 to 10^5. DDT and its metabolites are known to biomagnify in food chains.

DDE

Published information for DDE indicates that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,050 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No information is available concerning the chronic toxicity of DDE to sensitive freshwater aquatic life (USEPA 1980; WHO 1989).

Both the acute and chronic toxicities of DDE vary between species of aquatic organisms. Early life stages (e.g., egg and larval) are more sensitive than adults. Sublethal toxic effects include impairment of reproduction and development, cardiovascular modifications, and neurological changes. Daphnia reproduction is adversely affected by DDE.

DDE, DDD, and DDT have been found to reduce photosynthesis in sensitive aquatic plants. However, the information available is very limited (WHO 1989).

Although DDE is toxic to fish, the exact mode of action in fish remains unclear. Interference with both membrane function and enzyme systems have been suggested as possible explanations. However, experiments have shown that DDT and its metabolites (e.g., DDD and DDE) affects the normal function of so many systems that the primary action is difficult to assess.

Similarly, as summarized for DDD, the sublethal effects of DDE to mammals are numerous and include teratogenicity, mutagenicity, carcinogenicity, and possible synergism and/or antagonism.

One of the most widely reported effects of DDE is eggshell thinning, particularly in predatory species. It has been shown that DDE residues in birds and their eggs reduced the rate of recovery of affected raptor populations.

Bioaccumulation is an important fate process of DDE in aquatic systems and based on structural similarities to DDT, field studies, and microcosm experiments, bioconcentration factors (BCFs) for DDE are in the range of 10^4 to 10^5. DDT and its metabolites are known to biomagnify in food chains.

Polynuclear Aromatic Hydrocarbons (PAHs)

As summarized by ATSDR (1991), evidence exists to indicate that certain PAHs in the environment are carcinogenic to wildlife. Results from animal studies indicate that target organs or systems known to be affected include the hematopoietic and lymphoid systems, and perhaps other proliferating tissues, such as gonads and intestinal epithelium.

Several studies on freshwater invertebrates and lower vertebrates have shown that PAHs can produce cancer-like growths and cause teratogenetic and mutagenic effects. Fish exposed to hydrocarbon-contaminated sediments showed a significant number of liver tumors. It appeared that these fish had absorbed PAHs from the sediment (USEPA 1982b). Data from toxicity bioassays are available from several studies that indicate the general concentration ranges of PAHs that causes toxic effects (acute and chronic).

Reports have shown that PAHs at low concentrations tend to promote growth in bacteria and freshwater algae and can bioaccumulate in plants, aquatic organisms, and wildlife from intake of contaminated water, sediment, and food. Extensive metabolism of the compounds by high-trophic level consumers has been demonstrated; therefore, food chain biomagnification of the compounds does not appear to be significant.

9.4.4.2 Toxicity Benchmark Values

Toxicity benchmark values for the indicator species at the Cold Spring Brook Landfill site are of four general types:

- o Diet residue values for COPC concentrations in food items causing adverse chronic effects, expressed in units of mg chemical/kg diet/day;
- o Dose levels in food causing adverse chronic effects, expressed in units of mg chemical/kg body weight/day;
- o Tissue residues associated with adverse chronic effects, expressed in units of mg chemical/kg tissue; and
- o Sediment values associated with adverse chronic effects, expressed in units of mg chemical/kg sediment.

The toxicity benchmark values for each indicator species are provided for arsenic in Table 9-32 and for DDD/DDE in Table 9-33. Interim sediment quality criteria for PAHs are provided in Table 9-34.

For completeness, additional toxicity benchmark values for sediments are provided in Table 9-35. These values are derived from a database of contaminant effects on benthic invertebrates in both freshwater and marine sediments, and may not be indicative of effects in Cold Spring Brook Pond. The benchmark values are provided for COPCs as well as for additional parameters detected in the sediments, but not selected as COPCs.

Toxicity benchmark values were generally derived in a conservative fashion by considering less than the lowest observed effect levels (LOELs) for effects of chronic exposure on species of concern. Values for the most sensitive surrogate species were used if values were unavailable for the indicator species. In some cases, safety factors were used as indicated in Table 9-32 and Table 9-33. The use of these factors and their numerical values were based on best professional judgment and the general guidelines provided by the USEPA (1986f).

Despite a thorough literature review, few reliable values for arsenic and DDD/DDE were found. Nevertheless, the values given in Tables 9-32 and 9-33 are considered sufficiently authoritative for use

Table 9-32

TOXICITY BENCHMARK VALUES FOR SELECTED INDICATOR SPECIES - ARSENIC

Indicator Species	Receptor	Diet Residue (mg/kg Diet)	Dose (mg/kg BW)	Tissue Residue (mg/kg BW)	Sediment (mg/kg)	Critical Effects	Reference
Bluegill	Adult	—	—	5.0	—	Diminished growth and survival	NRCC 1978[a]
	Juvenile	—	—	1.3	—	Diminished growth and survival	NRCC 1978[a]
Water marigold	—	—	—	20	—	Critical level in tops of rice	Chino 1981[b]
Dragonfly	Larval	—	—	—	33	Limit of tolerance	See Table 9-4
Green frog/ Painted turtle	Adult	60	—	—	—	Growth depression, impaired feeding in rainbow trout, multiplied by Safety Factor = 0.5	Cockell and Hilton 1985[a]
Muskrat/Raccoon	Adult	5	1	—	—	Death or malformations in mammals, various species, chronic exposure	Eisler 1988
Mallard/Great blue heron	Adult	180	—	—	—	Maximum safe level in diets, domestic poultry, arsenic feed additives	NAS 1977[a]
		—	64.6	—	—	Mallard LD-50, multiplied by Safety Factor = 0.2	Eisler 1988
		—	—	10	—	Resides in liver or kidney; considered indicative of poisoning	Goede 1985[a]

RC424

[a]Eisler 1988.
[b]Adriano 1986.

Table 9-33

TOXICITY BENCHMARK VALUES FOR SELECTED INDICATOR SPECIES - DDD AND DDE

Indicator Species	Receptor	Diet Residue (mg/kg Diet)	Dose (mg/kg BW)	Tissue Residue (mg/kg BW)	Sediment (mg/kg C)	Critical Effects	Reference
DDD							
Bluegill	Juvenile	—	—	2.4	—	Related to death of lake trout fry (DDT)	WHO 1989
Dragonfly	Larval	—	—	—	9.0	Limit of tolerance	Persaud 1989
Great blue heron	Adult	89	—	—	—	Pheasant LC-50, multiplied by Safety Factor = 0.2	WHO 1989
DDE							
Bluegill	Juvenile	—	—	2.4	—	Related to death of lake trout fry (DDT)	WHO 1989
Dragonfly	Larval	—	—	—	21.3	Limit of tolerance	Persaud 1989
Great blue heron	Adult	0.3	—	—	—	No observable effect level, American kestrel eggshell thickness	Lincer 1975[a]

RC424

[a]WHO 1989.

Table 9-34

TOXICITY BENCHMARK VALUES FOR BENTHIC AQUATIC BIOTA - PAHs

Compound	Interim Sediment Quality Criterion (mg/kg C)
Benzo(a)anthracene	1,317
Benzo(a)pyrene	1,063
Fluoranthene	1,883
Pyrene	1,311
Phenanthrene	139

RC424

Source: USEPA 1989g.

Table 9-35

TOXICITY BENCHMARK VALUES FOR BENTHIC INVERTEBRATES
COLD SPRING BROOK POND SEDIMENTS

Parameter	Sediment ER-L (mg/kg)	Sediment ER-M (mg/kg)
Landfill Contaminants		
Metals		
Arsenic	33	85
Pesticides		
DDD	0.002	0.02
DDE	0.002	0.015
PAHs		
Benzo(a)anthracene	0.23	1.6
Benzo(a)pyrene	0.4	2.5
Fluoranthene	0.6	3.6
Pyrene	0.35	2.2
Phenanthrene	0.225	1.38
Other Parameters		
Metals		
Chromium	80	145
Copper	70	390
Lead	35	110
Mercury	0.15	1.3
Nickel	30	60
Zinc	120	270

RC424

Source: Compiled by Ecology and Environment, Inc., 1992 in this screening-level risk assessment. In particular, the No Observed Effect Level (NOEL) for eggshell thinning of 0.3 mg/kg DDE is more than 1 order of magnitude lower than the LOEL of 10 mg/kg for ducks (WHO 1989), and is likely to be protective of ducks as well as the great blue heron.

9.4.4.3 Field Observations of Stress

During the August 1991 field survey, no observations were made of stressed vegetation or other obvious signs of impacts of the landfill.

9.4.5 Risk Characterization

In this section, the ecological risks posed by COPCs at the Cold Spring Brook Landfill site are identified and summarized. In Section 9.4.5.1, risks are quantified using hazard index (HI) ratios calculated from estimated exposure and toxicity benchmark values for each receptor. The risks are then summarized and the principal uncertainties of the risk assessment are discussed in Section 9.4.5.2. The ecological significance of the findings is discussed in Section 9.4.5.3.

9.4.5.1 Hazard Index Ratios

The risks of site contamination were quantified by calculating an HI ratio for each COPC, pathway, receptor, and case that could be quantitatively evaluated. In addition, HIs were calculated for each critical effect that could be quantitatively evaluated on a dietary, body weight, tissue residue, or sediment basis. The HIs were calculated as follows:

$$HI = EE/TB,$$

where:

HI = hazard index,
TB = toxicity benchmark value, and
EE = estimated exposure.

Toxicity benchmark values were derived in the toxicity assessment. Estimated exposures were derived in the exposure assessment. The HIs for arsenic are provided in Table 9-36, the HIs for DDD/DDE are provided in Table 9-37, and the HIs for PAHs are provided in Table 9-38. The HIs for benthic invertebrates, calculated using the Long and Morgan benchmarks, are provided in Table 9-39.

An HI greater than 1 would be considered presumptive evidence for a risk of adverse chronic effects of a chemical on a given ecological receptor for a given case, a given pathway, and a given critical effect.

Table 9-36

**HAZARD INDEX RATIO VALUES FOR INDICATOR SPECIES - ARSENIC
COLD SPRING BROOK LANDFILL**

Indicator Species	Receptor	Case	Basis			
			Diet	Body Weight	Tissue Residue	Sediment
Bluegill	Adult	RME	--	--	1.2	--
		Average	--	--	0.4	--
	Juvenile	RME	--	--	4.7	--
		Average	--	--	1.5	--
Water marigold	--	RME	--	--	1.7	--
		Average	--	--	0.5	--
Dragonfly	Larval	RME	--	--	--	4.8
		Average	--	--	--	1.5
Green frog	Adult	RME	0.3	--	--	--
		Average	0.1	--	--	--
Painted turtle	Adult	RME	0.4	--	--	--
		Average	0.1	--	--	--
Muskrat	Adult	RME	7.8	2.0	--	--
		Average	2.5	0.6	--	--
Raccoon	Adult	RME	0.5	0.07	--	--
		Average	0.2	0.02	--	--
Mallard	Adult	RME	0.1	0.03	--	--
		Average	0.04	0.01	--	--
Great blue heron	Adult	RME	0.01	0.002	--	--
		Average	0.004	0.001	--	--

RC424

Note: Hazard index ratio values are unitless.

Source: Ecology and Environment, Inc. 1992.

Table 9-37

**HAZARD INDEX RATIO VALUES FOR INDICATOR SPECIES – DDD/DDE
COLD SPRING BROOK LANDFILL**

Indicator Species	Receptor	Case	Basis: Diet	Body Weight	Tissue Residue	Sediment
DDD						
Bluegill	Juvenile	RME	--	--	1.5	--
		Average	--	--	0.8	--
Dragonfly	Larval	RME	--	--	--	1.4
		Average	--	--	--	0.8
Great blue heron	Adult	RME	0.012	--	--	--
		Average	0.006	--	--	--
DDE						
Bluegill	Juvenile	RME	--	--	0.3	--
		Average	--	--	0.1	--
Dragonfly	Larval	RME	--	--	--	0.2
		Average	--	--	--	0.1
Great blue heron	Adult	RME	0.8	--	--	--
		Average	0.3	--	--	--

RC424

Note: Hazard index ratio values are unitless.

Source: Ecology and Environment, Inc. 1992.

Table 9-38

**HAZARD INDEX RATIO VALUES FOR BENTHIC AQUATIC BIOTA - PAHs
COLD SPRING BROOK LANDFILL**

Compound	Case	Sediment Quality Criterion Basis
Benzo(a)anthracene	RME	0.03
	Average	0.01
Benzo(a)pyrene	RME	0.06
	Average	0.01
Fluoranthene	RME	0.08
	Average	0.02
Pyrene	RME	0.12
	Average	0.02
Phenanthrene	RME	0.42
	Average	0.09

RC424

Source: Ecology and Environment, Inc. 1992.

Table 9-39

**HAZARD INDEX RATIO VALUES FOR BENTHIC INVERTEBRATES
COLD SPRING BROOK LANDFILL**

Parameter	Case	ER-L Ratio	ER-M Ratio
Landfill Contaminants			
Metals			
Arsenic	RME	4.85	1.88
	Average	1.52	0.59
Pesticides			
DDD	RME	645.0	64.5
	Average	210.0	21.0
DDE	RME	101.0	13.47
	Average	39.5	5.27
PAHs			
Benzo(a)anthracene	RME	18.74	2.69
	Average	2.96	0.43
Benzo(a)pyrene	RME	14.90	2.38
	Average	2.33	0.37
Fluoranthene	RME	24.50	4.08
	Average	4.13	0.69
Pyrene	RME	43.71	6.95
	Average	6.31	1.00
Phenanthrene	RME	26.13	4.26
	Average	3.73	0.61
Other Parameters			
Metals			
Chromium	RME	0.48	0.26
	Average	0.19	0.10
Copper	RME	0.50	0.09
	Average	0.16	0.03
Lead	RME	9.86	3.14
	Average	2.57	0.82
Mercury	RME	4.83	0.56
	Average	1.12	0.13
Nickel	RME	0.88	0.44
	Average	0.22	0.11
Zinc	RME	5.75	2.56
	Average	0.96	0.42

RC424

Source: Compiled by Ecology and Environment, Inc. using Long and Morgan (1990)

9.4.5.2 Summary of Risks and Uncertainties

HIs greater than 1 for arsenic are summarized in Table 9-40, and HIs greater than 1 for DDD/DDE are summarized in Table 9-41. These and other risks are summarized as follows:

- o For arsenic in pond sediments, food chain or direct exposures presumed to result in adverse effects are evident for bluegill, water marigold, dragonfly, and muskrat. No risks from arsenic are presumed for any of the other indicator species or pathways.

- o For DDD in pond sediments, exposures presumed to result in adverse effects are evident for bluegill and dragonfly (RME case only). No risks from DDD are presumed for these indicator species for the average case, and no risks are presumed for great blue heron. No risks from DDE are presumed for any of the indicator species or pathways.

The principal uncertainties of the ecological risk assessment are associated with the exposure assessment, toxicity assessment, and risk characterization.

The principal uncertainty in the exposure assessment has to do with estimating the bioavailable fraction of arsenic and DDE in sediments. The estimates provided are based on published BAF and AF values, which vary considerably and may not accurately represent conditions in Cold Spring Brook Pond. Additional uncertainties arise from a lack of information about direct ingestion and dermal pathways for wildlife. Moreover, each of the input variables used to derive estimated exposures for the food chain pathway were subject to uncertainty. Generally, the worst case was assumed to provide a conservative estimate.

Few reliable toxicity values were available for sediments and for the effects of the COPCs on wildlife. Considerable uncertainties are inherent in the extrapolation of toxicity values derived from laboratory studies to field situations and from the extrapolation of values from surrogate species to species of concern. As with the exposure assessment, reasonable worst case assumptions were made to provide a conservative estimate.

In general, the risk assessment is likely to overestimate rather than underestimate the risks of adverse ecological effects at the site, because of the conservative nature of the assumptions used.

9.4.5.3 Ecological Significance

The sediments of Cold Spring Brook Pond are contaminated with elevated levels of arsenic, and low levels of DDD/DDE and PAHs. These COPCs can be related to the Cold Spring Brook Landfill as a likely or possible source. Risks of adverse effects on aquatic and some semi-aquatic biota are presumed from the levels of arsenic found in the

Table 9-40

SUMMARY OF RISKS FOR INDICATOR SPECIES - ARSENIC
COLD SPRING BROOK LANDFILL

Indicator Species/ Receptor	Case	Pathway: Food Ingestion Basis: Diet Residue	Food Ingestion Body Weight	Sediment - Dermal Contact Human Risk	Sediment - Ingestion Human Risk	All Pathways Tissue Residue	All Pathways Sediment
Bluegill/Adult	RME	-	-	-	-	+	-
	Average	-	-	-	-	0	-
Bluegill/Juvenile	RME	-	-	-	-	+	-
	Average	-	-	-	-	+	-
Water Marigold	RME	-	-	-	-	+	-
	Average	-	-	-	-	0	-
Dragonfly/Larval	RME	-	-	-	-	-	+
	Average	-	-	-	-	-	+
Greenfrog/Adult	RME	0	-	-	-	-	-
	Average	0	-	-	-	-	-
Painted Turtle/Adult	RME	0	-	-	-	-	-
	Average	0	-	-	-	-	-
Muskrat/Adult	RME	+	+	0	+	-	-
	Average	+	0	0	+	-	-
Raccoon/Adult	RME	0	0	0	+	-	-
	Average	0	0	0	+	-	-
Mallard/Adult	RME	0	0	-	-	-	-
	Average	0	0	-	-	-	-
Great Blue Heron/Adult	RME	0	0	-	-	-	-
	Average	0	0	-	-	-	-

RC424

Key:

+ = Risks of adverse effects are presumed.
0 = No risks presumed.
- = Pathway not evaluated.

Table 9-41

SUMMARY OF RISKS FOR INDICATOR SPECIES - DDD/DDE
COLD SPRING BROOK LANDFILL

Indicator Species/ Receptor	Case	Pathway: Basis:	Food Ingestion: Diet Residue	Food Ingestion: Body Weight	Sediment - Dermal Contact: Human Risk	Sediment - Ingestion: Human Risk	All Pathways: Tissue Residue	All Pathways: Sediment
DDE								
Bluegill/Juvenile	RME		-	-	-	-	+	-
	Average		-	-	-	-	0	-
Dragonfly/Larval	RME		-	-	-	-	-	+
	Average		-	-	-	-	-	0
Great blue heron/Adult	RME		0	-	-	-	-	-
	Average		0	-	-	-	-	-
DDE								
Bluegill/Juvenile	RME		-	-	-	-	0	-
	Average		-	-	-	-	0	-
Dragonfly/Larval	RME		-	-	-	-	-	0
	Average		-	-	-	-	-	0
Great blue heron/Adult	RME		0	-	-	-	-	-
	Average		0	-	-	-	-	-

RC424

Key:

+ = Risks of adverse effects are presumed.
0 = No risks presumed.
- = Pathway not elevated.

pond sediments. Lesser risks to some aquatic biota, mainly fish and benthic invertebrates, are presumed from the levels of DDD/DDE in the sediments. PAHs are elevated in the sediments, but not at levels likely to adversely affect benthic aquatic life.

The comparisons of contaminant levels to the Long and Morgan (1990) benchmark values indicates HIs greater than 1 for PAHs and DDE (see Table 9-39), whereas these ratios were less than 1 using carbon-normalized benchmarks (see dragonfly HI values in Tables 9-37 and HIs for benthic invertebrates in Table 9-38). This is believed to result from the high degree of binding of contaminants to organic carbon in Cold Spring Brook, which is not accounted for by the Long and Morgan values. In addition, several metals that did not exceed background at more than one sample location nevertheless exceed their respective Long and Morgan benchmarks, in some cases. These exceedances are not likely to be ecologically significant.

The pond sediment COPCs are not of concern in terms of bioaccumulation in the terrestrial food chain. Most birds do not appear to be at risk from exposure to pond sediment COPCs. Apex predators should not be adversely affected by the direct toxic effects of pond contaminants, including DDD/DDE, which are known to biomagnify in the terrestrial food chain. The potential adverse effects of COPCs on benthic invertebrates and other aquatic biota could indirectly impact higher trophic levels by degrading the abundance of their food source. These indirect effects of COPCs are not likely to be significant, but they cannot be ruled out with the present information.

Although the risk assessment identifies risks of potential adverse effects of COPCs on the Cold Spring Brook Pond ecosystem, a variety of factors are considered likely to mitigate the toxicity of the COPCs under the prevailing environmental conditions. In particular, the high TOC, high iron, neutral pH, and rich nutrient status of the pond would be expected to decrease the bioavailability of some of the sediment-bound COPCs. The risks presented in this report are likely to represent a worst case scenario, but further investigation is warranted.

Finally, soil contamination from low levels of metals, DDT, and PAHs do not appear to be of concern to ecological receptors.

9.5 CONCLUSIONS AND RECOMMENDATIONS

9.5.1 Shepley's Hill Landfill

The ecological risk assessment for Shepley's Hill Landfill identified potential risks of sediment contamination to the Plow Shop Pond aquatic ecosystem. The site-related risks are mainly a result of elevated arsenic concentrations in the pond sediments. Cadmium, barium, and manganese levels could also adversely affect benthic invertebrates in the pond. In addition, limited evidence suggests that trees growing near the pond may be adversely affected by groundwater seepage of metals from the landfill.

Many uncertainties are inherent to the ecological risk assessment for the Shepley's Hill Landfill site, and further investigation of the site is recommended to determine the potential effects of site-related contamination on ecological receptors. In particular, sampling and analysis of fish and aquatic plants would provide a more direct measure of exposure of ecological receptors to COPCs in Plow Shop Pond. The chemical forms of arsenic in sediments and tissues should also be investigated. Potential impacts of metals on the benthic community should also be investigated through sediment toxicity testing and field surveys of benthic community composition, for example.

Finally, migration of contaminants from the site to downgradient areas appears to be of limited concern, since the Nonacoicus Brook samples were relatively uncontaminated. Upland terrestrial species are also likely to be unaffected by site contaminants.

9.5.2 Cold Spring Brook Landfill

The ecological risk assessment for Cold Spring Brook Landfill identified potential risks of sediment contamination to the Cold Spring Brook Pond aquatic ecosystem. The site-related risks are mainly a result of elevated arsenic concentrations in the pond sediments. The arsenic concentrations in Cold Spring Brook Pond are considerably lower than the levels of arsenic in Plow Shop Pond, however, and risks are correspondingly reduced. The levels of DDD in the pond sediments could potentially impact benthic invertebrates and fish in the pond.

Many uncertainties are inherent to the ecological risk assessment for the Cold Spring Brook Landfill site, and further investigation of the site is recommended to determine the potential effects of site-related contamination on ecological receptors. Some of the sampling activities recommended for Plow Shop Pond would also be appropriate for Cold Spring Brook Pond.

Finally, migration of contaminants from the site to downgradient areas appears to be of limited concern, since the Cold Spring Brook sample taken below Patton Road was relatively uncontaminated. Upland terrestrial species are also likely to be unaffected by site contaminants.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 SHEPLEY'S HILL LANDFILL

10.1.1 Human Health Risk

Investigative activities during the RI have essentially confirmed the conceptual model of Shepley's Hill Landfill derived from previous studies, but have better defined the scope and degree of impact of the site on the environment. The major new conclusions concern the impact of the site upon sediments in the adjoining Plow Shop Pond, which are shown to have elevated levels of arsenic, barium, cadmium, iron, and manganese apparently principally derived from the landfill. All of these metals except iron are contaminants of potential concern. The site contaminants estimated to pose potential excess lifetime cancer risks greater than the 10^{-6} benchmark include arsenic, beryllium, benzene, chloroform, 1,2-dichloroethane, dichloromethane, dieldrin, heptachlor, alpha-hexachlorocyclohexane, PCBs, 1,1,2,2-tetrachloroethane, and vinyl chloride. Site contaminants that pose potentially significant noncarcinogenic adverse health effects include arsenic, cadmium, chromium, and manganese.

Under existing site conditions, estimated potential excess cancer risks ranged from 7×10^{-5} to 2×10^{-3}, and the estimated hazard indices ranged from 1.0 to 40. Consumption of potentially contaminated fish from Plow Shop Pond was responsible for the greatest estimated cancer and noncancer risks. Although the estimated risks to adolescents coming in contact with contaminated sediment along the shore of the pond was about 10 times lower than the estimated risks of eating fish, the risks exceeded the benchmark level of 10^{-6}. Greater than 99 percent of all of the estimated cancer risks were due to arsenic in the sediment and in fish tissue. Arsenic also accounted for about 85 percent of the estimated noncancer risk from eating fish and 93 percent of the sediment contact risk. The remaining 15 percent of the noncancer fish consumption risk was due to cadmium. Cadmium and manganese each accounted for 3 percent of the sediment contact risk.

If future residential use of areas near the landfill is assumed, including use of the groundwater as a drinking water source, the total estimated potential excess cancer risks for receptors range from about 3×10^{-4} to about 2×10^{-2}, and the estimated hazard indices range from 3.9 to 85. The estimated risks associated with fish consumption are the same as for existing conditions. The estimated risks from contact with contaminated sediment along the shore of Plow Shop Pond increased about threefold because of the greater frequency of contact assumed for adolescents living near the pond compared to those living nearby in Ayer, for example, and visiting the area occasionally to play. The greatest potential risks associated with residential use of the area are those arising from use of the groundwater as a drinking water source. Water ingestion accounts for greater than 99 percent of both the cancer and noncancer risks estimated for domestic water usage. Arsenic again accounted for the vast majority of these estimated risks, 94 percent to 95 percent of the cancer risks and 86 percent of noncancer risks; PCBs accounted for most of the remaining cancer risks; and cadmium (11 percent) and manganese (3 percent) accounted for the remaining noncancer risks.

The risks estimated for domestic use of contaminated groundwater were only about 10 percent to 35 percent lower when calculated using the metals concentrations adjusted to remove the contribution of suspended sediment than when calculated using the original unadjusted data. This is because many of the higher metals concentrations found in the groundwater appear to be due, at least in part, to actual contamination rather than suspended sediment. The major differences between the two data sets will be seen when assessing the areal extent of the actual contamination in planning potential remedial activities.

Lead and bromide were not included in the quantitative risk assessment because there are no RfDs or SFs available for these chemicals. There is a Safe Drinking Water Act (SDWA) action level for lead in drinking water of 15 µg/l, a level expected to avoid most of the significant adverse effects of lead in young children who are most sensitive to the effects of lead. Since the greatest exposure to lead in groundwater is likely to result from using this groundwater as drinking water, the action level is an appropriate criterion to use in assessing the lead concentrations in groundwater.

Using the original unadjusted groundwater data, one background well sample (SHL-23, Round 1) and 13 out of 26 samples from wells within the landfill's zone of influence had lead concentrations greater than 15 µg/l. Using the data adjusted to remove the effect of suspended sediment, no background well samples, and only 3 out of 26 samples from within the landfill's zone of influence (SHL-4, Round 1; SHL-12, Round 2; and SHL-19, Round 2) had lead concentrations greater than 15 µg/l. The lead concentrations in SHL-15, which is outside the landfill's zone of influence, also exceeded 15 µg/l in both adjusted and unadjusted results. The lead concentrations in SHL-13, one of the four remaining wells outside the landfill's zone of influence, exceeded 15 µg/l in the original data but not after the data were adjusted. From these results, it appears that lead concentrations in the groundwater at a few locations around the landfill could pose a significant risk to human health. Using the original data, the average and maximum lead concentrations within the zone of influence exceeded the action level by factors of about 2 and 13, respectively. Using the adjusted data, the average and maximum concentrations are 0.4 and 5 times the action level, respectively.

No suitable criteria could be located for use in evaluating bromide concentrations in the groundwater. However, comparison of the oral LD_{50} values reported in Sax and Lewis (1989) for sodium bromide and sodium chloride for rats, mice, and rabbits suggest that bromide is comparable in toxicity to chloride and that the concentrations of bromide found in the groundwater (up to 517 µg/l) are unlikely to result in any adverse health effects.

In order to help the reader put the estimated potential site-related arsenic exposures in perspective, the estimated arsenic intakes for each exposure pathway are compared to the estimated daily exposure for the general population. Under current site conditions, the estimated average site-related arsenic intakes were less than the estimated intake for the general population. For the RME case, the estimated intakes ranged from slightly less than that of the general population to about 7 times higher. Assuming future residential use of the landfill area, estimated site-derived arsenic intakes range from about 2 to about 27 times the estimated intake of the general population.

The estimates of potential site-related arsenic exposure are based on conservative (health protective) exposure assumptions, and for the RME case, the highest observed arsenic concentrations in environmental media. Therefore, the estimated site-related exposures almost certainly overestimate any actual exposures that might occur.

Based on the hydrology and the contaminant levels, the monitoring wells around Shepley's Hill Landfill were grouped into six categories, two of which showed significant contamination attributable to the landfill. These were, Group 1 (SHL-4, SHL-11, SHL-19, and SHL-20), at the eastern edge of the central portion of the landfill, between the landfill and the southwest corner of Plow Shop Pond; and Group 2 (SHL-5, SHL-9, SHL-21, and SHL-22), at the north end of the landfill. Group 3 wells (SHL-3, SHL-10, SHL-12, SHL-17, and SHL-18), south and southeast of the landfill, are within or close to the zone of influence of landfill leachate, but showed little significant impact. Group 4 consists of SHL-15, which is significantly contaminated but apparently not by the landfill. Group 5 consists of background wells such as SHL-6, SHL-23, SHL-24, and SHL-25, which are uninfluenced by the landfill. Group 6 wells, i.e., SHL-7, SHL-8 (deep), SHL-8 (shallow), and SHL-13 are hydrologically outside the influence of the landfill, but suggest impacts from other sources, which could be Plow Shop Pond for SHL-8 (deep), SHL-8 (shallow), and SHL-13.

The air survey conducted at the landfill did not indicate any releases above background, and the three surface soil samples at possible leachate sites showed no indication of contamination.

10.1.2 Ecological Risk

The ecological risk assessment for Shepley's Hill Landfill identified potential risks of sediment contamination to the Plow Shop Pond aquatic ecosystem. The site-related risks are mainly a result of elevated arsenic concentrations in the pond sediments. Cadmium, barium, and manganese levels could also adversely affect benthic invertebrates in the pond. In addition, limited evidence suggests that trees growing near the pond may be adversely affected by groundwater seepage of metals from the landfill.

Many uncertainties are inherent to the ecological risk assessment for the Shepley's Hill Landfill site, and further investigation of the site is recommended to determine the potential effects of site-related contamination on ecological receptors. In particular, sampling and analysis of fish and aquatic plants would provide a more direct measure of exposure of ecological receptors to COPCs in Plow Shop Pond. The chemical forms of arsenic in sediments and tissues should also be investigated. Potential impacts of metals on the benthic community should also be investigated through sediment toxicity testing and field surveys of benthic community composition, for example.

Finally, migration of contaminants from the site to downgradient areas appears to be of limited concern, since the Nonacoicus Brook samples were relatively uncontaminated. Upland terrestrial species are also likely to be unaffected by site contaminants.

10.1.3 Recommended Action

It is recommended that additional fieldwork be performed in order to confirm the results of the RI. The fieldwork should include the following:

- o redevelopment of the monitoring wells to produce water of low turbidity and resampling for metals to confirm the effect of suspended sediment on the levels of metals in the original groundwater samples,
- o sampling of sediments along the Plow Shop Pond shoreline adjacent to the landfill and analysis for metals and total organic carbon to allow adjusted risk assessments for this exposure pathway,
- o collection of fish samples from Plow Shop Pond to confirm or modify the bioaccumulation and fish consumption risk models, and
- o preparation of a feasibility study to identify and select appropriate remedies for the contamination attributable to the landfill.

10.2 COLD SPRING BROOK LANDFILL

10.2.1 Human Health Risk

Results of the water table and surface water level measurements at Cold Spring Brook Landfill have indicated that the groundwater under the landfill primarily discharges to the adjacent pond, but that some groundwater from under the west end of the fill is captured by the Patton Well, which is used by Fort Devens as a source of drinking water.

The site contaminants estimated to pose potentially significant excess lifetime cancer risks include arsenic, beryllium, 4,4'-DDD, 4,4'-DDE, and the carcinogenic PAHs. Site contaminants that pose significantly noncarcinogenic adverse health effects include arsenic, chromium, and manganese.

The sampling of the Patton Well shows that the arsenic found in the monitoring wells at Cold Spring Brook Landfill has had no detectable impact on water quality at the Patton Well, which shows a different group of metals and anions.

Under existing site conditions, total estimated potential excess cancer risks ranged from 7×10^{-7} to 5×10^{-5}, and the total estimated hazard indices ranged from 7×10^{-3} to 0.9. Since all hazard indices were less than 1, noncarcinogenic adverse health effects would not be expected under existing site conditions. Consumption of potentially contaminated fish from Cold Spring Brook Pond was responsible for the greatest estimated cancer risks. Although the estimated risks to adolescents coming in contact with contaminated sediment along the shore of the pond was about 10 times lower than the estimated risks of eating fish, the risks were still significant for the RME case. Most of the estimated cancer risks from fish consumption were due to arsenic (63 percent) and the remainder were due to pesticides. Arsenic also accounted for 57 percent of the estimated cancer risk from direct contact with sediment. The remaining 43 percent of the estimated cancer risk from sediment was due to ingestion of PAHs. Note that these risk estimates do not include cancer risks from dermal exposure to some PAHs, because no appropriate toxicity indices exist.

If future residential use of areas near the landfill is assumed, including use of the groundwater as a drinking water source, the total estimated potential excess cancer risks for receptors range from about 1×10^{-5} to about 6×10^{-3}, and the estimated hazard indices range from 0.1 to 39. The estimated risks associated with fish consumption by future residents are 10 times the risks under existing conditions. The estimated risks from contact with contaminated sediment along the shore of Cold Spring Brook Pond are 20 times the current risk. The higher estimated risks result from the greater frequency of contact assumed for future residents living in the area when compared to occasional site visitors. The greatest potential risks associated with residential use of the area are those arising from use of the groundwater as a drinking water source. Water ingestion accounts for greater than 99 percent of both the cancer and noncancer risks estimated for domestic water usage. Arsenic accounted for the vast majority of these estimated risks, 99 percent of the cancer risks and 88 percent to 93 percent of noncancer risks; beryllium accounted for most of the remaining cancer risks; and manganese (7 percent to 11 percent) and chromium (about 1 percent) accounted for the remaining noncancer risks.

There is a Safe Drinking Water Act (SDWA) action level for lead in drinking water of 15 µg/l, a level expected to avoid most of the significant adverse effects of lead in young children who are most sensitive to the effects of lead.

Using the original unadjusted groundwater data, two of four background well samples (both from CSB-7) and four out of eight samples from wells within the landfill's zone of influence had lead concentrations greater than 15 µg/l. Using the data adjusted to remove the effect of suspended sediment, no background well samples, and only one out of eight samples from within the landfill's zone of influence (CSB-3, Round 1) had a lead concentration greater than 15 µg/l. From these results it appears that lead concentrations in the groundwater at CSB-3 are slightly elevated and could potentially pose a significant risk to human health.

Surface soils on the landfill showed elevated levels of several metals and PAHs. Groundwater under the landfill historically showed elevated arsenic, and possibly manganese, chromium, copper, lead, and nickel, although only at the west end of the landfill. Surface water sample results implied that the landfill is contributing arsenic, iron, manganese, and sulfate to the pond. The sediments in the pond also showed levels of heavy metals, which implies that the landfill was contributing arsenic and manganese to the pond. Lead, mercury, and zinc were elevated in some sediment samples but the sources could not be definitely identified. Low levels of PAHs and pesticides were also noted in sediments.

The small size of the landfill (approximately 2.5 acres) and its failure to impact the water quality of an actively pumped water supply well sited within 800 feet of the west end of the fill implies that the worst-case scenario for risk from groundwater ingestion is very conservative. The same conclusion must be made about the ingestion of zinc from fish, since the area of the pond is only two acres and it is very shallow. Consequently, this pond is unlikely to supply the quantity of fish of edible size required to present the calculated risk under the scenario used.

10.2.2 Ecological Risk

The ecological risk assessment for Cold Spring Brook Landfill identified potential risks of sediment contamination to the Cold Spring Brook Pond aquatic ecosystem. The site-related risks are mainly a result of elevated arsenic concentrations in the pond sediments. The arsenic concentrations in Cold Spring Brook Pond are considerably lower than the levels of arsenic in Plow Shop Pond, however, and risks are correspondingly reduced. The levels of DDD in the pond sediments could potentially impact benthic invertebrates and fish in the pond.

Many uncertainties are inherent to the ecological risk assessment for the Cold Spring Brook Landfill site, and further investigation of the site is recommended to determine the potential effects of site-related contamination on ecological receptors. Some of the sampling activities recommended for Plow Shop Pond would also be appropriate for Cold Spring Brook Pond.

Finally, migration of contaminants from the site to downgradient areas appears to be of limited concern, since the Cold Spring Brook sample taken below Patton Road was relatively uncontaminated. Upland terrestrial species are also likely to be unaffected by site contaminants.

10.2.3 Recommended Action

It is recommended that the following actions be taken:

- an attempt be made to redevelop CSB-4 and to sample it for metals to confirm the historical data;
- a new 4-inch well be installed close to CSB-4, but installed through the low permeability material in which CSB-4 is screened into the sand and gravel aquifer beneath;
- the new well be developed until it produces water of consistently low turbidity, and then sampled and analyzed for metals, to obtain a better estimate of the expected water quality from a domestic well at this location;
- fish samples be collected from the pond to confirm bioconcentration; and
- a feasibility study be performed if remediation is found to be necessary.

Note: The new four-inch well will have to be drilled through fill material, and special precautions should be taken to grout surface casing at the base of the low permeability layer into which the CSB-4 well screen is installed before drilling deeper.

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