BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT REPORT

Wells G&H Superfund Site, Southwest Properties
Operable Unit 2
Woburn, Massachusetts

February 2006

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I
ONE CONGRESS STREET SUITE 1100
BOSTON, MASSACHUSETTS 02114-2023

February 9, 2006

See Attached Address List

RE: Baseline Risk Assessment for the Southwest Properties, dated March 2004, at the Wells G&H Superfund Site

Dear Recipients:

The U.S. Environmental Protection Agency (EPA) issued the Baseline Human Health and Ecological Risk Assessment (BRA) for the Southwest Properties of the Wells G&H Superfund Site on March 2004. Subsequent review of the results of the risk assessment noted an error with the human health toxicological factor for trivalent chromium (chromium-III). EPA determined that the calculation of risk associated with trivalent chromium in sediment was inadvertently calculated with the more conservative toxicological value for hexavalent chromium (chromium-VI). Accordingly, EPA has prepared replacement pages for affected portions of the BRA.

Note that the revised human health risk estimates show that chromium contamination in the sediment of the Murphy Wetland does not pose a risk to human receptors. Nonetheless, the Murphy Wetland sediments are still associated with human health risk above risk management criteria primarily due to polychlorinated biphenyls (PCBs) in sediment. The overall conclusions do not change for human health; only the significant risk contributors have changed.

The aforementioned error does not affect the conclusions of the ecological risk assessment. Chromium remains a significant risk contributor for ecological risks at the Murphy Wetland.

If you have any questions regarding this notification, please contact me at (617) 918-1323. Note that corrections to the electronic copy of the BRA will soon be implemented on the internet at EPA's Wells G&H web site. Correction pages are summarized and included in Attachment A.

Sincerely,

Joseph F. LeMay, P.E.
Remedial Project Manager
Office of Site Remediation and Restoration

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ATTACHMENT A – REPLACEMENT PAGES FOR MARCH 2004 BRA

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TRC
Customer-Focused Solutions

EPA Contract No. 68-W6-0042
EPA Work Assignment No. 128-RSDB-0146

EPA Project Officer: Diana King
EPA Remedial Project Manager: Joseph F. LeMay, P.E.

BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

VOLUME I

TEXT AND FIGURES

Southwest Properties, Wells G&H Superfund Site
Operable Unit 2
Woburn, Massachusetts

Revised February 2006

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EXECUTIVE SUMMARY

A Baseline Human Health and Ecological Risk Assessment was conducted by TRC Environmental Corporation (TRC) for the United States Environmental Protection Agency (EPA) Region 1 at the Southwest Properties Site, in Woburn, Massachusetts. The Southwest Properties Site is comprised of three contiguous parcels of land known as Aberjona Auto Parts (Aberjona property), Whitney Barrel (Whitney property), and Murphy Waste Oil (Murphy property).

The Southwest Properties Site is part of the Wells G&H Superfund Site. The Wells G&H Superfund Site is a triangular-shaped parcel of land comprising approximately 330 acres bounded by Route 128/Interstate 95 to the north, the Boston and Main (B&M) Railroad to the west, Interstate 93 to the east and Salem and Cedar Streets to the south. The Southwest Properties are associated with Operable Unit 2 (OU-2) of the Wells G&H Superfund Site and are also listed as three separate Massachusetts Department of Environmental Protection (MADEP) "Chapter 21-E" sites under the Bureau of Waste Site Cleanup (BWSC) for the three constituent properties (Aberjona Auto Parts, Whitney Barrel, and Murphy's Waste Oil).

The Southwest Properties Site is rectangular with its long axis oriented approximately northeast southwest along Salem Street. The Aberjona River flows north to south along the eastern boundary of the Site. The B&M railroad abuts the Site to the west and Salem Street to the south. Three industrially zoned properties with wood framed structures that appear to be former residences abut the Murphy's Waste Oil site to the southwest of the Site. The Wildwood Conservation Corporation site lies on the adjacent parcel to the north.

The land use at and in vicinity of the Southwest Properties is highly developed with light commercial and light industrial parks bordering the wetlands area associated with the Aberjona River floodplain. The Southwest Properties current land uses are commercial/industrial at all three properties, with a residence located on the Aberjona property. The Southwest Properties are zoned industrial (City of Woburn, 1997). Currently, the Aberjona property is comprised of an idle auto salvage yard enclosed within a locked fence and a single family residence. The

commercial buildings at Aberjona are currently utilized by an automotive repair facility and a landscaper. The Whitney property is utilized by a variety of small businesses (e.g., landscaping, automotive glass repair). The Murphy property is leased by Clean Harbors Environmental Services, and is a registered Treatment, Storage, and Disposal Facility (TSDF) under the Resource Conservation and Recovery Act (RCRA), currently used for treatment and storage of waste oil. In the recent past, the Aberjona, Whitney and Murphy properties have served as salvage yard/service station, barrel washing facility, and a waste oil reclamation facility, respectively. A wetland area lies between the Murphy and Whitney properties, and the Wildwood property to the north, and is referred to as the Murphy Wetland. Figure ES-1 present's a plan of the Southwest Properties

Data used to prepare this risk assessment were obtained from several different investigations, and include recently collected soil, sediment, surface water, and groundwater samples. Table ES-1 summarizes the investigative work used to prepare the human health and ecological risk assessments. Soil and groundwater data were used as inputs to transport and dilution/dispersion models in order to estimate indoor and outdoor air concentrations for the human health risk assessment. These transport and dilution/dispersion models used property-specific information on depth to groundwater and building dimensions as well as appropriate values for soil properties to establish reasonably conservative site-specific modeled exposure point concentrations.

Numerous Chemicals of Potential Concern (COPCs) were detected in Site media. In soil, COPCs generally consisted of the following classes of compounds: chlorinated VOCs, PAHs, pesticides, metals, PCBs, and PCB congeners, as well as aromatic and aliphatic petroleum hydrocarbons. In groundwater, the COPC classes included chlorinated and non-chlorinated VOCs, SVOCs (including PAHs), aromatic and aliphatic petroleum hydrocarbons, metals, PCB congeners, and pesticides. Indoor air COPCs included chlorinated and non-chlorinated VOCs, and PAHs, as well as aromatic and aliphatic petroleum hydrocarbons. Outdoor air COPCs included aromatic and aliphatic petroleum hydrocarbons. COPCs in sediment included chlorinated and non-chlorinated VOCs, PAHs, aromatic and aliphatic petroleum hydrocarbons, metals (including hexavalent chromium), PCBs, PCB congeners and pesticides. In surface

Table ES-1
Summary of Data Utilized – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2
Woburn, Massachusetts

Property	Investigation Dates	Sample Data Utilized [(1)]	General Analytical Suite	Source Documents
Aberjona	1993	18 soil	VOC, SVOC, pesticide, PCB, metals, cyanide	RETEC 1994
	2002	18 soil 13 groundwater	VOC, SVOC, pesticide, PCB, PCB congeners, metals, cyanide	RETEC 2003 TRC 2004
Whitney	1993	8 soil	VOC, SVOC, pesticide, PCB, metals, cyanide	RETEC 1994
	2001	3 groundwater	VOC, SVOC, VPH, EPH, metals, hex chrome, cyanide, pesticide, PCB, PCB congeners	RETEC 2003
	2002	23 soil 9 groundwater	VOC, SVOC, pesticide, PCB, PCB congeners, metals, cyanide	RETEC 2003 TRC 2004
Murphy	1987-1998	57 soil	VOC, SVOC, pesticide, PCB, metals, cyanide	Clean Harbors 1996, 1998
	1997-1998	52 sediment	PCBs, chromium, lead, petroleum	Clean Harbors 1996, 1998
	1993	7 soil 3 wetland soil	VOC, SVOC, pesticide, PCB, metals, cyanide	RETEC 1994
	2001	27 groundwater		RETEC 2003
	2002	8 soil 12 sediment 6 groundwater 3 surface water	VOC, SVOC, pesticide, PCB, PCB congeners, metals, cyanide	RETEC 2003 TRC 2004

Notes:
(1) – Only groundwater or surface water samples from 2001/2002 investigations were utilized in HHRA.
VOC – volatile organic compounds
VPH – volatile petroleum hydrocarbons
EPH – extractable petroleum hydrocarbons
SVOC – semivolatile organic compounds
PCB – polychlorinated biphenyls

water, COPCs were limited to inorganics (aluminum, barium, chromium, cyanide and manganese).

Human Health Risk Assessment Summary. Potential non-carcinogenic and carcinogenic human health risks were quantitatively assessed for the central tendency (CT) and reasonable maximum exposure (RME) cases for surface soil, subsurface soil, groundwater, air, surface water and sediment at each exposure point determined to be accessible to human receptors currently or in the future.

The arsenic bioavailability study that was performed as part of the Aberjona River Study Operable Unit 3 Risk Assessment was also used in this risk assessment. The bioavailability study was completed to assist in the quantification of sediment risks. This site-specific bioassay determined that arsenic is absorbed less efficiently from sediment than from a water medium. The most conservative relative bioavailability estimate determined in the study was used to quantify sediment ingestion risks at the Southwest Properties.

Site-specific hexavalent chromium data were collected and used in the risk assessment to more accurately characterize soil, groundwater, and sediment risks at the Southwest Properties. Only hexavalent chromium data obtained using the ion chromatography method for soil/sediment and Method 7196A for groundwater were quantitatively evaluated in the human health risk assessment.

EPA requires calculation of the 95% UCL on the arithmetic mean concentration for the estimation of both the Reasonable Maximum Exposure (RME) and Central Tendency (CT) risk (EPA, 1989; 1992; and 1994d) for most scenarios. Therefore, whenever possible, the 95% UCL has been calculated and used as the EPC for both the RME and CT exposure cases. When the 95% UCL was greater than the maximum detected value, the maximum and average concentrations were used. The 95% UCLs were calculated using EPA's program ProUCL Statistical Software Version 2.1 (USEPA, 2002a). The 95% UCL values were calculated by this program where four or more samples were available from an exposure point. When less than four samples were available, the program was unable to calculate a 95% UCL value.

Possible human exposure to the selected COPCs was characterized through exposure pathways for current and future land use. An exposure pathway describes the course a chemical follows while moving through environmental media to a receptor. An exposure pathway may consist of a mechanism of release of contaminants to an environmental medium (e.g., soil), an exposure route (e.g., ingestion) and a receptor (e.g., trespasser). An exposure pathway is considered complete when contact by a receptor with contaminated media may occur currently or in the future. For purposes of this risk assessment, only potentially complete exposure pathways were quantitatively evaluated.

Current land use is commercial/industrial at all three sites. However, a residence exists on the southeast portion of the Aberjona property. The Southwest Properties are zoned industrial (City of Woburn, 1997). Many of the on-site areas of known contamination are currently fenced. However, access is not limited for a portion of the Aberjona property (Aberjona Triangle) and all of the Whitney property. In addition, commercial workers may access the secured areas. Based on this information, current receptors include residential at the Aberjona residence, commercial at all three properties and trespasser at the Aberjona Triangle and Whitney properties. Future receptors for all three properties include commercial, trespasser, recreational and construction worker. The future residential scenario is evaluated for the Aberjona property only. In addition, the future off-site resident is evaluated for exposure to groundwater to address the potential for future potable use of contaminated groundwater originating from the Southwest Properties.

A summary of the exposure points evaluated in the risk assessment is provided below by scenario.

Exposure Point	Current Scenario	Future Scenario
Aberjona Residence	X	X
Aberjona Triangle	X	N/A
Aberjona Property (Salvage Yard and Triangle)	X	X
Whitney Property	X	X
Murphy Property (upland)	X	X
Murphy Wetland	X	X
Off-Site Residence	N/A	X

Notes: N/A – Not applicable X – Included exposure point

Estimated risks were compared to the EPA target cancer risk range of 10^{-6} to 10^{-4} and target hazard index (HI) of 1 for non-carcinogenic effects.

Table ES-2 summarizes the results of the estimated cancer and non-cancer risk for the evaluated properties/areas for the major contributors to risk: Incremental Lifetime Cancer Risks (ILCRs) $>10^{-4}$ or HIs >1. Risks are summarized for both the RME and CT receptors for each of the evaluated areas. When risks were estimated for a child and adult receptor, the child HIs are presented as the most conservative, while ILCR are the sum of the child and adult risks (i.e., a total receptor cancer risk). The risks presented by property have been summed together, as appropriate, when a receptor would be exposed to more than one medium during site activities. The Murphy wetland area was evaluated as a separate exposure point because of its location (i.e., located between both the Whitney and Murphy properties). In cases where the total pathway HI exceeded 1, COPCs having similar systemic effects were summed for each pathway and medium. The following summarizes the scenarios and contaminants that are major contributors to risk (ILCRs $>10^{-4}$ or HIs >1). Other contributors to risk ($10^{-4} \geq$ ILCRs $> 10^{-6}$ and HIs = 1) are discussed in Sections 3.0 and 5.0 of this report.

Aberjona. The ILCRs and HIs are all below risk management criteria for all scenarios evaluated.

Whitney. The RME and/or CT ILCR and HI exceed the target risk range for the Current and Future Commercial Worker, Future Recreational User, and Future Construction Worker. Major risk drivers contributing to the exceedances for the Commercial Worker include direct contact with PCB Aroclors in surface soil as well as C5-C8 Aliphatic and C9-C18 Aliphatic Hydrocarbons in indoor air attributable to subsurface soil. The major risk drivers contributing to the exceedance for the Recreational Worker are direct contact with PCB Aroclors in surface soil, and PCB Aroclors, PCB congeners, alpha-chlordane and gamma-chlordane in subsurface soil. The major risk drivers for the Construction Worker are PCB Aroclors, alpha-chlordane, and gamma-chlordane in subsurface soil.

Murphy. The ILCRs and HIs are all below risk management criteria for all scenarios and pathways evaluated.

Murphy Wetland. The RME ILCR exceeds the target risk range for the Future Young Child/Adult Recreational User. The RME and CT HIs were above the target HI of 1 for the Future Older Child Trespasser and the Future Young Child/Adult Recreational User. The major risk driver associated with exceedances for the Future Trespasser is PCB Aroclors in sediment. The major risk drivers contributing to the exceedance for the Future Recreational receptor are PCB Aroclors in sediment for the RME case and PCB Aroclors for the CT case.

Off-Site Resident. The RME and CT cancer and non-cancer risks exceed risk management criteria for the future off-site resident exposed to groundwater during household use. The major risk drivers associated with RME exceedances are direct contact with 1,3,-dichlorobenzene, benzene, cis-1,2-dichloroethene, trichloroethene, vinyl chloride, C9-C18 Aliphatic Hydrocarbons, C11-C22 Aromatic Hydrocarbons, arsenic, and manganese. In the CT case, trichloroethene and vinyl chloride were the major risk drivers. The inhalation pathway also had RME exceedances of the cancer and non-cancer risk management criteria with 1,1,2-trichloroethane and trichloroethene as major risk drivers.

Lead in soil and sediment was evaluated through the use of EPA models for children and adults. The lead evaluation indicated that exposures to lead in current and future scenarios would not result in adult or childhood blood lead levels in excess of blood lead level goals. Therefore, lead in soil and sediment was determined not to be of concern for human receptors at the Southwest Properties. Since the average concentration of lead in groundwater was below the Safe Drinking Water Act (SDWA) action level of 15 ug/L, the model default value was used. This results in a more conservative evaluation.

Risks associated with background soil was evaluated using combined background data collected from Aberjona, Whitney and Murphy. Background soil COPCs were identified by comparing the maximum detected concentration of a chemical in surface soil and subsurface soil with preliminary remedial goals (PRGs) published by EPA Region 9 (EPA, 2002b). Arsenic was

identified as a COPC in surface and subsurface soil and manganese was identified in subsurface soil. However, calculated risk was determined to be less than the target risk range for cancer effects and less than the target HI.

In addition, the risks calculated for sediment in the Murphy Wetland were compared to the risk calculated for wetland sediment background from the Wells G&H OU-3 River Study based on an equivalent recreational user scenario adjusted for 78 day per year exposures. Risks compared were for arsenic and benzo(a)pyrene contamination since these contaminants were identified as risk drivers in the Murphy Wetland and were also assessed in OU-3 background. This comparison is provided below:

Contaminant	Risk Basis	Murphy Wetland Recreational User	OU-2 Wetland 4-Day Recreational User*
Arsenic	ILCR	2E-06	8E-06
Benzo(a)pyrene	ILCR	8E-06	6E-06

* - Adjusted from 104 days per year to 78 days per year for equal comparison to the Murphy Wetland Recreational User.

Ecological Risk Assessment

The effects-based screening resulted in the selection of 5 COPCs in surface water (all inorganics) and 60 COPCs in sediment/surface soil (VOCs, SVOCs, pesticides/PCBs, and inorganics) for evaluation in the ERA. Five receptor species or communities were selected to evaluate risks associated with exposure to the COPCs in the surface water and sediment of the Site. Endpoints in the ERA were selected to represent ecological attributes that are to be protected (assessment endpoints) and a measurable characteristic of those attributes (measurement endpoints) that can be used to gauge the degree of impact that has or may occur.

Each endpoint has associated with it a magnitude of risk and a degree of uncertainty. The magnitude of risk incorporates both the degree to which the endpoint was exceeded and also the proportion of the habitat affected. If the lower effects threshold (i.e., chronic AWQC, ER-L or LEL, NOAEL TRV) was exceeded at the site, the contaminant was concluded to pose a low risk to populations. The highest risk was associated with contaminants that exceeded upper threshold

effects levels (i.e., acute AWQC, ER-M or SEL, LOAEL TRVs). If high HQs were present only for the maximum (or 95% UCL) COPC concentration, the magnitude of the overall risk to the population from exposure to the COPC was considered low.

Figure ES-3 summarizes the results of the ecological risk assessment for each of the assessment endpoints showing a high risk potential within the Murphy Wetland. The ERA suggests that PCBs (both Aroclors and congeners) may pose current and future risks to the macrobenthic community as well as mammalian indicator populations of herbivores and/or insectivores as represented by the muskrat and short-tailed shrew, respectively. In addition, several inorganic contaminants (chromium and lead) may also pose risk to mammalian herbivores foraging within the seasonally ponded area as well as to the macrobenthic invertebrate community present at this habitat. The benthic invertebrate endpoints suggest that there may be impacts from inorganic and PCB contaminants to invertebrate communities inhabiting the seasonally ponded area of the Murphy Wetland. The strength of the evidence was based entirely on exceedances of upper threshold sediment-effects benchmarks.

Analysis of the mean exposure assessment for muskrat indicated HQs greater than 1 based on LOAEL TRVs, for PCB Aroclors 1254 and 1260, PCB congeners, chromium, and lead. Due to the elevated HQs (particularly for PCB Aroclor 1254), the magnitude of the risk for muskrat exposure to these COPCs is high. These results indicate a potential impact on reproduction of mammal populations such as muskrat exposed to PCBs, chromium, and lead in the diet while foraging in the seasonally ponded area of the Murphy Wetland.

Short-tailed shrew exposure models were used to evaluate potential risk to small mammal populations living in and near the Murphy Wetland. Analysis of the mean exposure assessment for shrew indicated HQs greater than 1, based on LOAEL TRVs, for PCB Aroclors 1254 and 1260 and PCB congeners at the seasonally ponded area of the Murphy Wetland while PCB Aroclor 1254 has an HQ greater than 1 (also based on LOAEL TRV) at the forested/scrub-shrub area of the Murphy Wetland. The mean exposure doses of PCB Aroclor 1254 estimated to be received by the shrew at the seasonally ponded and the forested/scrub-shrub areas of the Murphy Wetland indicate a potential impact on reproduction of mammal insectivore populations such as

shrews exposed to PCBs in their diet while foraging in the seasonally ponded and forested/ scrub-shrub areas of the Murphy Wetland.

Table ES-2
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

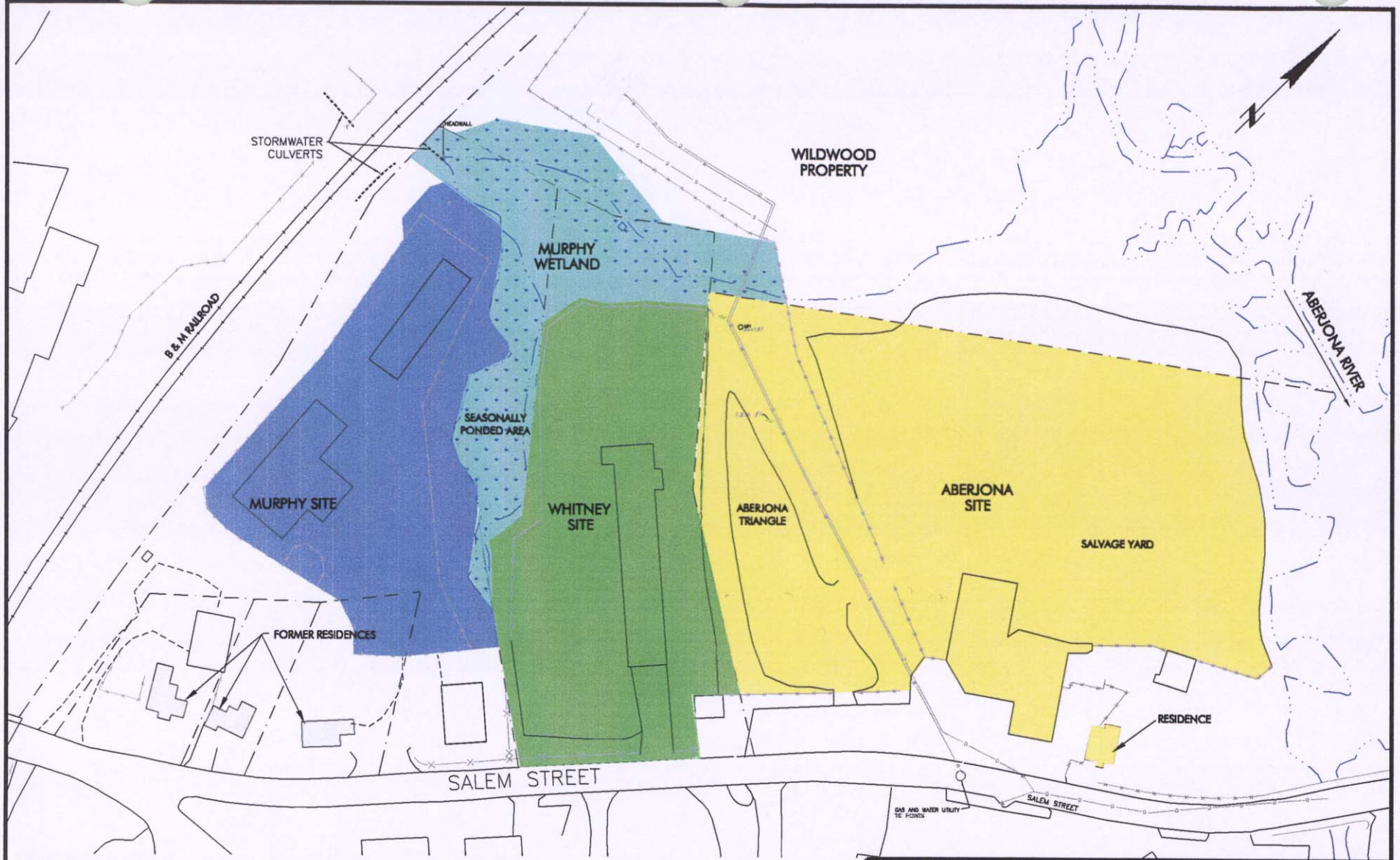
Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Major Contributors to Risk** (> 1E-04, HI > 1)
Whitney	Current	Commercial Worker	Adult	RME	1E-04	2E+00	Surface Soil	PCB Aroclors
	Future	Commercial Worker	Adult	RME	1E-04	1E+01	Surface Soil	PCB Aroclors
							Indoor Air	C5-C8 Aliphatic Hydrocarbons C9-C18 Aliphatic Hydrocarbons
				CT	1E-05	6E+00	Indoor Air	C5-C8 Aliphatic Hydrocarbons
		Recreational User* (Surface Soil)	Young Child/Adult	RME	1E-04	8E+00	Surface Soil	PCB Aroclors
		Recreational User* (Subsurface Soil)	Young Child/Adult	RME	1E-03	2E+02	Subsurface Soil	PCB Aroclors PCB Congeners alpha-chlordane gamma-chlordane
				CT	4E-05	4E+01	Subsurface Soil	PCB Aroclors
		Construction Worker (Surface Soil)	Adult	RME	9E-06	4E+00	Surface Soil	PCB Aroclors alpha-chlordane gamma-chlordane
		Construction Worker (Subsurface Soil)	Adult	RME	9E-05	1E+02	Subsurface Soil	PCB Aroclors
				CT	1E-05	3E+01	Subsurface Soil	PCB Aroclors

Table ES-2 (Continued)
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Major Contributors to Risk** (> 1E-04, HI > 1)
Murphy Wetland	Future	Trespasser	Older Child	RME	2E-05	3E+00	Sediment	PCB Aroclors
		Recreational User*	Young Child/Adult	RME	3E-04	2E+01	Sediment	PCB Aroclors
				CT	6E-06	4E+00	Sediment	PCB Aroclors
Off-Site Resident	Future	Resident*	Young Child/Adult	RME	2E-02	2E+02	Tap Water	1,3-dichlorobenzene benzene cis-1,2-dichloroethene trichloroethene vinyl chloride C9-C18 Aliphatic Hydrocarbons C11-C22 Aromatic Hydrocarbons arsenic manganese
							Inhalation of Volatiles from Groundwater	1,1,2-trichloroethane trichloroethene
				CT	4E-04	8E+00	Tap Water	1,1,2-trichloroethane trichloroethene vinyl chloride

Notes:
* - Cancer risks shown for adult and young child are summed. Non-cancer risks are shown for young child only.
** - See Section 3.0 and 5.0 for a summary and discussion of other risk contributors ($10^{-4} \geq$ ILCR $> 10^{-6}$ and HI=1).
RME – Reasonable Maximum Exposure CT – Central Tendency HI – Hazard Index ILCR – Incremental Lifetime Cancer Risk



SOURCE:
SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT, SOUTHWEST PROPERTIES, VOLUME I OF XXIII, WELLS G&H SUPERFUND SITE, WOBURN, MASSACHUSETTS, AUGUST 2003

- ABERJONA SITE
- WHITNEY SITE
- MURPHY WETLAND
- MURPHY SITE

02136/SOUTHWEST/RISK ASSESSMENT/ES-1

APPROXIMATE GRAPHIC SCALE
0' 50' 100'

LEGEND
- STREAM OR WETLAND
- PROPERTY LINE

FIGURE ES-1
SITE PLAN

SOUTHWEST PROPERTIES
WELLS G&H SUPERFUND SITE
OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

Metcalf & Eddy

TRC
Boott Mills South
Foot of John Street
Lowell, MA 01852
978-970-5600

TRC PROJ. NO.: 02136-0390-01467

EPA CONTRACT NO.: 68-W6-0042

RAC SUBCONTRACT NO.: 107061

MURPHY WETLAND	
Major Risk Drivers	Media
PCB Aroclors	SD

WHITNEY SITE			
Major Risk Drivers	Media		
PCB Aroclors	SS		
C5–C8 Aliphatic Hydrocarbons (Future Only)		IA	
C9–C18 Aliphatic Hydrocarbons (Future Only)		IA	
PCB Aroclors (Future Only)			S
Chlordanes (Future Only)			S
PCB Cogeners (Future Only)			S

GROUNDWATER RISK TO OFF-SITE RESIDENT		
Major Risk Drivers	Media	
1,3–dichlorobenzene	DW	
benzene	DW	
cis–1,2–dichloroethene	DW	
trichloroethene	DW	IS
vinyl chloride	DW	
C9–C18 Aliphatic Hydrocarbons	DW	
C11–C22 Aromatic Hydrocarbons	DW	
arsenic	DW	
manganese	DW	
1,1,2–trichloroethane		IS

NO RISK FROM SURFACE WATER

STORMWATER CULVERTS

HEADWALL

HEADWALL TOW=44.6 INV.=42.3 18" RCP

TREATMENT BUILDING

DECON. AREA

ROAD

SHED

MURPHY WETLAND

WILDWOOD PROPERTY

MURPHY SITE

WHITNEY SITE

ABERJONA SITE

FORMER RESIDENCES

RESIDENCE

SALEM STREET

GAS AND WATER UTILITY TIE POINTS

LEGEND:

- COPCs CONTRIBUTING TO FUTURE RISK
- COPCs CONTRIBUTING TO CURRENT AND FUTURE RISK.
- GROUNDWATER WITH FUTURE DW/IS RISK TO OFFSITE RESIDENT

Affected Media	
Surface Soil	SS
Subsurface Soil	S
Indoor Air	IA
Inhalation During Showering	IS
Sediment	SD
Groundwater/Drinking Water	DW

NOTE:
MAJOR RISK DRIVERS ONLY (ILCR $>10^{-4}$ AND TARGET ORGAN HI >1). SEE REPORT FOR DISCUSSION OF OTHER RISK CONTRIBUTORS.

APPROXIMATE GRAPHIC SCALE

0' 50' 100'

SOURCE:
SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT, SOUTHWEST PROPERTIES, VOLUME I OF XXIII, WELLS G&H SUPERFUND SITE, WOBURN, MASSACHUSETTS, AUGUST 2003

LEGEND

WETLAND

STREAM OR WETLAND

PROPERTY LINE

FIGURE ES–2
HUMAN HEALTH
MAJOR RISK DRIVERS

SOUTHWEST PROPERTIES
WELLS G&H SUPERFUND SITE
OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

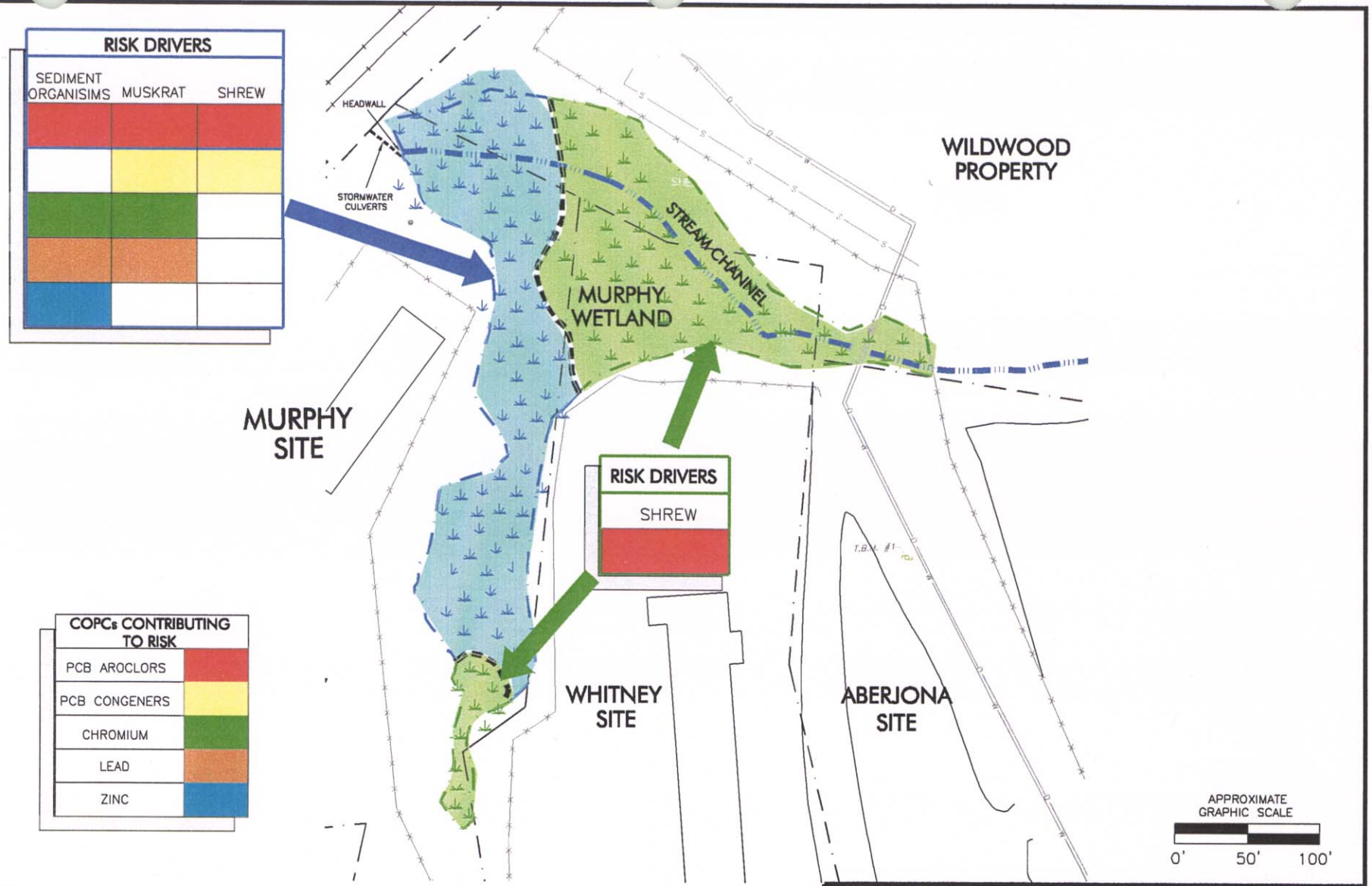
TRC
Boott Mills South
Foot of John Street
Lowell, MA 01852
978–970–5600

TRC PROJ. NO.: 02136–0390–01467

EPA CONTRACT NO.: 68–W6–0042

M&E Metcalf & Eddy

RAC SUBCONTRACT NO.: 107061



SOURCE:
SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT, SOUTHWEST PROPERTIES, VOLUME I OF XXIII, WELLS G&H SUPERFUND SITE, WOBURN, MASSACHUSETTS, AUGUST 2003

LEGEND

FORESTED SCRUB SHRUB WETLAND AREA

SEASONALLY PONDED WETLAND AREA

APPROXIMATE PONDED/FORESSTED WETLAND BOUNDARY

STREAM OR WETLAND

PROPERTY LINE

02136/SOUTHWEST/RISK ASSESSMENT/ES-3

FIGURE ES-3
ECOLOGICAL RISK ASSESSMENT SUMMARY
SOUTHWEST PROPERTIES
WELLS G&H SUPERFUND SITE
OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

Metcalf & Eddy

TRC
Boott Mills South
Foot of John Street
Lowell, MA 01852
978-970-5600

TRC PROJ. NO.: 02136-0390-01467

EPA CONTRACT NO.: 68-W6-0042

RAC SUBCONTRACT NO.: 107061

1.0 INTRODUCTION

1.1 Purpose Scope and Organization of the Report

Metcalf & Eddy (M&E) received Work Assignment (WA) No. 128-RSDB-0146 under the United States Environmental Protection Agency (EPA) Response Action Contract (RAC) No. 68-W6-0042 to perform Remedial Investigation/Feasibility Study (RI/FS) Oversight at the Wells G&H Superfund Site Operable Unit 2 (OU-2), (Southwest Properties) in Woburn, Massachusetts (i.e., the Site). M&E assigned primary responsibilities for most of the tasks in this project to RAC Team Subcontractor, TRC Environmental Corporation (TRC). Site activities included oversight of a Potentially Responsible Party (PRP) conducting environmental sampling (e.g., groundwater, sediment, surface water and soil), related data gathering, and split sampling, in areas of interest to EPA.

The objective of this assignment is the preparation of this baseline human health and ecological risk assessment (HHRA/ERA) for the Southwest Properties. This objective has been addressed by evaluating site characterization data from soil, groundwater, surface water, and sediment samples from the Southwest Properties.

The text of the report is presented in the following five sections:

- Section 1.0, Introduction, presents a description of the Southwest Properties, including the environmental setting, geology, hydrogeology and surface hydrology, background information on Site history, relevant previous investigations, and the study objectives;
- Section 2.0, Site Investigation, describes the scope and methods of field studies, laboratory investigations and data validation, and discusses the nature and extent of contamination;
- Section 3.0, Baseline Human Health Risk Assessment, evaluates the baseline human health risks associated with the Site;
- Section 4.0, Baseline Ecological Risk Assessment, evaluates the baseline ecological risks associated with the Site;

- Section 5.0, Summary and Conclusions, summarizes the report findings and describes the conclusions of the field investigation, HHRA, and the ERA; and
- Section 6.0, References, contains the reference citations for the Executive Summary and Sections 1 through 5.

Volume one of this report also contains the figures and tables referred to in the text. A second volume contains the appendices that provide additional supporting materials from prior field investigations (Appendix A), analytical results (Appendix B), HHRA supporting information (Appendix C), and ERA supporting information (Appendix D).

The remainder of this section of the report contains a discussion of the objectives of the project (Section 1.2), historical and prior investigation information relative to the Southwest Properties (Section 1.3), a description of the Southwest Properties area (Section 1.4), and the geologic/hydrogeologic setting (Section 1.5).

1.2 Project Objectives

The overall purpose of this assignment is to determine if contamination of the Southwest Properties Site poses potential risks to human health and the environment. The general objectives are summarized below:

- Identify the contaminated environmental media and contaminants of potential concern (COPCs) at the Southwest Properties;
- Identify potential pathways of exposure and potential toxicological effects of contaminated environmental media at the Southwest Properties; and
- Identify sampling locations at the Southwest Properties Site where COPC concentrations in environmental media do and do not appear to pose potential risk to human and ecological receptors, based on conservative exposure and toxicity assumptions.

A field sampling program conducted by the PRP at the request of EPA was designed to collect the data needed to augment existing data and meet the objectives described above. Sampling objectives and design are described in Section 2.0 of this report. This document addresses the study objectives related to human and ecological receptors.

1.3 Southwest Properties History and Previous Investigations

The Southwest Properties Site is comprised of three contiguous parcels of land known as Aberjona Auto Parts (Aberjona), Whitney Barrel (Whitney), and Murphy Waste Oil (Murphy). The Southwest Properties are located in Woburn, Massachusetts, as shown on Figure 1-1.

The Southwest Properties Site is part of the Well G&H Superfund Site, which is comprised of a triangular-shaped parcel of land comprising approximately 330 acres bounded by Route 128/Interstate 95 to the north, the Boston and Main (B&M) Railroad to the west, Interstate 93 to the east and Salem and Cedar Streets to the south (see Figure 1-1). The Southwest Properties are associated with Operable Unit 2 (OU-2) of the Wells G&H Superfund Site and are also listed as three separate Massachusetts Department of Environmental Protection (MADEP) "Chapter 21-E" sites under the Bureau of Waste Site Cleanup (BWSC).

The Southwest Properties Site boundary is rectangular in shape with its long axis oriented approximately northeast-southwest along Salem Street (See Figure 1-2). A wetland area known as the Murphy wetland lies between the Murphy and Whitney properties, and the Aberjona River flows north to south along the eastern boundary of the Site next to the Aberjona property. The B&M railroad abuts the Site to the west next to the Murphy property and Murphy wetland. Salem Street abuts the Site to the south. The Wildwood property abuts the Site to the north. Three industrially-zoned properties with wood-framed structures that appear to be former residences abut the Murphy's Waste Oil parcel to the southwest of the Site.

OU-2, also referred to as the Central Area, was identified by EPA in the September 14, 1989 Wells G&H Record of Decision (ROD) as an area requiring further evaluation. A RI/FS of the Central Area was undertaken by several PRPs pursuant to a September 8, 1991 Consent Decree

(Decree), which specified the obligations for each PRP, and specifically identified the three Southwest Properties (Aberjona Auto Parts, Whitney Barrel, and Murphy Waste Oil) as part of the Central Area. A separate RI of the Southwest Properties was conducted by Remediation Technologies, Corporation (RETEC) on behalf of one of the PRPs (Beatrice Corporation) and presented in the *Draft Remedial Investigation, Southwest Properties, Wells G&H Superfund Site, Woburn, Massachusetts,* dated February 16, 1994 (1994 Draft RI). One of the objectives for the RETEC work was to gather the data necessary for EPA to prepare a baseline risk assessment for the Southwest Properties to assess the need for remedial action. EPA's review of the Southwest Properties RI found significant deficiencies that required additional data gathering to support EPA's risk assessment. The PRP addressed the deficiencies through the preparation of a Supplemental Remedial Investigation.

1.3.1 Wells G&H

Wells G&H were municipal potable water supply wells developed by the City of Woburn in 1964 and 1967, respectively, in response to urban growth during the 1960s. The wells, screened in the Aberjona aquifer in deep overburden, were capable of supplying two million gallons of water per day, but were initially intended only for use during times of water shortage or emergencies. Local officials estimate that 27 to 28 percent of the community's water supply was provided by Wells G&H.

Local records indicate that the water from Wells G&H exhibited high concentrations of manganese and iron, which resulted in unpleasant taste and odor. Prompted by citizens' complaints concerning water quality, and in order to meet anticipated increased demand for water, the City of Woburn examined the feasibility of treating the water from Wells G&H in 1974. However, treatment was not implemented.

On May 4, 1979, 184 55-gallon drums containing polyurethane and toluene diisocyanate were found on a vacant lot located on Mishawum Road on property owned by the Massachusetts Bay Transportation Authority (MBTA). The drums were removed by unknown parties during negotiations with the Massachusetts Department of Environmental Quality Engineering (DEQE)

(now the MADEP). This incident prompted DEQE to sample the nearest downgradient water supply (i.e., Wells G&H) as a precautionary measure.

Several chlorinated volatile organic compounds (VOCs) including 1,l,l-trichloroethane (1,1,1-TCA), trans-1,2-dichloroethene (trans-l,2-DCE), tetrachloroethene (PCE), trichloroethene (TCE), chloroform, and trichlorotrifluoroethane were detected by DEQE in water from Wells G&H at concentrations ranging from 1 to 400 parts per billion (ppb). Wells G&H were subsequently shut down on May 21, 1979, forcing the City of Woburn to use Metropolitan District Commission (MDC) water to supplement its public water supply. Currently, the MDC (now the Massachusetts Water Resources Authority or MWRA) supplies approximately one third of the city's water needs (approximately two million gallons per day). The remainder, approximately four million gallons per day, is supplied by the Horn Pond Well Field to the south of Salem Street (TRC, 2002).

As a result of the contamination at Wells G&H and disposal problems discovered at the nearby Industri-Plex Site, an EPA contractor, Ecology and Environment, Inc. (E&E), was directed to conduct a hydrogeologic investigation and groundwater quality evaluation of a ten square-mile area east and north of Wells G&H. The purpose of this investigation was to determine the extent and degree of contamination, and to identify the sources of contamination. Based on the direction of groundwater flow, areal extent of groundwater contamination, and site inspections of 17 active and inactive facilities within the ten square-mile area, E&E identified the general source areas for TCE, trans-l,2-DCE, 1,1,1-TCA, and PCE detected at Wells G&H to be within a one square-mile area surrounding the wells. The contamination at the Industri-Plex Site was not linked with groundwater contamination found at Wells G&H. EPA developed a Hazard Ranking System (HRS) score for the Wells G&H Site utilizing E&E's preliminary investigations and the analytical information provided by the DEQE. The Site was listed on the National Priorities List (NPL) on December 21, 1982.

In May 1983, as a result of E&E's investigations, three administrative orders pursuant to Section 3013 of the Resource Conservation and Recovery Act (RCRA) were issued to W.R. Grace and

Co., Inc. Cryovac Division (Grace), Unifirst Corporation (formerly Interstate Uniform Services Corporation; Unifirst), and Beatrice Foods, Inc. (Beatrice).

These orders required submittal of proposals by each company for the sampling, analysis, monitoring, and reporting that would address the problem of possible groundwater contamination on or emanating from their properties. Groundwater monitoring programs and related data gathering were subsequently initiated by the three companies at their respective properties.

On March 24, 1987, the EPA authorized Foster Wheeler (formerly Ebasco Services Incorporated) to conduct a Supplemental RI/FS for the Wells G&H site in Woburn, Massachusetts. The Foster Wheeler Supplemental RI was conducted at the Site from September 1987 through January 1988. The results of the Foster Wheeler Supplemental RI data were used with previously collected data to perform the FS. The Foster Wheeler Supplemental RI was also used to finalize an Endangerment Assessment document (TRC, 2002).

Foster Wheeler's Supplemental RI activities included collection of soil and groundwater samples from properties that the EPA identified as potential sources of the groundwater contamination at Wells G&H. These included W.R. Grace and Co., Inc., Unifirst, Olympia Nominee Trust (Olympia), Wildwood Conservation Corporation (Wildwood or Beatrice), and New England Plastics Corporation (NEP). Surface water and sediment samples were also collected in the Aberjona River to provide additional data for the Endangerment Assessment.

The Foster Wheeler Supplemental RI indicated the presence of five likely groundwater contamination areas in the vicinity of Wells G&H. The likely source areas for each of these plumes were the Grace, Unifirst, Wildwood, NEP and Olympia properties.

In September 1989, EPA issued a ROD for the Wells G&H Site. The ROD required, among other things, that groundwater contamination beneath the Grace and Unifirst properties be remediated by extracting the groundwater and removing the contamination (EPA, 1989).

A Decree was signed by EPA and the PRPs in 1991. The PRPs then began work on respective areas of the Site. The five facilities that were identified as sources of contaminants and define Operable Unit 1 (OU-1) are located on the properties of Grace, UniFirst, Wildwood, NEP, and Olympia (also known as the Source Area Properties).

Primary contaminants include VOCs, lead, pesticides, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs).

1.3.2 Southwest Properties

The September 1989 ROD for the Wells G&H site "calls for a study of the central aquifer area to determine the most effective way of addressing contamination in the Central Area." (EPA, 1989). The approximate boundaries of the Central Area (or OU-2), as referenced in the ROD, are delineated in Figure 1-3. The ROD states that the objectives of the Central Aquifer/Aberjona River Study include but are not limited to the following:

- Define the nature and extent of contamination in the Aberjona River;
- Define the upgradient introduction of contaminants to the Aberjona River;
- Refine the present understanding of the interaction of the Aberjona River and the aquifer systems on the Site;
- Evaluate the effectiveness of pump and treat as a remedial alternative for the cleanup of contaminated groundwater in the Central Area;
- Evaluate the impact of pumping the central aquifer on the Aberjona River and associated wetlands;
- Identify and evaluate innovative remedial technologies for aquifer restoration, e.g., in-situ bioremediation; and
- Evaluate the mobility of contaminants including semivolatile organics and metals under ambient and pumping conditions.

The work and division of PRP responsibility for the above objectives are set forth pursuant to the Decree between Beatrice, UniFirst, Grace, NEP, EPA, and MADEP.

The Decree states that, for purposes of the Decree-mandated RI/FS, the Central Area "consists of all groundwater and land masses within Route 128 to the north, Route 93 to the east, Salem and Cedar Streets to the south, and the Boston and Maine Railroad to the west, excluding the Source Area Properties as defined in the Consent Decree and the Aberjona River, its tributaries, and their sediments, and associated wetlands on the east side of the Aberjona River." Under the Decree, the Central Area now includes all of the area outside of the Source Area Properties at the Wells G&H Site, specifically including the Murphy, Whitney, and Aberjona properties located south of the Wildwood property and west of the river (Southwest Properties), and other miscellaneous properties within the Wells G&H Site.

The inclusion of the Southwest Properties in the Decree–expanded Central Area necessitated an evaluation of soil and groundwater at those properties, which had not been subject to as much prior investigation and interpretation as the Source Area Properties. RI work has been undertaken in the Central Area by GeoTrans, Inc of Harvard, Massachusetts (GeoTrans) on behalf of Grace, Beatrice, Unifirst, and NEP. This joint RI work includes background information on the Southwest Properties. However, a separate RI of the Southwest Properties was conducted by Remediation Technologies, Corporation (RETEC) on behalf of one PRP (Beatrice) and presented in the *Draft Remedial Investigation, Southwest Properties, Wells G&H Superfund Site, Woburn, Massachusetts*, dated February 16, 1994 (RETEC, 1994). One of the objectives for this work was to gather the data necessary for EPA to prepare a baseline risk assessment for the Southwest Properties to assess the need for remedial action. EPA's review of the Southwest Properties RI found significant deficiencies that required additional data gathering to support EPA's risk assessment, which were communicated to Beatrice in two detailed requests for additional data dated February 22 and October 15, 2000, respectively. In response, RETEC prepared a Sampling and Analysis Plan (SAP) for a Supplemental Remedial Investigation of the Southwest Properties dated July 19, 2002, which, following EPA commentary, was updated with page insert revisions dated September 19, 2002. The SAP as revised was conditionally approved by EPA in a letter dated October 18, 2002.

1.4 Site Description

Land use at and in vicinity of the Southwest Properties is highly developed with light commercial and light industrial areas bordering the wetlands area associated with the Aberjona River floodplain. Currently, the Aberjona property includes a fenced, idle auto salvage yard. A residence is also located outside the fenced salvage yard area. The Whitney property is occupied by a variety of small businesses (e.g., landscaping). The Murphy property is leased by Clean Harbors Environmental Services, and is a registered Treatment, Storage, and Disposal Facility (TSDF) under RCRA, currently used for treatment and storage of waste oil.

1.4.1 Parcel-by-Parcel Description

The following summarizes relevant descriptive, background, and investigative data for each parcel in the Southwest Properties: Aberjona, Whitney, and Murphy. Excerpts of tables and figures from relevant referenced reports are included in Appendix A.

1.4.1.1 Aberjona Auto Parts Property

The Aberjona property is a 6.43-acre parcel that abuts the Aberjona River to the northeast, Salem Street to the southeast, Whitney to the southwest, and Wildwood to the northwest. There are three buildings on the Aberjona property. The largest of these buildings housed the former auto parts store and offices. The back portion of the building was used for storage and removal of parts. The eastern half of this building currently houses an auto repair shop. The other two buildings on the property are a house (residence) and detached garage. Most of the property is a fenced auto salvage yard, except for the residence's yard, a small parking area along Salem Street, and a triangular portion next to the Whitney property. The current ground surface is fill material ranging from six inches to five feet in thickness over the original ground surface. Environmental data for the Aberjona property has been obtained by work conducted on behalf of or by EPA by various contractors, and on behalf of a Potentially Responsible Party (PRP) by RETEC, which is summarized below.

EPA Investigations at Aberjona. During a site inspection of the Aberjona property by E&E personnel in 1987, no evidence of unconsolidated deposit, groundwater, or surface water contamination was identified. A degreasing solvent was used to clean engine parts on the property and the spent solvent was discharged to the municipal sewer system. The inspectors identified a number of empty 55-gallon drums and were notified that three underground petroleum storage tanks were located on the property.

NUS Corporation performed an investigation of Aberjona as part of the Wells G&H Site RI in 1985 and Ebasco conducted a later study of Aberjona as part of the Wells G&H Supplemental RI in 1988 (NUS, 1986 and Ebasco, 1988). These investigations included the collection and analysis of soil samples and the installation of groundwater monitoring wells S-83 and AB-1. The soil samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), and PCBs. Five VOCs were detected in subsurface soils at depths up to 11 feet below ground surface (bgs) including 2-butanone, acetone, chloroform, methylene chloride, and toluene. Groundwater collected from well AB-1 contained the following four VOCs (with maximum concentrations shown in parentheses): acetone (110 ug/L), toluene (18J ug/L), chloroform (6J ug/L), and total xylenes (6J ug/L). (The "J" flag indicates an estimated concentration value.) The following two SVOCs were detected, with results shown in parentheses: n-nitrosodiphenylamine (28B ug/L maximum) and bis(2-ethylhexyl) phthalate (10B ug/L). The acetone, n-nitrosodiphenylamine and bis(2-ethylhexyl) phthalate detected in AB-1 were also detected in a blank sample. Well S-83 was sampled five times between April 1985 and June 1985 and contained the following four VOCs (with results shown in parentheses): PCE (15 ug/L maximum), TCE (1400J ug/L), 1,2-DCE (7 ug/L), and trans-1,2-DCE (110 ug/L maximum).

RETEC Investigations at Aberjona. RETEC conducted an investigation of the Southwest Properties in 1993 that included sampling and analysis of surface soil (0-0.5 ft), subsurface soil (above the water table), and groundwater. During RETEC's 1993 investigation at Aberjona, RETEC collected nine surface soil samples, nine subsurface soil samples, and six groundwater samples. Revised data summary tables provided by RETEC in 2003 (RETEC, 2003) and excerpted figures from RETEC's 1994 Draft RI for the Southwest Properties (RETEC, 1994) are provided in Appendix A.2.

In seven of the nine surface soil samples collected in 1993 at Aberjona, 1,1-dichloroethene (1,1-DCE) was identified below the sample quantitation limit (SQL) and reported as estimated values ranging from 0.0011J to 0.0048J mg/kg. This was the only chlorinated VOC detected by RETEC in the surface soil on the Aberjona property.

Total BTEX concentrations were detected above the SQLs in two surface soil samples at this site. The highest concentration of total BTEX was detected in AB-SS5 at a concentration of 0.201 mg/kg. This sample was located in the northeast corner of the Aberjona property. Xylene (total) was the principal constituent present in this sample, identified at 0.162 mg/kg. Sample AB-SS8 had a total BTEX concentration of 0.0109 mg/kg. All other surface soil samples had BTEX concentrations below the SQL.

Soil sample AB-SS5 had the highest concentration of PAHs of the nine surface soil samples collected on the Aberjona property in 1993. Chrysene was detected at 1.489 mg/kg in this sample. Other PAHs identified in this sample include, but are not limited to, the following (concentrations shown in parentheses): benzo(a)anthracene (1.064 mg/kg), benzo(b)fluoranthene (1.56 mg/kg), benzo(k)fluoranthene (1.064 mg/kg), benzo(a)pyrene (1.064 mg/kg), and indeno(1,2,3-cd)pyrene (1.064 mg/kg). Dibenzofuran was reported below the SQL at an estimated concentration of 0.142J mg/kg.

PAHs were also identified in surface soil at AB-SS6, at estimated concentrations below the SQL. All other surface soil samples collected on the Aberjona property identified estimated values of fluoranthene and pyrene, with the exception of surface soil sample locations AB-SS8 and AB-SS9 where fluoranthene and pyrene were not detected.

Five surface soil samples collected from the Aberjona property in 1993 contained pesticides at concentrations ranging from non-detect to 0.0167 mg/kg (total pesticides). The principal compounds identified are as follows (with the maximum detected concentration in parentheses): 4,4'-DDE (0.0046 mg/kg), 4,4'-DDD (0.0167J mg/kg), 4,4'-DDT (0.116J mg/kg), alpha-

chlordane (0.0069J mg/kg), gamma-chlordane (0.0051J mg/kg), Aldrin (0.0038J mg/kg), and Endosulfan II (0.0023J mg/kg)

PCBs were detected in all but three of the surface soil samples collected on the Aberjona property by RETEC. Concentrations ranged from the SQL to 0.763 mg/kg total PCBs, with Aroclors 1254 and 1260 detected most frequently.

Arsenic was identified in all surface soil samples collected at the Aberjona property by RETEC in 1993 with a concentration range of 1.8 to 11.9 mg/kg. However, the lowest and highest concentrations of arsenic were identified in AB-SS9 and its duplicate, respectively. Total chromium was also identified in all soil samples collected on the Aberjona property. Concentrations of total chromium ranged from 8.4 to 20.8 mg/kg. The highest concentration was identified in AB-SS6. Lead was detected in Aberjona surface soil at concentrations ranging from 41.0J mg/kg (AB-SS9) to 838 mg/kg (AB-SS5). Cyanide was not detected above the SQL in any of the samples collected on Aberjona property.

Nine samples and one duplicate sample were collected from in 1993 subsurface soil at the Aberjona property at depths generally ranging from three to four feet bgs. BTEX and 1,1-DCE were the only groups of constituents detected at this site. Total BTEX ranged from 0.0017 mg/kg in AB-SS5D to 0.0352 mg/kg in AB-SS9D. Xylene represented the largest contributor to the AB-SS9D total at 0.0271 mg/kg. 1,1-DCE was detected in seven subsurface soil samples at Aberjona in concentrations ranging from 0.0009J mg/kg (AB-SS1D) to 0.0014J mg/kg (AB-SS3D).

Nearly all subsurface soil samples collected on the Aberjona property in 1993 had SVOCs reported as estimated concentrations below the SQL or with a blank qualifier. Total PAH concentrations ranged from 0.199 mg/kg in AB-SS5D to 0.233 mg/kg in AB-SS3D. Di-n-butlphthalate and butybenzylphthalate were detected at maximum concentrations of 0.203J mg/kg (AB-SS1D duplicate) and 0.104J mg/kg (AB-SS9D duplicate), respectively.

Pesticides identified in subsurface soil at the Aberjona property included Aldrin, 4,4'-DDT, and Endrin Aldehyde. Aldrin was reported in two subsurface soil samples, AB-SS4D and AB-SS7D, at 0.0021J mg/kg and 0.0018J mg/kg, respectively. 4,4'-DDT was reported at the highest concentration of the pesticides detected in subsurface soil at Aberjona and was identified in two soil samples, AB-SS3D (0.0089 mg/kg) and AB-SS8D (0.0220 mg/kg). The highest concentrations of PCB Aroclors were identified in soil sample AB-SS8D at 0.283 mg/kg and 0.232 mg/kg for Aroclors 1242 and 1260, respectively. PCBs were reported as non-detect or estimated below the SQL (AB-SS1D, Aroclor 1260, 0.0750J mg/kg) the highest concentrations in all other subsurface soil samples at Aberjona.

Metals detected in subsurface soil at the Aberjona property in 1993 include, but are not limited to, arsenic, cadmium, chromium, and lead. Arsenic was detected in subsurface soil at concentrations ranging from 1.4 to 42.6J mg/kg. The lowest arsenic concentration was detected in sample AB-SS5D and the highest concentration was detected in sample AB-SS8D. Cadmium concentrations ranged from 1.1 mg/kg (AB-SS3D) to 8.2 mg/kg (AB-SS8D). Chromium ranged from 5.8J mg/kg (AB-SS4D) to 544 mg/kg (AB-SS8D). The concentration of lead in subsurface soil varied across the Aberjona property with a concentration range of 1.1J mg/kg (AB-SS4D) to 637 mg/kg (AB-SS8D). Cyanide was not detected above the SQL in any of the subsurface soil samples collected on the Aberjona property.

The chlorinated volatile organic compounds identified in groundwater at the Aberjona property included 1,2-DCE (total), TCE, and PCE. 1,2-DCE (total) was identified in wells AB-1 and S-83M at 4.0 and 1.3J µg/L, respectively. TCE was reported in three wells, S-83M, AB-2M and AB-2R, with a concentration range of 4.4 to 363 µg/L. The highest concentration of TCE was reported in AB-2M. TCE was identified in the bedrock well AB-2R at 144 µg/L. This bedrock well is screened ten feet into competent bedrock. PCE was also reported in these three wells at concentrations ranging from 0.9J to 21.2J µg/L. The highest concentration was reported in AB-2M, with 20.7 µg/L in the bedrock well AB-2R.

BTEX concentrations were not reported above the SQL in any of the groundwater samples collected on the Aberjona property. However, the detection limits in AB-2M and AB-2R were reported as 50 to 20 µg/L, respectively.

PAHs were not detected in groundwater samples collected from the Aberjona property by RETEC. Phenol was reported below the SQL at an estimated value of 3J µg/L in S-83M. No pesticides or PCBs were detected in groundwater at the Aberjona property by RETEC.

Only two metals were detected in groundwater on the Aberjona property in excess of MCLs in 1993: manganese and arsenic. Manganese was detected above the EPA secondary MCL of 50 µg/L in monitoring wells AB-1, AB-2SS, AB-2M, AB-2R and S-83M. The highest concentration was reported in monitoring well AB-2SS at 734 µg/L. Manganese was also detected at 536 µg/L in the intermediate well, AB-2M, and at 179 µg/L in the bedrock well (AB-2R). Arsenic was identified at 13 µg/L (AB-1), above the EPA MCL of 10 µg/L promulgated by EPA for enaction in 1/23/06. Cyanide was not detected in any monitoring well on the Aberjona property.

1.4.1.2 Whitney Barrel Property

To the west of the Aberjona property is the 2.73 acre former Whitney Barrel Company property. Although the barrel company is no longer in operation at the Whitney property, the long rectangular building that formerly housed the barrel company is currently occupied by several companies (e.g., landscapers, automotive glass company). Wetland areas surround the property to the northwest and west, and fill material has been placed over the original ground surface over the remainder of the property. The open area around the long rectangular building is cluttered with brick, wood and metal debris. The area also includes old automobiles. Environmental data for the Whitney property has been generated by work conducted on behalf of EPA by Ecology & Environment, Inc., as well as the property owner by GHR Engineering Associates (GHR). RETEC also performed work at Whitney on behalf of the PRP. This work is summarized below:

EPA Investigations at Whitney. The first investigation conducted on the Whitney property was performed by E&E in 1980 on behalf of EPA. The E&E inspection of the Whitney Barrel property noted a large number of empty tanks and drums at Whitney. Some of the empty drums displayed labels for pesticides and solvents. A number of empty steel drums and one full cardboard drum bore caustic material labels. In addition to the drums and tanks, the property was reported to be covered with scrap metal, debris, and trailers.

EPA characterized the Whitney Barrel property as having widespread, low concentrations of VOCs, PCBs and pesticides in soil and groundwater. The chlorinated and petroleum compounds identified in soils were reported as estimated values below the SQL. The source of these constituents is a result of industrial activities at Whitney, specifically, metal salvage, drum and tank cleaning, spills or leaks of solvents and degreasers.

GHR Investigations at Whitney. In 1985, soil impacts were detected at the Whitney property during the Wells G&H RI, which prompted MADEP to order Whitney to conduct a site investigation of the property. Soil and groundwater data summary tables for the GHR investigation discussed below were obtained from RETEC 1994 and are provided in Appendix A.3.

GHR conducted a site assessment in 1988 on behalf of the Whitney property owners, including a geophysical survey, soil vapor screening, test pitting, soil boring advancement, and monitoring well installation. GHR reported the results of 23 soil samples. Compounds detected in soils included VOCs, SVOCs, pesticides, PCBs, and low concentrations of inorganics considered by GHR to be within the range of observed background concentrations (GHR, 1988).

Eleven VOCs were detected in soil samples collected by GHR. The following summarizes the VOCs detected with the maximum detected concentration provided in parentheses: 1,1,1-TCA (2 mg/kg), 1,2-DCE (0.032 mg/kg), acetone (0.062 mg/kg), carbon disulfide (0.001J mg/kg), chlorobenzene (0.28 mg/kg), ethylbenzene (3.9 mg/kg), methylene chloride (0.005J mg/kg), PCE (320 mg/kg), toluene (31 mg/kg), total xylenes (28 mg/kg), and TCE (330 mg/kg). PCE methylene chloride, and TCE were the most frequent VOCs detected in Whitney soil by GHR.

PCE was detected in 8 out of 23 soil samples. Methylene chloride was detected in 5 out of 23 soil samples. TCE was detected in 4 out of 23 soil samples.

Twenty-seven SVOCs were detected in the soil samples collected by GHR. The following summarizes the SVOCs detected with the maximum detected concentration provided in parentheses: 1,2,4-trichlorobenzene (2 mg/kg), 1,2-dichlorobenzene (0.073J mg/kg), 1,3-dichlorobenzene (0.36 mg/kg), 1,4-dichlorobenzene (0.92 mg/kg), 2-methylnaphthalene (0.82 mg/kg), acenaphthene (2.3 mg/kg), acenaphthylene (0.20J mg/kg), anthracene (1.4 mg/kg), benzo(a)anthracene (1.1 mg/kg), benzo(a)pyrene (1.2 mg/kg), benzo(b)fluoranthene (0.96 mg/kg), benzo(g,h,i)perylene (1 mg/kg), benzo(k)fluoranthene (0.64 mg/kg), benzylbutylphthalate (5.7 mg/kg), bis(2-ethylhexyl)phthalate (11 mg/kg), chrysene (1.4 mg/kg), dibenzofuran (0.82 mg/kg), dibenz(a,h)anthracene (0.240J mg/kg), diethyl phthalate (0.01 mg/kg), di-n-butyl phthalate (2.9 mg/kg), fluoranthene (2.6 mg/kg), fluorene (1.6 mg/kg), indeno(1,2,3 cd)pyrene (0.6 mg/kg), naphthalene (3.9 mg/kg), phenanthrene (2.4 mg/kg), pyrene (3 mg/kg), and 2,4,5-trichlorophenol (0.093J mg/kg).

PAHs and phthalate compounds were the most frequent SVOCs detected in Whitney soil by GHR. For example, both pyrene and bis(2-ethylhexyl)phthalate were detected in 22 out of 23 soil samples.

The pesticide chlordane was detected in all of the surface soil samples collected on Whitney property by GHR and in two subsurface samples. Chlordane concentrations ranged from 0.06 to 26.8 mg/kg. PCBs were detected in 21 samples with a maximum concentration of 94.8 mg/kg (Aroclor 1260). Aroclor 1260 was the most frequently detected PCB compound in soil at the Whitney property having been detected in 16 out of 23 soil samples. The depth of contamination is unclear because the GHR samples were collected as composites over broad depth intervals. However, the identification of widespread distribution of pesticides and PCBs is consistent with historical information compiled by GHR.

GHR analyzed Whitney soils for 18 metals/elements. Antimony was detected at concentrations ranging from 22 to 30 mg/kg. Arsenic was found in all samples at concentrations ranging from

2.02 mg/kg to 415 mg/kg. Total chromium was detected in all samples at concentrations ranging from 5.9 to 450 mg/kg. Lead was also detected in all soil sample locations at Whitney with concentrations ranging from 10 to 252 mg/kg.

GHR detected varying concentrations of VOCs, SVOCs, and PCBs in groundwater. VOCs were detected at all well locations. Examples of VOCs detected by GHR include: 1,1-dichloroethane (1,1-DCA), 1,1-DCE, 1,2-dichloroethane (1,2-DCA), 1,1,1-TCA, TCE, PCE, vinyl chloride, and BTEX compounds. Three VOCs (benzene, vinyl chloride, and 1,4-dichlorobenzene) were detected in excess of MCLs. PCBs were also detected in two wells with a maximum concentration of 10 µg/L, which is greater than the MCL of 0.5 µg/L. The highest concentrations of chlorinated compounds were detected in monitoring well MW-4S. During GHR's 1988 investigation, 1,1-DCE was found at concentrations ranging from 49 µg/L (MW-2S) to 300 µg/L (MW-4S). The MCL for 1,1-DCE is 7 ug/L.

Arsenic was detected in two wells by GHR in excess of the MCL. Arsenic was detected at a concentration of 11 µg/L in MW-1S, which is located on the southwest side of the property near the property boundary with Murphy's waste oil. Well MW-3S, located in the rear of the property of the southwest corner of the main building, had arsenic at a concentration of 62 µg/L.

RETEC Investigations at Whitney. During the 1993 Southwest Properties RI, RETEC conducted additional soil investigations at Whitney to supplement the 23 soil samples collected previously by GHR. A total of four surface (0-0.5 feet) and four subsurface soil samples were collected. Revised data summary tables provided by RETEC in 2003 (RETEC, 2003) and excerpted figures from RETEC's Draft RI for the Southwest Properties (RETEC 1994) are provided in Appendix A.2.

One surface soil sample at Whitney (WB-S4) contained 1,1-DCE (0.0016J mg/kg) and BTEX. Benzene and toluene were detected in WB-S4 at concentrations of 0.0008J mg/kg and 0.0015J mg/kg, respectively.

The SVOCs detected by RETEC in surface soil at Whitney are summarized as follows with the maximum detected concentration provided in parentheses: 2-methylphenol (0.036J mg/kg), naphthalene (0.394 mg/kg), 2-methylnaphthalene (0.502 mg/kg), fluorene (0.036J mg/kg), phenanthrene (0.394 mg/kg), anthracene (0.179J mg/kg), di-n-butylphthalate (0.179J mg/kg), fluoranthene (0.466 mg/kg), pyrene (0.609 mg/kg), butylbenzylphthalate (0.588 mg/kg), benzo(a)anthracene (0.466 mg/kg), chrysene (0.394 mg/kg), bis(2-ethylhexyl)phthalate (29.216 mg/kg), benzo(b)fluoranthene (0.968 mg/kg), benzo(k)fluoranthene (0.466 mg/kg), benzo(a)pyrene (0.753 mg/kg), dibenz(a,h)anthracene (0.179J mg/kg) and benzo(g,h,i)perylene (0.968 mg/kg).

Pesticides were detected in all four surface soil samples. The primary pesticides included 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, chlordane, aldrin, and endrin. The maximum chlordane result was 1.309 mg/kg (total of alpha- and gamma-chlordane) and was detected in WB-SS3. Concentrations of 4,4'-DDD and 4,4'-DDT in surface soil ranged from non-detect to 0.131 mg/kg.

PCBs were detected in three of the four surface soil samples at concentrations ranging from 0.06 mg/kg to 0.571 mg/kg (both Aroclor 1254).

Several inorganics were also detected in surface soil at Whitney. Examples include the following with maximum concentrations shown in parentheses: lead (1,207 mg/kg), cadmium (5.9J mg/kg), chromium (618J mg/kg), and cyanide (1.8J mg/kg).

Subsurface soils collected by RETEC at Whitney contained VOCs, SVOCs, pesticides, PCBs and metals. The results of the subsurface soil analyses are summarized below.

VOCs detected by RETEC in subsurface soils at Whitney are summarized as follows with their maximum soil concentrations in parentheses: methylene chloride (2.69 mg/kg), acetone (0.94 mg/kg), 1,1-DCE (0.0011J mg/kg), benzene (0.0006J mg/kg), PCE (0.57J mg/kg), toluene (0.28J mg/kg), chlorobenzene (0.0007J mg/kg), ethylenebenzene (0.57J mg/kg), and total xylenes (3.33 mg/kg).

The SVOCs detected by RETEC in subsurface soil at the Whitney property include 14 PAHs and one phthalate compound. The PAHs detected are summarized as follows with their maximum detected concentrations in parentheses: acenaphthene (0.038J mg/kg), fluorene (0.038J mg/kg), phenanthrene (0.538 mg/kg), anthracene (0.358 mg/kg), di-n-butylphthalate (0.114J mg/kg), fluoranthene (2.366 mg/kg), pyrene (1.398 mg/kg), benzo(a)anthracene (1.111 mg/kg), chrysene (1.434 mg/kg), benzo(b)fluoranthene (1.613 mg/kg), benzo(k)fluoranthene (0.753 mg/kg), benzo(a)pyrene (1.290 mg/kg), indeno(1,2,3-cd)pyrene (0.968 mg/kg), dibenz(a,h)anthracene (0.287J mg/kg), and benzo (g,h,i) perylene (1.254 mg/kg).

Seven pesticide compounds were detected in subsurface soils at Whitney, which are summarized as follows with the maximum detected concentration in parentheses: aldrin (0.0197 mg/kg), dieldrin (0.0032J mg/kg), 4,4'-DDE (0.0535 mg/kg), endrin (0.0123J mg/kg), 4,4'-DDD (0.0491 mg/kg), alpha-chlordane (0.0368 mg/kg), and gamma-chlordane (0.0319 mg/kg).

Two PCB Aroclor compounds were detected in subsurface soil at Whitney. The detected PCBs are summarized as follows with their maximum detected concentrations in parentheses: Aroclor-1254 (1.414 mg/kg) and Aroclor-1260 (0.090 mg/kg).

In general, the inorganic compounds detected in surface soils at Whitney were similar to those detected in subsurface soils. Arsenic concentrations ranged from 1.6J to 5.8J mg/kg, cadmium from 2.9J to 5.3J mg/kg, chromium from 7.5J to 61J mg/kg, lead from 4.6J to 387J mg/kg, and cyanide from 0.2J to 0.77J mg/kg.

Several VOCs were detected in groundwater samples at Whitney by RETEC, including 1,1-DCE, 1,1-DCA, 1,2-DCE, chloroform, 1,1,1-TCA, TCE, benzene, and PCE. These compounds were detected in unconsolidated deposits and shallow bedrock. The VOCs detected are summarized as follows with the maximum detected concentration provided in parentheses: 1,1-DCE (1.4J ug/L), 1,1-DCA (3.5 ug/L), 1,2-DCE (3.7 ug/L), 1,1,1-TCA (2.9 ug/L), TCE (3.0 ug/L), benzene (1.1J ug/L), and PCE (1.8J ug/L). Of the above-listed compounds with MCLs

(1,1-DCE; 1,1,1-TCA; TCE; benzene; and PCE), none were found at concentrations in excess of an MCL.

No SVOCs or PCBs were detected in groundwater by RETEC. The only pesticide detected in groundwater at Whitney was chlordane at an estimated concentration of 1.0J µg/L (total alpha- and gamma-chlordane) in monitoring well MW-4SS.

Manganese was also detected in 4 out of 5 groundwater monitoring wells at Whitney at concentrations ranging from 85 to 480 µg/L. This concentration range exceeds the secondary MCL of 50 µg/L. Mercury was detected at one well location (WB-1SS) at an estimated concentration of 0.4 µg/L. Arsenic was detected in the same well (WB-1SS) at 2.0 B µg/L. (The "B" qualifier on inorganic results indicates the reported value is less than the SQL, but greater than or equal to the instrument detection limit). Chromium and lead were both detected in monitoring well MW-4SS at concentrations of 4.0B µg/L and 1.0B µg/L, respectively. Nitrate/nitrite was detected in all Whitney monitoring wells. Concentrations ranged from 0.07 mg/L (WB-15S) to 10.0 mg/L (WB-1M).

1.4.1.3 Murphy Waste Oil Property

The Murphy property lies to the west of Whitney and to the east of the B&M Railroad. It is predominantly covered by fill. North and east of the fence that surrounds the waste oil facility is a wetland area. The foundation of a former building occupies the northern portion of the property. The current oil storage facility is a single building within the confines of the fence on the northwest side of the property. Two buildings on the outside of the fence are used for storage and office space. Environmental data for this property have been generated by work conducted on behalf of or by EPA, Clean Harbors, and RETEC, and are summarized below.

EPA Investigations at Murphy. In 1988, EPA's Technical Assistance Team (TAT) contractor Roy F. Weston, Inc. collected a single surface soil sample (A-1) from the northern part of the Murphy property in an area where the surface was identified as "oil stained." Sample A-l was

analyzed for PCBs and SVOCs. The laboratory results identified PCBs at concentrations of 0.01 mg/kg, fluoranthene at 0.96 mg/kg and pyrene at 2.4 mg/kg.

Clean Harbors Investigations at Murphy. Between 1987 and 1990, Clean Harbors performed a series of investigations in preparation of the property becoming a permitted waste oil handling facility. Soil borings and monitoring wells were installed by Clean Harbors and sampled for total petroleum hydrocarbons (TPH), PCBs, and VOCs. Groundwater was analyzed for TPH. In 1989, approximately 1,100 cubic yards of petroleum-impacted soils were excavated under Clean Harbors oversight from the central portion of the Murphy property where new facility structures were being built. Eight samples of stockpiled soil were analyzed for VOCs, PCBs, TCLP metals, pH, flashpoint, total solids, reactive sulfide and reactive cyanide. Excerpted data summary tables and figures from Clean Harbors reports are provided in Appendix A.4, including the results of soil stockpile sampling.

Based on the Clean Harbors data, the Murphy property is characterized by petroleum contaminated soils and groundwater contaminated with 1,1-DCE and TCE at concentrations above MCLs. The wetland located between the Murphy property and the Whitney property is characterized by PCB, petroleum, lead, and chromium contamination. Clean Harbors also detected hexavalent chromium in "wetland soil." In addition, petroleum contaminated soils were identified below fill material that was brought on-site after an interim removal action taken by Clean Harbors. The petroleum contamination is a direct result of the oil recycling conducted at the facility.

Clean Harbor's groundwater analytical program identified chlorinated compounds including trans-1,2-DCE, 1,1-DCA, 1,1,1-TCA, TCE, and PCE. TCE was reported above the MCL of 5 µg/L in monitoring well MR-2SS at 22.4 µg/L. These compounds have also been detected in soil.

Following the sampling at Murphy associated with the 1993 Southwest Properties RI performed by RETEC (described below), Clean Harbors collected additional data at Murphy in accordance with a RCRA Part B permit issued by MADEP. These studies have helped to further define the

nature and extent of soil and groundwater impacts at the property and have included hydrogeologic characterization studies to satisfy RCRA Part B permit requirements, an evaluation of substantial release migration, a sewer manhole investigation, and groundwater monitoring well investigations. Clean Harbors also conducted a Focused Human Health and Imminent Hazard Evaluation and Evaluation of Imminent Hazard to Environmental Receptors.

RETEC Investigations at Murphy. During the 1993 Southwest Properties RI, RETEC performed sampling of surface soil, subsurface soil, wetland soil, and groundwater at the Murphy property. Revised summary tables provided by RETEC (RETEC, 2003) and excerpted figures from RETEC's Draft RI for the Southwest Properties (RETEC, 1994) are provided in Appendix A.2.

Surface soil samples from Murphy collected by RETEC contained low concentrations (up to 0.0016 mg/kg) of 1,1-DCE and (0.0018J mg/kg) TCE. BTEX was also detected in three of the six surface soil samples at low concentrations (up to 0.0314J mg/kg total BTEX). No VOCs were detected in three wetland soil samples collected. SVOCs were detected in all Murphy surface soil samples.

Twenty SVOCs were detected in Murphy surface soil, most of which were PAHs. The SVOCs detected in surface soil are summarized as follows with the maximum detected concentration provided in parentheses: 2-methylnaphthalene (0.069J mg/kg), acenaphthylene (0.070J mg/kg), acenaphthene (0.070J mg/kg), dibenzofuran (0.035J mg/kg), fluorene (0.070J mg/kg) phenanthrene (0.275J mg/kg), anthracene (0.140J mg/kg), carbazole (0.070J mg/kg), di-n-butyl phthalate (0.070J mg/kg), fluoranthene (1.193 mg/kg), pyrene (1.158 mg/kg), butylbenzyl phthalate (0.035J mg/kg), benzo(a)anthracene (0.702 mg/kg), chrysene (0.912 mg/kg), benzo(b)fluoranthene (1.018 mg/kg), benzo(k)fluoranthene (0.596 mg/kg), benzo(a)pyrene (0.807 mg/kg), indeno(1,2,3-cd)pyrene (0.702 mg/kg), dibenz(a,h)anthracene (0.140J mg/kg), and benzo(g,h,i)perylene (0.737 mg/kg).

Thirteen SVOCs were detected by RETEC in wetland soil at Murphy and are summarized as follows with the maximum detected concentration provided in parentheses: dimethylphthalate

(0.043J mg/kg), phenanthrene (0.323J mg/kg), di-n-butylphthalate (0.404J mg/kg), fluoranthene (0.860J mg/kg), pyrene (0.753J mg/kg), benzo(a)anthracene (0.323J mg/kg), chrysene (0.538J mg/kg), bis(2-ethylhexyl)phthalate (5.051J mg/kg), benzo(b)fluoranthene (0.753J mg/kg), benzo(k)fluoranthene (0.430J mg/kg), benzo(a)pyrene (0.323J mg/kg), indeno(1,2,3-cd) pyrene (0.323J mg/kg), and benzo (g,h,i) perylene (0.430J mg/kg).

Three pesticide compounds were detected in surface soil at the Murphy property. These include endrin, alpha-chlordane, and gamma-chlordane at maximum concentrations of 0.0006J mg/kg, 0.0520 mg/kg, and 0.0290 mg/kg, respectively.

Seven pesticide compounds were detected in wetland soil at the Murphy property. The detected pesticides are summarized as follows with the maximum detected concentration provided in parentheses: aldrin (0.0028J mg/kg), 4,4'-DDE (0.0120J mg/kg), 4,4'-DDE (0.0483 mg/kg), 4,4'-DDT (0.1200J mg/kg), endrin aldehyde (0.0177J mg/kg), alpha-chlordane (0.8920 mg/kg), and gamma-chlordane (1.977 mg/kg).

PCBs were detected once in surface soil at a concentration of 0.0530 mg/kg (Aroclor 1260) in sample MR-SS3. However, PCBs were detected in all wetland soil samples and at greater concentrations. Both Aroclor 1254 and Aroclor 1260 were detected in wetland soil at maximum concentrations of 21.014 mg/kg and 5.958 mg/kg, respectively.

RETEC analyzed surface soil and wetland soil at the Murphy property for 23 metals plus cyanide. Notable metals detected in all surface soil and wetland soil samples include arsenic, chromium, and lead. In general, metals concentrations in wetland soil were greater than those detected in surface soil. For example, total chromium in surface soil ranged in concentration from 20.3 mg/kg to 75.7 mg/kg, but in wetland soil the total chromium concentration ranged from 569J mg/kg to 8193J mg/kg. Lead concentrations in surface soil ranged from 21.2 mg/kg to 142 mg/kg. In wetland soil, lead concentrations ranged from 295 mg/kg to 1245J mg/kg. Mercury was detected once in surface soil (0.72 mg/kg), but was detected in all wetland soil samples at concentrations ranging from 0.96 mg/kg to 7.4J mg/kg. Cyanide was not detected in

surface soil, but was detected in two wetland soil samples a concentration range of 0.34 to 4.7 mg/kg.

Subsurface soil samples collected by RETEC at the Murphy property contained VOCs, SVOCs, pesticides, and metals. The results of the subsurface soil sampling are provided below.

Ten VOCs were detected in subsurface soil at the Murphy property. The detected VOCs are summarized as follows with the maximum detected concentration provided in parentheses: methylene chloride (20.761J mg/kg), acetone (12.975J mg/kg), 1,1-DCE (0.011J mg/kg), total 1,2-DCE (1.557J mg/kg), 2-butanone (5.19J mg/kg), TCE (2.076J mg/kg), PCE (0.0016J mg/kg), toluene (3.114J mg/kg), ethylbenzene (1.557J mg/kg), and total xylenes (10.64 mg/kg).

Two PAHs and one phthalate compound were the only SVOCs detected by RETEC in subsurface soil. Each compound was detected once. They include 2-methynaphthalene (1.873J mg/kg), pyrene (3.745J mg/kg), and di-n-butylphthalate (0.078J mg/kg).

Four pesticides were detected in subsurface soil. These include the following (with maximum detected concentrations shown in parentheses): delta-BHC (0.0034 mg/kg), endrin (0.0085 mg/kg), alpha-chlordane (0.1290 mg/kg), and gamma-chlordane (0.1280 mg/kg). No PCBs were detected in subsurface soil.

Notable metals detected in subsurface soil at Murphy include arsenic, total chromium, and lead. Arsenic was detected in all samples at concentrations ranging from 1.3J to 9.3 mg/kg. Total chromium was detected in all samples at concentrations ranging from 6.6 mg/kg to 24 mg/kg. Lead was also detected in all samples at concentrations ranging from 1.6 mg/kg to 485 mg/kg.

RETEC sampled two wells installed on the Murphy property. Contaminants detected include VOCs, SVOCs and metals.

Nine VOCs were detected in groundwater at the Murphy property. The detected VOCs include (with maximum detected concentrations shown in parentheses) the following: 1,1-DCE (1.3J

µg/L), 1,1-DCA (2.6 µg/L), total 1,2-DCE (461 µg/L), 1,1,1-TCA (3.7 µg/L), TCE (22.6 µg/L), benzene (8.6J µg/L), PCE (3.8 µg/L), toluene (12.9 µg/L) and total xylenes (324 µg/L). TCE and benzene were detected in excess of their respective MCLs (both 5 µg/L).

Five SVOC compounds were detected in Murphy groundwater. The detected SVOCs include (with maximum detected concentrations in parentheses) include: 1,2-dichlorobenzene (9J µg/L), naphthalene (21 µg/L), 2-methylnaphthalene (19 µg/L), pyrene (3J µg/L), and bis(2-ethylhexyl)phthalate (2J µg/L). Only one of these detected SVOCs has a comparable EPA MCL (bis(2-ethylhexl)phthalate); the MCL for this compound (6 µg/L) was not exceeded.

No pesticides or PCBs were detected in the two wells sampled at the Murphy property by RETEC.

RETEC analyzed for 23 metals plus cyanide in groundwater at the Murphy property. Only lead was detected above a corresponding primary MCL/action level (15 µg/L) at a concentration of 29 µg/L.

1.5 Geologic/Hydrogeologic

1.5.1 Local Geology

The area in the vicinity of the Southwest Properties is underlain by unconsolidated glacial deposits that unconformably overlie crystalline bedrock (GeoTrans, 1994). Figure 1-4 is a surficial geology map of the Site area that shows the surficial distribution of the unconsolidated deposits and bedrock outcrops within the Wells G&H Site.

The unconsolidated deposits at the edges of the Aberjona River Valley are primarily ground moraine deposits. Within the Eastern Uplands, two varieties of till have been identified, a lodgment till and an ablation till. The lodgment till lies directly on the bedrock surface and is as much as 30 feet thick. The lodgment till was deposited at the base of the glacial ice, is very densely packed, generally has low permeability, and does not easily yield water to wells. Overlying the lodgment till is a thin layer of ablation till. The ablation till has a more sandy

texture and is less densely packed than the lodgment till. In the Eastern Uplands, the ablation till generally exists above the water table (GeoTrans, 1994).

The low lying western portion of the Central Area Aquifer is comprised of stratified outwash deposits. Geologic logs of wells and borings indicate that within the buried bedrock valley, the outwash deposits generally overlie the bedrock surface directly. In some areas, there is a thin layer of lodgment till between the outwash deposits and bedrock surface (GeoTrans, 1994).

The swamp deposits consist of decayed vegetal matter, silt, sand, and possibly clay. These deposits generally lie at the surface, except where covered by artificial fill, and are found within the wetlands that border the Aberjona River and its tributaries. Based on geologic logs from wells drilled through the swamp deposits, the thickness, which varies considerably and is probably a result of the surface topography of the outwash deposits, is generally less than 5 feet. The deposits are thickest in areas where there are depressions in the outwash surface on the flood plain of the Aberjona River. The thickest deposits, measured at S89, are approximately 25 feet thick. No measurements of hydraulic conductivity have been made (GeoTrans, 1994).

The stratified drift deposits fill the Aberjona River Valley, make up the Central Area Aquifer, and are up to 130 feet thick. The stratified drift deposits are well sorted and possess much higher hydraulic conductivity than the till. City of Woburn public water supply wells G&H and the J. J. Riley supply wells were constructed in the stratified drift because the high hydraulic conductivity of these deposits and proximity to the Aberjona River allowed large well yields (GeoTrans, 1994).[1] Several other industrial supply wells were operated in the stratified drift deposits north of the Wells G&H Site (Delaney and Gay, 1980).

The hydraulic conductivity of the stratified drift deposits, based on hydraulic testing in 31 individual wells and 43 grain size analysis estimates, range from 0.1 feet per day in the finer grained deposits to 350 feet per day in the gravelly layers (Myette et al., 1987). The

[1] The J.J. Riley facility is a former tannery located at the corner of Salem Street and Wildwood Road to the west of the Southwest Properties.

transmissivity of the Central Area Aquifer was determined to be between 17,000 and 30,000 square feet per day based on Wells G&H (Myette et al., 1987).

The bedrock underlying the Wells G&H Site has been mapped as Salem Granodiorite, Dedham Granite, and undifferential metavolcanics (Barosh et al., 1977). The underlying bedrock surface rises steeply from an elevation less than –100 feet National Geodic Vertical Datum (NGVD) along the buried valley axis, to an elevation greater than 100 feet NGVD near the intersection of Washington Street and Route 128. In general, available data indicate the bedrock is generally competent and is not extensively fractured, but contains localized fracture zones capable of yielding water to wells (GeoTrans, 1994). Figure 1-5 contains a bedrock geologic map of the Site area.

The hydraulic conductivity of the bedrock is generally low and, in general, potential well yields would be low. Localized areas within the Site, however, have been discovered where water yields have been sufficient for well installation such as Johnson Brothers greenhouses and New England Plastics (GeoTrans, 1987 and 1994; HMM, 1990).

1.5.2 Regional Hydrogeology

The Aberjona River, which has its headwaters in the Town of Reading and empties into the Mystic Lakes in the Town of Winchester, flows north to south through the Site. Relatively small amounts of groundwater enter the Aberjona River Valley from upgradient areas north of Interstate 95 (Route 128), and exit the narrow southern end of the valley south of Salem Street. A 38-acre wetland area exists along both sides of the Aberjona River that is located within the 100-year floodplain of the Aberjona River (EPA, 1989). The drainage basin area of the Aberjona River upstream of the Salem Street Bridge, which marks the downstream end of the Wells G&H Site, is approximately seven square miles (GeoTrans, 1994).

The United States Geological Survey (USGS) maintains a surface water gauging station at Winchester, which is about four miles downstream of the Salem Street Bridge. The average river discharge, as measured at the Winchester gauging station, for the period of record is 28.7

cubic feet per second (cfs). Extreme flows at Winchester during the period of record range from 0.25 cfs on October 10, 1950, to 1,330 cfs on January 25, 1979 (USGS, 1991). Since the early 1940s, there has been a general increase in both the frequency and magnitude of high flow events (GeoTrans, 1994).

River sediments are composed of silt and sand ranging in thickness from 0.5 to 2 feet and are underlain by peat averaging 7 feet in thickness. The peat, a relatively loose nearly saturated material, permits groundwater discharge to the Aberjona River (EPA, 1989).

1.5.3 Local Hydrogeology

Under non-pumping conditions, groundwater within the boundaries of the Wells G&H Site generally flows laterally in the unconsolidated deposits and bedrock from the edges of the valley toward the center of the valley. In the center of the valley and near the Aberjona River, groundwater which originated in the upland areas converges with groundwater flowing from north of Route 128 and generally assumes a more southerly flow direction approximately parallel to the course of the Aberjona River (GeoTrans, 1994).

In 1987, the USGS completed a hydrogeologic investigation of the central Aberjona River valley and evaluated the area of influence and zone of contribution to City of Woburn municipal Wells G&H. Figures 1-6 and 1-7 illustrate the area studied by the USGS and present representative cross-sections showing the generalized stratigraphy and a conceptual model of the groundwater flow system.

According to the USGS, groundwater in the Aberjona River valley in the vicinity of Wells G&H is present mainly in a 0.5-1.0-mile wide stratified drift aquifer that fills a deep, narrow bedrock channel. The USGS developed a generalized stratigraphy for the central Aberjona River valley that included four stratigraphic layers (with the upper three layers considered the local aquifer). The uppermost stratigraphic layer consists of sand, silt, clay, and deposits of peat, and has a thickness of 0 to 30 feet. It is underlain by an intermediate layer of fine-to-coarse sand that has a thickness of 10 to 50 feet.

Groundwater in the stratified drift is unconfined, and water levels fluctuate continuously in response to recharge and discharge. The water table is generally at or near the ground surface in most of the low-lying areas. The direction of groundwater flow is typically inward toward the central axis of the river. Under non-pumping conditions, groundwater discharges to the river and adjacent wetlands. Appreciable vertical hydraulic gradients were generally only observed near the outer river valley walls (downward) or directly adjacent to the river channel (upward). Groundwater flow elsewhere was primarily horizontal (GeoInsight, 2000). The lowermost aquifer layer, where Wells G&H were screened, consists of 20 to 50 feet of course sand and gravel. A layer of fine grained sand and silt (up to 40 feet thick) occupies the deepest portions of the river valley and is situated directly on top of bedrock (GeoInsight, 2000).

With respect to the Southwest Properties, groundwater generally flows across the Southwest Properties Site toward the Aberjona River and associated wetland areas. The surface configuration of the Southwest Properties and vicinity reflects the underlying bedrock surface. A fault extends north-south under the Aberjona River Valley. Many bedrock outcrops are present in the highlands to the east of the river valley. Vertical hydraulic gradients are typically downward on the valley flanks and upward in the center of the valley (RETEC, 2002).

Depth to groundwater at the Southwest Properties varies, but ranges from 5 to 9 feet from the ground surface. The direction of shallow groundwater flow is to the east toward the Aberjona River.

2.0 SITE INVESTIGATION

2.1 Field Investigation

A Supplement Remedial Investigation was conducted by the PRP to update and supplement data previously collected at the Southwest Properties. The results of the Supplemental RI are documented in the *Supplemental Remedial Investigation Report, Southwest Properties, Wells G&H Superfund Site, Woburn, Massachusetts*, prepared by the RETEC Group, Inc. on behalf of the Beatrice Company (RETEC, 2003). Please refer to this document for additional information on the associated field investigation, nature and extent of contamination and contaminant fate and transport.

On behalf of EPA, TRC performed oversight of the PRP's Supplemental Remedial Investigation, including split-sampling. The results of the split-sampling performed by TRC are documented in TRC's split-sampling report, which is currently in press. (TRC, 2004)

2.2 Environmental Data Utilized

Environmental data collected during several sampling events conducted by property operators, PRPs, and split samples collected on behalf of EPA by TRC were utilized to prepare the baseline human health and ecological risk assessment. These data are contained in the following three main data source documents:

- RETEC 1994, *Draft Remedial Investigation, Southwest Properties, Wells G&H Site, Woburn, Massachusetts, 1994*.

- RETEC 2003, *Supplemental Remedial Investigation, Southwest Properties, Volumes I through XXIII, Wells G&H Site, Woburn, Massachusetts*. Prepared by the RETEC Group, Inc., Concord, Massachusetts, August 2003.

- TRC 2004, *EPA/TRC and RETEC Split Sample Comparison Report for the Wells G&H – Southwest Properties, Supplemental Remedial Investigation, Woburn, Massachusetts.* Prepared by TRC Environmental Corporation, Lowell, Massachusetts, February 2004.

Additional data for the Murphy property were obtained from:

- Clean Harbors 1998, *Corrective Action Investigation Report (Part II),* Volume I of I, Murphy's Waste Oil Services, Inc., Woburn, Massachusetts, *1998*.

- Clean Harbors 1996, *Corrective Action Investigation Report*, Volumes 1, 2, and 3. Murphy's Waste Oil Service, Inc., 252 Salem Street, Woburn, Massachusetts, April 15, 1996.

Note that the Supplemental Remedial Investigation (RETEC, 2003) also includes groundwater data for samples collected in 2001 by Clean Harbors. Wells sampled by Clean Harbors in 2001 are located on the Murphy, Whitney and Wildwood properties, but only data from the Murphy and Whitney properties were used in this risk assessment.

Refer to Appendix B for media specific tables that summarize the data used to prepare the baseline human health and ecological risk assessment.

2.3 Data Validation

Data obtained as part of the Supplemental RI and associated TRC split data (RETEC, 2003; TRC, 2004) were validated according to Region I, *EPA-NE Data Validation Functional Guidelines for Evaluating Environmental Analyses,* December 1996, as described in the Supplemental RI and the TRC Split Report. The validation guidelines were modified to accommodate the non-CLP methods. The respective analytical results are discussed in the Supplemental RI and the TRC Split Report.

Data obtained from the Clean Harbors 1998 Corrective Action Investigation Report (Part II) were not validated when published. EPA determined that within the limited circumstances of

this project, validation of a representative subset of the analytical data may provide reasonable confidence in the quality of the data. EPA required that validation be conducted on a minimum of 25 percent of the total samples analyzed using EPA Tier II protocols, and 5 percent of the samples using EPA Tier III protocols, in accordance with EPA Region I data validation guidelines. However, no Tier III validation was performed due to lack of required data needed to perform Tier III. In almost all cases, only a limited Tier II validation was performed.

2.4 Data Treatment

This subsection discusses the use and treatment of the analytical data prior to use in the baseline human health and ecological risk assessment.

The following criteria were applied to the analytical data:

- If a value is not flagged, the value was used as reported (a detected value);
- If a value is flagged with "J", "EB", or "FB", the value was used as reported (a detected value);
- If a value is flagged with "R", the value was considered not to exist and was not used (a rejected value); and
- If the value is flagged with "U" or "UJ", the result was considered a nondetect (an undetected) value.

Prior to using analytical data for a primary sample with an associated field duplicate, the analytical values for the primary sample and the field duplicate were averaged together (EPA 1989a and 1989b) to provide a single set of values for the field duplicate pair. The following conventions were used for averaging field duplicate samples together:

- If both samples have detected values (flagged with "J" or unflagged), the average of the values was used. If one value or both values are flagged with "J", "EB", or "FB" prior to averaging, the resulting averaged value was flagged with "J", "EB", or "FB", as appropriate.

- If both samples have nondetected values (flagged with “U” or “UJ”), the lower value and its flag were used.

- If one sample has a nondetect value (flagged with “U” or “UJ”) and the other sample has a detected value (flagged with “J” or unflagged) the following is done:

  - If the detected value is less than or equal to the nondetected value, the detected value and its flag were used; or

  - If the detected value is greater than the nondetected value, the average of detected value and ½ the nondetected value were used. The resulting averaged value was flagged with “J”.

  - If one sample has a nonrejected value (flagged with “J”, “U”, “UJ”, “EB”, “FB” or unflagged) and one sample has a rejected value (flagged with “R”), the nonrejected value and its flag were used.

The range of detection limits was determined based on the individual sample-specific detection limit (or sample quantitation limit) for each analyte. Because of sample dilution and/or sample weights, laboratory detection limits for individual samples can be higher than the method-specified detection limits. Minimum and maximum SQLs were determined for each non-detect analyte using the sample’s SQL.

The frequency of detection is the number of samples with detected values per the number of samples analyzed. The number of samples with detected values was determined by totaling all samples with detected values. The number of samples analyzed was determined by totaling all samples with detected or nondetected values (flagged with “U”, “UJ”, “J” or unflagged). Rejected values (flagged with “R”) were not included in the total number of samples analyzed. For field duplicate samples, only one value was used when determining the number of samples analyzed and the number of detected values (as determined using the procedure described above).

Arithmetic mean concentrations and 95-percent Upper Confidence Limits (UCLs) were calculated using EPA's Pro UCL version 2.1 and included all detected values and ½ of the SQL for non-detected values. When the mean or 95-percent UCL was greater than the maximum value because of high or widely varying detection limits, or because a detected value is below the SQL (flagged with "J" on the laboratory report), or because a small data set was used, then the maximum detected result was used. Detected values below the SQL are considered to be estimated concentrations, but are used in the risk assessments.

3.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

3.1 Introduction

This section of the report contains the baseline human health risk assessment for the Southwest Properties in Woburn, Massachusetts. The focus of this risk assessment is the quantitative, and in some cases qualitative, evaluation of potential risks to human receptors who have the potential for current and/or future exposure to contaminants in soil, groundwater, air, sediment, and surface water. All three Southwest Properties are active commercial properties, one of which includes a residence (the Aberjona residence). Soils in the backyard of the Aberjona residence were evaluated as part of the Wells G&H Operable Unit 3 (OU-3) risk assessment and have not been included in this report. Portions of each of the properties are paved. A wetland area is found between the Murphy and Whitney properties (i.e., the Murphy wetland). Exposures associated with sediment and surface water at the Aberjona property were previously evaluated as part of the Wells G&H OU-3 risk assessment using a recreational scenario. Therefore, these data are not included in this report.

3.1.1 Purpose and Scope

The purposes of the baseline human health risk assessment are: 1) to evaluate the potential human health risks that may be posed by chemical contamination of the soil, groundwater, air, surface water, and sediment within currently accessible and future potentially accessible portions of the Site; and 2) to provide a basis for decisions as to whether remedial action is necessary. This baseline risk assessment may also be used qualitatively to identify site conditions (chemicals, exposure pathways, locations) of greatest potential concern.

According to EPA guidelines (EPA, 1989), the baseline risk assessment generally consists of four basic steps summarized below:

- **Hazard Identification.** Determination of the nature and amount of chemicals that could potentially be encountered at a site, and selection of those chemicals that are of potential concern for the assessment of the impact on human health.

- **Exposure Assessment.** Quantification of the extent, frequency, and duration of actual or potential exposure to chemicals by pathways relevant to a site and the activities of potential receptors.

- **Toxicity Assessment.** Identification of the types of health effects that could be associated with exposure to these chemicals, determination of the relationship between exposure (dose) and the probability of occurrence of the health impact (response).

- **Risk Characterization.** Estimation of the probability that an adverse health impact may occur as a result of exposure to chemicals in the amount and by the pathways identified and the uncertainty in those estimates.

The baseline human health risk assessment for the Site was conducted using methodologies required by EPA guidelines (EPA, 1989; 1992; 1993a; 1994b; 1995; 1996a; 1997a; 2001a; 2001b; 2002a; and 2003b). A baseline risk assessment is intended to be site-specific; therefore, site-specific information was incorporated into the evaluation whenever available. In the absence of site-specific information, default assumptions, as specified by EPA guidance, or professional judgment were used.

The baseline human health risk assessment provides estimates of risk, under both current use and hypothetical future use scenarios, to both the central tendency (CT) receptor and the reasonable maximum exposure (RME) receptor. The CT receptor is used to represent average exposures occurring at an exposure point while the RME receptor is used to represent the maximum (upper-bound) exposure that is reasonably expected to occur at an exposure point. Exposure pathways and exposure routes are selected based on current and future land use. Exposure assessments model human exposure by these pathways according to algorithms in relevant guidelines. Variables contributing most to estimates of risk or to the uncertainty in the risk assessment have been identified. Each of these steps is discussed in more detail in the appropriate sections of the report.

This baseline human health risk assessment consists of several sections. Subsection 3.1.2 identifies current and future exposure points and receptors. Section 3.2, Hazard Identification, describes the environmental samples used for the risk assessment, the selection of chemicals of potential concern (COPCs) from among the chemicals identified at the Site, and the determination of Exposure Point Concentrations (EPCs). Section 3.3, Exposure Assessment, describes the selection of receptors and exposure pathways to be evaluated and the calculation of dose to the receptors selected. Section 3.4, Toxicity Assessment, summarizes the toxicity of the COPCs including both potential carcinogens and noncarcinogens. Section 3.5, Risk Characterization, includes a summary of Site risks and an uncertainty analysis. Table 3-1 (Selection of Exposure Pathways) provides a conceptual model for the Site, identifying the exposure media, exposure points, receptors, and routes of exposure quantitatively evaluated as part of the baseline human health risk assessment.

3.1.2 Identification of Current/Future Exposure Points and Receptors

The purpose of this section is to briefly describe current and future exposure points and receptors selected for evaluation in the human health risk assessment, based on land use, Site characteristics and history.

The Southwest Properties consist of three adjacent properties with soil and groundwater contamination, each with unique ownership and land use histories (see Section 1) and contaminant sources (see the RETEC Supplemental RI). The Aberjona, Whitney and Murphy properties are, therefore, evaluated as separate exposure points in the risk assessment. The wetland located on the Murphy property (Murphy Wetland) is evaluated as an additional exposure point because it may have been impacted by more than one of these properties or by other neighboring properties. Approximately 54% of the wetland lies on the Murphy property. The remainder is located on the Whitney property (approximately 31%) and the Wildwood property (approximately 15%). Additional Aberjona-related exposure points include the triangular portion of the Aberjona property (the Aberjona Triangle) that is less secure than the remainder of the Aberjona property and may allow current access to trespassers (current), the Aberjona residence that is evaluated for potential indoor air impacts (current and future), and the

Aberjona property, including the triangle and salvage yard (current and future). In addition, the potential for off-site groundwater use is evaluated in the future time frame as a separate off-site residence exposure point that accounts for potential future potable use of contaminated groundwater originating from the Southwest Properties.

A summary of the exposure points evaluated in this risk assessment is provided below by scenario.

Exposure Point	Current Scenario	Future Scenario
Aberjona Residence	X	X
Aberjona Triangle	X	X
Aberjona Property (Salvage Yard and Triangle)	X	N/A
Whitney Property	X	X
Murphy Property (upland)	X	X
Murphy Wetland	X	X
Off-Site Residence	N/A	X

Notes: N/A – Not applicable X – Included exposure point

Figures 3-1A and 3-1B depict the current and future exposure points, respectively.

Current Receptors. The Southwest Properties are commercially active and zoned industrial (City of Woburn, 1997). Surrounding properties are also industrially zoned. Consequently, current human exposures evaluated in this risk assessment are primarily, but not entirely, associated with commercial use. Each property has two or three buildings which are occupied by residents (Aberjona only) or commercial workers. Contaminants present in soil and groundwater could impact indoor air in occupied buildings through gas phase migration.

The indoor air pathway is typically evaluated where contaminants in soil or groundwater with the potential to impact indoor air (i.e., sufficient volatility and toxicity) are located in close proximity to an occupied building (i.e., soil and groundwater within 30 feet of the building and up to 15 feet in depth). No currently occupied buildings were identified under these criteria at the three properties. Therefore, based on Tier 1 – Primary Screening Criteria from EPA's *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and*

Soils (*Subsurface Vapor Intrusion Guidance*) (USEPA, 2002b), the vapor intrusion pathway under current conditions is incomplete. However, contaminants with the potential to impact indoor air were detected in groundwater immediately upgradient of the Aberjona residence and the occupied commercial building on the Aberjona property. Because groundwater data close to these buildings are not available to rule out current exposures, residential and commercial exposures to indoor air attributable to groundwater contaminants are evaluated on the Aberjona property to minimize uncertainty in coverage in proximity to these buildings.

No currently occupied structure on the Whitney or Murphy property is downgradient of groundwater monitoring wells containing contaminants with the potential to impact indoor air. The Whitney and Murphy buildings are either unoccupied or are located in off-site background locations and, therefore, do not warrant an analysis of indoor air impacts. These buildings include the large central building at Whitney (unoccupied storage building), the Action Glass building at Whitney (background location), the Main Office building at the Murphy Property (background location), and the garage at the entrance to the Murphy property (unoccupied storage building).

There is no potable or non-ingestion use of groundwater at the Site. Site facilities are connected to the municipal water supply. Therefore, groundwater contaminant exposures are limited to potential impact to indoor air in occupied Aberjona buildings as discussed above.

Current soil exposures are limited to surface soils (0 to 2 feet) because excavation or invasive construction activities are not occurring at this time. Consequently, there are no current exposures to deeper soils (up to 15 feet in depth) because there are no activities occurring that would bring contaminated soil at depth to the ground surface.

Most areas of known soil contamination are currently fenced, which limits access by trespassers and other non-commercial receptors. However, trespassers may gain access to unsecure areas and incur exposure to contaminated surface soil. The Aberjona Triangle is currently accessible due to poor fencing and an unsecured gate. The front gate of the Whitney property is also unsecured. Consequently, trespassers are assumed to freely access the Aberjona Triangle and

Whitney property and incur exposure to contaminated surface soil. The remainder of the Aberjona property (i.e., the automotive salvage yard) is not accessible to trespassers due to the presence of a fence, locked gates, and a concrete wall.

The western boundary of the Whitney property abutting the Murphy wetland is not fenced and the wetland is accessible from the unsecure Whitney property; therefore, the Murphy wetland is currently accessible to a trespasser. A portion of the wetland is only seasonally ponded; therefore, exposure to sediments in the entire wetland is evaluated. As with soil, sediment exposure in the Murphy wetland is limited to the surficial interval since intrusive/excavation activities are not occurring in the wetland. Wading rather than swimming is the primary type of activity expected in the Murphy wetland due to the shallow depth of surface water. Commercial workers are assumed to not enter the wetland as part of job-related activities. The evaluation of trespasser exposures provides a conservative indication of commercial exposures should they be occurring.

Future Receptors. Commercial land use is assumed to continue in the future. Since fencing and gates may be removed in the future, trespassers or other non-commercial receptors may access the site with increased frequency compared to current receptors. This assumption eliminates the need for the Aberjona Triangle exposure point since the entire Aberjona property is considered accessible in the future. Future commercial workers and trespassers are assumed to be exposed to surficial soil contaminants.

Future development or improvements at the Southwest Properties may require excavation or construction activities. Therefore, construction-related exposures to surface soil (0 to 2 feet) and subsurface soil (2 to 15 feet) are possible. Future exposures may also include impacted outdoor air in construction settings (e.g., trenches) and direct contact exposures to shallow groundwater. Soil and groundwater sampling locations as deep as 15 feet are evaluated for the outdoor air and direct contact exposure pathways.

Residential land use at the Aberjona property is assumed to continue unchanged in the future. However, future residential development of the Whitney and Murphy properties, or at the Aberjona salvage yard, is considered highly unlikely.

A potential redevelopment option includes use of the properties for recreational activities with the construction of on-site recreational facilities. Because the change in land use may result in the movement of soils currently at depth to the surface, future recreational soil exposures are assumed for both the surface and subsurface interval. In addition, future recreational exposures to surface water and sediment are evaluated. Recreational users are likely to visit the site with greater frequency than trespassers.

Commercial or recreational buildings could be constructed in any area of the Southwest Properties, except the Murphy wetland. Therefore, an evaluation of indoor air impacts attributable to contaminants in soil and groundwater is warranted because of the potential for a complete vapor intrusion pathway in the future.

Based on information obtained from the Massachusetts Geographic Information System (Mass GIS), the Site is within an area classified by MADEP as a potentially productive aquifer (see Figure 3-2), and is therefore classified by MADEP as a GW-1 area under the Massachusetts Contingency Plan (310 CMR 40.0000). Because the site is located in this groundwater resource area, future potable use of groundwater by a resident at an off-site exposure point is possible, and is evaluated herein as the off-site resident exposure point. All groundwater from the Site, regardless of depth, is evaluated in this scenario due to the mobile nature of ground water (horizontal gradients and flow directions are well established) and the potential for groundwater to be pumped, rendering exposure to groundwater from any area of the Site possible.

Vertical gradients are also present in groundwater at the site. Data from the most recent groundwater elevation survey conducted at the site by RETEC indicate that the vertical gradients are mostly upward, but are spatially variable. This is consistent with other studies that indicate vertical gradients to be downward at the valley edge and upward in the center of the river valley (RETEC, 2003). However, the vertical gradients do not appear to be a significant factor in the

movement of contaminants at this site over the period of record (1993 to 2002). Therefore, contaminant concentrations in shallow groundwater are likely to represent the most significant contributors to indoor and outdoor air currently and in the foreseeable future.

3.2 Hazard Identification

The purpose of this section is the determination of the type and amount of chemicals present at the Site and the selection of the COPCs with regard to human health. In addition, this section summarizes the methodology used to determine EPCs for COPCs in each medium.

Environmental data used in this hazard identification are from samples that were collected during several sampling events conducted by property operators, PRPs, and split samples collected on behalf of EPA by TRC. These data are contained in the following three main data source documents:

- RETEC 1994, *Draft Remedial Investigation, Southwest Properties, Wells G&H Site, Woburn, Massachusetts, 1994*.

- RETEC 2003, *Supplemental Remedial Investigation, Southwest Properties, Volumes I through XXIII, Wells G&H Site, Woburn, Massachusetts.* Prepared by the RETEC Group, Inc., Concord, Massachusetts, August 2003.

- TRC 2004, *"EPA/TRC and RETEC Split Sample Comparison Report for the Wells G&H – Southwest Properties, Supplemental Remedial Investigation, Woburn, Massachusetts.* Prepared by TRC Environmental Corporation, Lowell, Massachusetts, February 2004.

Additional data for the Murphy property were obtained from:

- Clean Harbors 1998, *Corrective Action Investigation Report (Part II)*, Volume I of I, Murphy's Waste Oil Services, Inc., Woburn, Massachusetts, *1998*.

- Clean Harbors 1996, *Corrective Action Investigation Report*, Volumes 1, 2, and 3. Murphy's Waste Oil Service, Inc., 252 Salem Street, Woburn, Massachusetts, April 15, 1996.

Note that the Supplemental Remedial Investigation (RETEC, 2003) also includes groundwater data for samples collected in 2001 by Clean Harbors. Wells sampled by Clean Harbors in 2001 are located on the Murphy, Whitney and Wildwood properties, but only data from the Murphy and Whitney properties were used in this risk assessment.

Data available from prior documents/investigation efforts at the Site, and certain data contained in the above-referenced documents, were deemed unsuitable for use in the human health risk assessment. The reasons for this determination are summarized below:

- **Filtered Groundwater Data.** Historical groundwater samples collected for metals analysis at the Aberjona, Whitney, and Murphy properties were filtered. Since metals data collected using low-flow techniques are preferred for risk assessment purposes, only groundwater data collected using low-flow sampling procedures have been quantitatively evaluated.

- **Hexavalent Chromium Data.** Hexavalent chromium samples collected prior to the RETEC 2003 and TRC 2004 investigations were analyzed using a colorimetric method (Method 7196A), or the analytical method was undocumented. Method comparison data collected for the Wells G&H OU-3 risk assessment indicate that ion chromatography (Method 7199) is the preferred method for hexavalent chromium in solid matrices. Therefore, hexavalent chromium data presented in Clean Harbors 1998 and 1996 were not quantitatively used in this risk assessment. Only hexavalent chromium data obtained using the ion chromatography method for soil and Method 7196A for groundwater were quantitatively evaluated in the human health risk assessment.

- **Historical Groundwater Data.** Only groundwater data from sampling conducted in 2001 and 2002 was utilized in the human health risk assessment. Prior data from sampling conducted at Aberjona and Whitney in 1993 (or earlier) and Murphy in 1998 (or earlier) are unlikely to represent current site conditions.

- **Total Petroleum Hydrocarbons Data.** Total Petroleum Hydrocarbons data from the Murphy property documented in Clean Harbors 1996 and 1998 were converted to VPH/EPH petroleum hydrocarbon ranges based MADEP guidance for the assessment of risk from petroleum contamination (MADEP, 2002). Since TPH is essentially a summation of the 3 EPH hydrocarbon fractions (i.e., C9-C18 Aliphatics, C19-C36 Aliphatics, and C11-C22 Aromatics), it is possible to "convert" TPH data into the EPH fractions, by making informed and reasonably conservative judgments on the chemistry of the TPH data.

  In using and applying assumptions on the composition of petroleum hydrocarbons, relevant factors considered, include (1) level of certainty of identification of petroleum product(s) released at the site, (2) reliability, validity, and bias of TPH/screening techniques, and (3) sensitivity of pollutant receptors. Given the wide variability in "TPH" analytical methods, and inherent biases of these methods, the determination of true TPH concentration was approached conservatively. Since no finger print data was available and given the nature of historic site operations, TPH was considered to be 100% C11-C22 Aromatics, the most toxic fraction.

- **Broad Soil Composite Depth Intervals.** Prior soil data from the former Whitney Barrel property collected by GHR Engineering Associates in 1988 and a limited number of soil samples collected from the Murphy property by Clean Harbors (Clean Harbors, 1998) were collected as composites from broad depth intervals (e.g., 0 to 8 feet). Samples from such broad composite intervals are unsuitable for use in the human health risk assessment because the exposure interval (surface or subsurface) cannot be determined.

3.2.1 Background and Reference Samples

Background samples for soil and groundwater were collected as part of investigation activities conducted at the Site. Background locations for surface soil are identified as samples AB-10SS and AB-17SS (Aberjona), WB-5SS and WB-14SS (Whitney), and MR-8SS and MR-19SS (Murphy). Subsurface soil background samples were collected in the same locations as the

background surface soils and include AB-10D, AB-17D, WB-5D, WB-14D, MR-8D and MR-19D. Groundwater data representative of background for the Site were collected from Murphy wells MW-1 and MW-2.

For sediment and surface water, the reference data set used by EPA as part of the Wells G&H OU-3 risk assessment is the most appropriate source of data to assess background conditions for the Murphy wetland.

Reference/background samples were collected from areas not considered to be affected by OU-3 or OU-2 site activities and not displaying visual evidence of contamination. The background data for the media evaluated for human exposures at the Southwest Properties are presented in data summary tables in Appendix C.1. The results of risk calculations for Southwest Properties soil and groundwater background data are provided in Appendix C.2. The results of risk calculations for surface water and sediment reference samples/background from the Wells G&H OU-3 risk assessment are presented in Appendix C.3, with identification of reference stations. Reference or background analyte concentrations do not impact the selection of COPCs (subsection 3.2.3) or EPCs (subsection 3.2.4).

The Southwest Properties background sampling locations are shown in Figure 3-3 and sample-specific analytical results are presented in the Supplemental RI and in the media-specific tables in Appendix B of this report. Wells G&H OU-3 wetland reference locations are identified as stations 24, HB and SA. Their locations are shown relative to the Southwest Properties in Appendix C.3, which includes excerpted Figure 2-1 from the Wells G&H OU-3 risk assessment.

3.2.2 Data Used in Risk Assessment

As discussed in Section 2.0, environmental data considered for use in this risk assessment were collected during several sampling events.

Detailed discussions of sampling approaches and the quality assurance and control activities implemented during the collection of the data, where available, are provided in the source documents. A discussion of data validation procedures is provided in Section 2.0.

The following procedures used to summarize the analytical data are in accordance with *Risk Assessment Guidance for Superfund (RAGS)* (EPA, 1989) and supplemental guidance (EPA, 1992). The analytical data were summarized by environmental medium and grouped into exposure areas. Indoor and outdoor air data were modeled from soil and shallow groundwater data using dilution/dispersion modeling (see Appendix C.4). These transport and dilution/dispersion models used property-specific information on the depth to groundwater (i.e., observed minimum depth to groundwater from the available record) and building dimensions (e.g., footprint area, floor/wall seam perimeter) as well as appropriate values for soil properties to establish reasonably conservative site-specific modeled exposure point concentrations. For the baseline HHRA, the following media and exposure points were selected for quantitative evaluation:

- Surface soil, subsurface soil, shallow groundwater and air at the Aberjona property;
- Surface soil, subsurface soil, shallow groundwater and air at the Whitney property;
- Surface soil, subsurface soil, shallow groundwater and air at the Murphy property;
- Site-wide groundwater for the future off-site residential scenario; and
- Surface water and sediment in the Murphy wetland.

The following sections summarize the environmental data available for use in the quantitative risk assessment for each of the exposure points.

3.2.2.1 Aberjona Data

Surface soil, subsurface soil, and groundwater samples were collected from the Aberjona property. Analytical results of compounds detected in these media are presented in the documents referenced in Section 3.2. Samples collected and analyzed in 1993 by RETEC are discussed and presented in the Draft Remedial Investigation Report (RETEC, 1994). Results for

samples collected and analyzed in 2002 by RETEC, and split with EPA, are discussed and presented in the Supplemental RI (RETEC, 2003) and in TRC's Split Report (TRC, 2003), respectively. The data used to prepare this risk assessment are presented in the media-specific tables in Appendix B of this report. Sampling locations for all sampling conducted at Aberjona and used in this risk assessment can be found in the Supplemental RI and in Appendix B.

For the purposes of this risk assessment, only groundwater results from RETEC's 2002 sampling event and associated EPA splits have been used quantitatively. The last documented prior groundwater monitoring event at Aberjona took place in 1993. Groundwater analytical data available for the Aberjona property from 1993 (or prior) are unlikely to represent current conditions and, therefore, have not been quantitatively used in the risk assessment.

Surface soil samples are defined as the most surficial interval of overburden material. Soil from the 0 to 2 foot depth interval are included as surface soil since these represent contaminant concentrations that humans may currently encounter. None of the surface soil samples were collected from beneath pavement. Surface soil samples collected from the Aberjona property are summarized below:

Aberjona Property Surface Soil Samples (0 to 2 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference/Notes**
AB-SS1	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS2	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS3	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS4	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS5	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS6	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS7	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS8	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS9	0-0.5	RETEC 1994, 1993 Sampling Event
AB-13SS	0-2	RETEC 2003, 2002 Sampling Event
AB-13	0-2	TRC 2004, 2002 Split Sample Event
AB-14SS	0-2	RETEC 2003, 2002 Sampling Event
AB-14	0-2	TRC 2004, 2002 Split Sample Event
AB-15SS	0-2	RETEC 2003, 2002 Sampling Event

Aberjona Property Surface Soil Samples (0 to 2 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference/Notes**
AB-15	0-2	TRC 2004, 2002 Split Sample Event
AB-16SS	0-2	RETEC 2003, 2002 Sampling Event
AB-16	0-2	TRC 2004, 2002 Split Sample Event

For current trespasser exposures, the Aberjona triangle is the only accessible area of this property. The subset of soil samples from the Aberjona triangle is summarized below:

Aberjona Property Surface Soil Samples – Triangular Portion (0 to 2 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
AB-SS1	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS2	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS3	0-0.5	RETEC 1994, 1993 Sampling Event
AB-SS4	0-0.5	RETEC 1994, 1993 Sampling Event
AB-13SS	0-2	RETEC 2003, 2002 Sampling Event
AB-13	0-2	TRC 2004, 2002 Split Sample Event

Subsurface soil samples were also collected from the Aberjona property. Subsurface soil samples are representative of the deeper interval, which human receptors may encounter under future site reuse conditions. The subsurface interval includes soils from 2 to 15 feet below ground surface. Subsurface soil samples collected at Aberjona include the following:

Aberjona Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
AB-SS1D	4-5	RETEC 1994, 1993 Sampling Event
AB-SS2D	4-5	RETEC 1994, 1993 Sampling Event
AB-SS3D	4-5	RETEC 1994, 1993 Sampling Event
AB-SS4D	4-5	RETEC 1994, 1993 Sampling Event
AB-SS5D	3-4	RETEC 1994, 1993 Sampling Event
AB-SS6D	3-4	RETEC 1994, 1993 Sampling Event
AB-SS7D	3-4	RETEC 1994, 1993 Sampling Event
AB-SS8D	3-4	RETEC 1994, 1993 Sampling Event
AB-SS9D	3-4	RETEC 1994, 1993 Sampling Event
AB-13D	5-7	RETEC 2003, 2002 Sampling Event

Aberjona Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
AB-13	5-7	TRC 2004, 2002 Split Sample Event
AB-14D	2-4	RETEC 2003, 2002 Sampling Event
AB-15D	4-4.5	RETEC 2003, 2002 Sampling Event
AB-15	4-4.5	TRC 2004, 2002 Split Sample Event
AB-102	6.0	RETEC 2003, underground storage tank (UST) investigation sample, 2002 Sampling Event

Groundwater samples were collected from a variety of depth intervals at the Aberjona property, including bedrock. Groundwater monitoring well screens were installed at depths that ranged from 3 to 132 feet below ground surface. Groundwater samples collected at Aberjona, and utilized in this human health risk assessment, include the following:

Aberjona Property Groundwater Monitoring Locations		
Sample Name	**Screen Interval (feet)**	**Source Reference, Notes**
S-83SS	3-13	RETEC 2003, 2002 Sampling Event
S-83M	70-80	RETEC 2003, 2002 Sampling Event
AB-1	6.5-11.5	RETEC 2003, 2002 Sampling Event
AB-1	6.5-11.5	TRC 2004, 2002 Split Sample Event
AB-4SS	2-12	RETEC 2003, 2002 Sampling Event
AB-4M	50-60	RETEC 2003, 2002 Sampling Event
AB-2SS	3-13	RETEC 2003, 2002 Sampling Event
AB-2SS	3-13	TRC 2004, 2002 Split Sample Event
AB-2M	58-68	RETEC 2003, 2002 Sampling Event
AB-2R	122-132	RETEC 2003, 2002 Sampling Event
AB-6SS	4-14	RETEC 2003, 2002 Sampling Event
AB-6SS	4-14	TRC 2004, 2002 Split Sample Event and Additional Coverage Sample
AB-6M	35-45	RETEC 2003, 2002 Sampling Event

Shallow groundwater monitoring well data were evaluated separately and include data from monitoring wells S-83SS, AB-1, AB-4SS, AB-2SS, and AB-6SS. Sampling locations are shown in the RETEC Supplemental RI and Appendix B. A comprehensive tabulation of these data may

be found in Appendix B.1 (Soil Data Summary Tables) and B.2 (Groundwater Data Summary Tables).

Summaries of surface and subsurface soil data are presented in Tables 3-2.1.1 and 3-2.2.1, respectively for the Aberjona Property. Shallow groundwater data for the Aberjona property are summarized in Table 3-2.4.1. All groundwater data for the three properties are combined and discussed in Section 3.2.1.4. Each of the summary tables for chemicals detected in soil and groundwater provide the frequency of detection, range of SQLs for samples where compounds were not detected, range of detected concentrations, and locations of maximum detected results.

3.2.2.2 Whitney Data

Surface soil, subsurface soil, and groundwater samples were collected from the Whitney property. One sediment sample was collected from the Whitney property, which is discussed later as part of the Murphy wetland (Section 3.2.2.6). Analytical results of compounds detected in these media are presented in the documents referenced in Section 3.2. Samples collected and analyzed by RETEC in 1993 are discussed and presented in the Draft Remedial Investigation Report (RETEC, 1994). Results for samples collected and analyzed in 2002 by RETEC, and split with EPA, are presented in the Supplemental RI (RETEC, 2003) and in TRC's Split Report (TRC, 2004), respectively. TRC also collected soil samples for non-split analyses to provide additional analytical and/or spatial coverage in certain areas of the property (e.g., new and old fill) as identified in TRC 2004. The data used to prepare this risk assessment are presented in the media-specific tables in Appendix B of this report. Sampling locations for all sampling conducted at Whitney and used in this risk assessment can be found in the Supplemental RI and in Appendix B.

For the purposes of the human health risk assessment, only groundwater results from sampling conducted for Clean Harbors in 2001, and the 2002 RETEC and EPA split sampling events have been used quantitatively. The last documented prior groundwater monitoring event at Whitney took place in 1993. Groundwater samples collected in 1993 (or prior) are unlikely to represent current conditions and, therefore, have not been quantitatively evaluated in the risk assessment.

Surface soil samples (0 to 2 feet) were collected from the Whitney property. None of the surface soil samples were collected from beneath pavement. Surface soil samples collected from the Whitney property are summarized below:

Whitney Property Surface Soil Samples (0 to 2 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
WB-SS1	0-0.5	RETEC 1994, 1993 Sampling Event
WB-SS2	0-0.5	RETEC 1994, 1993 Sampling Event
WB-SS3	0-0.5	RETEC 1994, 1993 Sampling Event
WB-SS4	0-0.5	RETEC 1994, 1993 Sampling Event
WB-6SS	0-2	RETEC 2003, 2002 Sampling Event
WB-6	0-2	TRC 2004, 2002 Split Sample Event
WB-7SS	0-2	RETEC 2003, 2002 Sampling Event
WB-7	0-2	TRC 2004, 2002 Split Sample Event
WB-8SS	0-1	RETEC 2003, 2002 Sampling Event
WB-8	0-1	TRC 2004, 2002 Split Sample Event and Additional Coverage Sample
WB-10SS	0-2	RETEC 2003, 2002 Sampling Event
WB-10	0-2	TRC 2004, 2002 Split Sample Event
WB-11SS	0-1	RETEC 2003, 2002 Sampling Event
WB-11	1-1.75	TRC 2004, 2002 Additional Coverage Sample
WB-12SS	1-2	RETEC 2003, 2002 Sampling Event
WB-13SS	0-2	RETEC 2003, 2002 Sampling Event
WB-13	0-2	TRC 2004, 2002 Split Sample Event

Subsurface soil samples (2 to 15 feet) collected at Whitney include the following:

Whitney Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
WB-SS1D	3-4	RETEC 1994, 1993 Sampling Event
WB-SS2D	3-4	RETEC 1994, 1993 Sampling Event
WB-SS3D	3-4	RETEC 1994, 1993 Sampling Event
WB-SS4D	3-4	RETEC 1994, 1993 Sampling Event
WB-6D	2-4	RETEC 2003, 2002 Sampling Event

Whitney Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
WB-6	2-4	TRC 2004, 2002 Split Sample Event
WB-7D	2-4	RETEC 2003, 2002 Sampling Event
WB-7	2-4	TRC 2004, 2002 Split Sample Event
WB-10D	2-4	RETEC 2003, 2002 Sampling Event
WB-10	2-4	TRC 2004, 2002 Split Sample Event

Groundwater samples were collected from a variety of depth intervals at the Whitney property, including bedrock. Groundwater monitoring well screens were installed at depths that ranged from 3 to 120.5 feet below ground surface. Groundwater samples collected at Whitney and utilized in this human health risk assessment include the following:

Whitney Property Groundwater Monitoring Locations		
Sample Name	**Screen Interval (feet)**	**Source Reference, Notes**
MW-1S	6-11	RETEC 2003, 2002 Sampling Event
MW-4S	3-13	RETEC 2003, Clean Harbors 2001 Data*
MW-4S	3-13	TRC 2004, 2002 Split Sample Event and Additional Coverage Sample
MW-4M	35-45	RETEC 2003, Clean Harbors 2001 Data*
MW-4D	90-95	RETEC 2003, Clean Harbors 2001 Data*
MW-5S	5-15	RETEC 2003, 2002 Sampling Event
MW-6S	5-15	RETEC 2003, 2002 Sampling Event
MW-6S	5-15	TRC 2004, 2002 Split Sample Event and Additional Coverage Sample
WB-1SS	3-13	RETEC 2003, 2002 Sampling Event
WB-1M	35-45	RETEC 2003, 2002 Sampling Event
WB-1R	110.5-120.5	RETEC 2003, 2002 Sampling Event
WB-1R	110.5-120.5	TRC 2004, 2002 Split Sample Event and Additional Coverage Sample

* As discussed in the Supplemental RI, the Clean Harbors groundwater data are from samples collected in November 2001. Laboratory digestates from this sampling event were used by RETEC to obtain additional metals data within holding times. Select wells were resampled by RETEC to obtain data for constituents with expired holding times (mercury and cyanide) and to collect other constituent data of interest to EPA.

Shallow groundwater monitoring well data were evaluated separately and include data from monitoring wells MW-1S, MW-4S, MW-5S, MW-6S, and WB-1SS. Sampling locations are shown in the RETEC Supplemental RI and Appendix B. A comprehensive tabulation of these

data may be found in Appendix B.1 (Soil Data Summary Tables) and B.2 (Groundwater Data Summary Tables).

Summaries of surface and subsurface soil data are provided in Tables 3-2.1.2 and 3-2.2.2 for the Whitney property. Shallow groundwater data for the Whitney property are summarized in Table 3-2.4.2. All groundwater data for the three properties are combined and discussed in Section 3.2.1.4. Each of the summary tables for chemicals detected in soil and groundwater provide the frequency of detection, range of SQLs for samples where compounds were not detected, range of detected concentrations, and locations of maximum detected results.

3.2.2.3 Murphy Data

Surface soil, subsurface soil, and groundwater samples were collected from the Murphy property. Samples of surface water and sediment were also collected from the wetland on the Murphy property, but are discussed separately in Section 3.2.2.6. Analytical results of compounds detected in these media are presented in the documents referenced in Section 3.2. Samples collected and analyzed in 1993 by RETEC are discussed and presented in the Draft Remedial Investigation Report (RETEC, 1994). Results for samples collected from the Murphy property at various times by Clean Harbors are presented in Clean Harbors 1998, with the exception of the 2001 groundwater data collected for Clean Harbors that are included in the RETEC Supplemental RI (RETEC, 2003). Samples collected and analyzed in 2002 by RETEC, and split with EPA, are presented in the Supplemental RI (RETEC, 2003) and in TRC's Split Report (TRC, 2004), respectively. TRC also submitted soil samples for non-split analyses to provide additional analytical and/or spatial coverage as identified in the TRC 2004. The data used to prepare this risk assessment are presented in the media-specific tables in Appendix B of the report. Sampling locations for all sampling conducted at Murphy and used in this risk assessment can be found in Appendix B.

For the purposes of the human health risk assessment, only groundwater results from sampling conducted for Clean Harbors in 2001, and the 2002 RETEC and EPA split sampling events have been used quantitatively. Groundwater samples collected or prior to 2001 are unlikely to

represent current conditions and, therefore, have not been quantitatively evaluated in the risk assessment.

Surface soil samples (0 to 2 feet) were collected from the Murphy property. None of the surface soil samples were collected from beneath pavement. Surface soil samples collected from the Murphy property are summarized below:

Murphy Property Surface Soil Samples (0 to 2 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
MR-SS1	0-0.5	RETEC 1994, 1993 Sampling Event
MR-SS2	0-0.5	RETEC 1994, 1993 Sampling Event
MR-SS3	0-0.5	RETEC 1994, 1993 Sampling Event
MR-10SS	0-2	RETEC 2003, 2002 Sampling Event
MR-10	0-2	TRC 2004, 2002 Additional Coverage Sample
B-4 SS-1	0-2	Clean Harbors 1998, 1995 Sampling Event
B-8 SS-1	0-2	Clean Harbors 1998, 1995 Sampling Event
B-13 SS-1	0-2	Clean Harbors 1998, 1995 Sampling Event
B-18 SS-1	0-2	Clean Harbors 1998, 1995 Sampling Event
MW-1 SS-1	0-2	Clean Harbors 1998, 1994 Sampling Event
MW-2 SS-1	0-2	Clean Harbors 1998, 1994 Sampling Event
MW-3 SS-1	0-2	Clean Harbors 1998, 1994 Sampling Event
MW-4 SS-1	0-2	Clean Harbors 1998, 1994 Sampling Event
MW-5S SS-1	0-2	Clean Harbors 1998, 1994 Sampling Event
MW-6 SS-1	0-2	Clean Harbors 1998, 1994 Sampling Event
MW-18D SS-1	0-2	Clean Harbors 1998, 1997 Sampling Event
CHI-7/88	0-2	Clean Harbors 1998, 1988 Sampling Event
W-89-S1	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S3	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S4	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S14	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S15	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S16	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S17	0-2	Clean Harbors 1998, 1989 Sampling Event
W-89-S18	0-2	Clean Harbors 1998, 1989 Sampling Event

Subsurface soil samples (2 to 15 feet) collected from the Murphy property include the following:

Murphy Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
MR-SS1D	4-5	RETEC 1994, 1993 Sampling Event
MR-SS2D	4-5	RETEC 1994, 1993 Sampling Event
MR-SS3D	4-5	RETEC 1994, 1993 Sampling Event
MR-SS4D	4-5	RETEC 1994, 1993 Sampling Event
MR-10D	3-5	RETEC 2003, 2002 Sampling Event
MR-10	3-5	TRC 2004, 2002 Split Sample Event
B-1 SS-3	4.5-6.5	Clean Harbors 1998,1995 Sampling Event
B-1 SS-5	8.5-10.5	Clean Harbors 1998, 1995 Sampling Event
B-2 SS-3	4.5-6.5	Clean Harbors 1998, 1995 Sampling Event
B-4 SS-6	10-12	Clean Harbors 1998, 1995ampling Event
B-5	7-10	Clean Harbors 1998, 1988 Sampling Event
B-5	13-15	Clean Harbors 1998, 1988 Sampling Event
B-6	7-11	Clean Harbors 1998, 1995 Sampling Event
B-6 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event
B-7 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event
B-8 SS-4	6-8	Clean Harbors 1998, 1988 Sampling Event
B-8	7-8	Clean Harbors 1998, 1988 Sampling Event
B-8	8-12	Clean Harbors 1998, 1988 Sampling Event
B-9	6-10	Clean Harbors 1998, 1988 Sampling Event
B-9 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event
B-10	4-6	Clean Harbors 1998, 1988 Sampling Event
B-10	6-10	Clean Harbors 1998, 1988 Sampling Event
B-10	10-14	Clean Harbors 1998, 1988 Sampling Event
B-10 SS-6	10-12	Clean Harbors 1998, 1995 Sampling Event
B-11 SS-4	6-8	Clean Harbors 1998, 1995 Sampling Event
B-11 SS-6	10-12	Clean Harbors 1998, 1995 Sampling Event
B-12	4-8	Clean Harbors 1998, 1988 Sampling Event
B-12	8-12	Clean Harbors 1998, 1988 Sampling Event
B-12 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event
B-13 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event

Murphy Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
B-14 SS-2	2.5-4.5	Clean Harbors 1998, 1995 Sampling Event
B-14 SS-5	8.5-10.5	Clean Harbors 1998, 1995 Sampling Event
B-15 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event
B-15 SS-7	12-14	Clean Harbors 1998, 1995 Sampling Event
B-16 SS-6	10-12	Clean Harbors 1998, 1995 Sampling Event
B-17 SS-2	2-4	Clean Harbors 1998, 1995 Sampling Event
B-18 SS-3	4-6	Clean Harbors 1998, 1995 Sampling Event
B-19 SS-4	6-8	Clean Harbors 1998, 1995 Sampling Event
B-20 SS-4	6-8	Clean Harbors 1998, 1995 Sampling Event
B-21 SS-4	6-8	Clean Harbors 1998, 1997 Sampling Event
B-24 SS-4	6-8	Clean Harbors 1998, 1997 Sampling Event
B-25 SS-3	4-6	Clean Harbors 1998, 1997 Sampling Event
B-26 SS-4	6-8	Clean Harbors 1998, 1997 Sampling Event
CHI-1/88	2-4	Clean Harbors 1998, 1988 Sampling Event
CHI-2/88	4-6	Clean Harbors 1998, 1988 Sampling Event
CHI-3/88	6-8	Clean Harbors 1998, 1988 Sampling Event
CHI-4/88	2-4	Clean Harbors 1998, 1988 Sampling Event
CHI-5/88	2-4	Clean Harbors 1998, 1988 Sampling Event
CHI-6/88	2-4	Clean Harbors 1998, 1988 Sampling Event
CHI-8/88	5-7	Clean Harbors 1998, 1988 Sampling Event
W-89-S1	2-4	Clean Harbors 1998, 1989 Sampling Event
W-89-S1	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S1	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S1	10-12	Clean Harbors 1998, 1989 Sampling Event
W-89-S3	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S3	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S3	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S3	10-12	Clean Harbors 1998, 1989 Sampling Event
W-89-S4	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S4	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S4	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S14	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S14	6-8	Clean Harbors 1998, 1989 Sampling Event

Murphy Property Subsurface Soil Samples (2 to 15 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
W-89-S14	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S15	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S15	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S15	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S16	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S16	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S16	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S16	10-12	Clean Harbors 1998, 1989 Sampling Event
W-89-S17	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S17	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S17	8-10	Clean Harbors 1998, 1989 Sampling Event
W-89-S18	4-6	Clean Harbors 1998, 1989 Sampling Event
W-89-S18	6-8	Clean Harbors 1998, 1989 Sampling Event
W-89-S18	8-10	Clean Harbors 1998, 1989 Sampling Event
MW-1 SS-5	8-10	Clean Harbors 1998, 1994 Sampling Event
MW-2 SS-2	2-4	Clean Harbors 1998, 1994 Sampling Event
MW-2 SS-4A	7.5-9.5	Clean Harbors 1998, 1994 Sampling Event
MW-3 SS-4	6-8	Clean Harbors 1998, 1994 Sampling Event
MW-3 SS-6	10-12	Clean Harbors 1998, 1994 Sampling Event
MW-4 SS-5	8-10	Clean Harbors 1998, 1994 Sampling Event
MW-4 SS-6	10-12	Clean Harbors 1998, 1994 Sampling Event
MW-5 SS-6	10-12	Clean Harbors 1998, 1994 Sampling Event
MW-7 SS-2	2.5-4.5	Clean Harbors 1998, 1995 Sampling Event
MW-7 SS-4	6.5-8.5	Clean Harbors 1998, 1995 Sampling Event
MW-9 SS-6	10-12	Clean Harbors 1998, 1995 Sampling Event
MW-11 SS-3	4-6	Clean Harbors 1998, 1995 Sampling Event
MW-11 SS-5	8-10	Clean Harbors 1998, 1995 Sampling Event
MW-14 SS-3	4-6	Clean Harbors 1998, 1997 Sampling Event
MW-16 SS-3	4-6	Clean Harbors 1998, 1997 Sampling Event

Groundwater samples were collected from a variety of depth intervals at the Murphy property, including bedrock. Groundwater monitoring well screens were installed at depths that ranged

from 2 to 91 feet below ground surface. Groundwater samples collected at Murphy and utilized in the human health risk assessment include the following:

Murphy Property Groundwater Monitoring Locations		
Sample Name	**Screen Interval (feet)**	**Source Reference, Notes**
MR-1SS	3-13	RETEC 2003, Clean Harbors 2001 Data*
MR-2SS	5-15	RETEC 2003, Clean Harbors 2001 Data*
MW-3	4-14	RETEC 2003, Clean Harbors 2001 Data*
MW-3D	44-49	RETEC 2003, Clean Harbors 2001 Data*
MW-3BR	81-91	RETEC 2003, Clean Harbors 2001 Data*
MW-4	5-15	RETEC 2003, Clean Harbors 2001 Data*
MW-5S	5-15	RETEC 2003, Clean Harbors 2001 Data*
MW-5D	73.5-83.5	RETEC 2003, Clean Harbors 2001 Data*
MW-6	8-18	RETEC 2003, Clean Harbors 2001 Data*
MW-7	3-12	RETEC 2003, Clean Harbors 2001 Data*
MW-8	3-12	RETEC 2003, Clean Harbors 2001 Data*
MW-9	3-12	RETEC 2003, Clean Harbors 2001 Data*
MW-10	36-41	RETEC 2003, Clean Harbors 2001 Data*
MW-11	2-12	RETEC 2003, Clean Harbors 2001 Data*
MW-12	2.4-5.4	RETEC 2003, Clean Harbors 2001 Data*
MW-13	2.3-5.3	RETEC 2003, Clean Harbors 2001 Data*
MW-14	3-12	RETEC 2003, Clean Harbors 2001 Data*
MW-15	2-12	RETEC 2003, Clean Harbors 2001 Data*
MW-16	3-12	RETEC 2003, Clean Harbors 2001 Data*
MW-17	4-14	RETEC 2003, Clean Harbors 2001 Data*
MW-18S	5-10	RETEC 2003, Clean Harbors 2001 Data*
MW-18S	5-10	TRC 2004, 2002 Split Sample Event and Additional Coverage Sample
MW-18D	53-58	RETEC 2003, Clean Harbors 2001 Data*
MW-19	2.4-5.4	RETEC 2003, Clean Harbors 2001 Data*
MW-20	3-12	RETEC 2003, Clean Harbors 2001 Data*
MW-21	2.5-5.5	RETEC 2003, Clean Harbors 2001 Data*

* As discussed in the Supplemental RI, the Clean Harbors groundwater data are from samples collected in November 2001. Laboratory digestates from this sampling event were used by RETEC to obtain additional metals data within holding times. Select wells were resampled by RETEC to obtain data for constituents with expired holding times (mercury and cyanide) and to collect other constituent data of interest to EPA.

Shallow groundwater monitoring well data were evaluated separately and include data from monitoring wells MR-1SS, MR-2SS, MW-3, MW-4, MW-5S, MW-6, through -9, MW-11 through -17, MW-18S, and MW-19 through -21. Sampling locations are shown in the RETEC Supplemental RI (RETEC, 2003) and in Appendix B. A comprehensive tabulation of these data may be found in Appendix B.1 (Soil Data Summary Tables) and B.2 (Groundwater Data Summary Tables).

Summaries of surface and subsurface soil data are provided in Tables 3-2.1.3 and 3-2.2.3 for the Murphy Property. Shallow groundwater data for the Murphy property (samples and splits) are summarized in Table 3-2.4.3. All groundwater data for the three properties are combined and discussed in Section 3.2.1.4. Each of the summary tables for chemicals detected in soil and groundwater provide the frequency of detection, range of SQLs for samples where compounds were not detected, range of detected concentrations, and locations of maximum detected result.

3.2.2.4 Off-Site Residence

All groundwater data for the three properties, regardless of depth, were combined to evaluate a future residential groundwater use scenario. The samples utilized have been previously presented in Sections 3.2.1.1, 3.2.1.2 and 3.2.1.3 for the Aberjona, Whitney and Murphy properties, respectively. All groundwater data combined are summarized in Table 3-2.3. The summary table for chemicals detected in groundwater provides the frequency of detection, range of SQLs for samples where compounds were not detected, range of detected concentrations, and locations of maximum detected result.

3.2.2.5 Air Data

Volatile contaminants detected in surface soil, subsurface soil and groundwater from the Aberjona, Whitney and Murphy properties combined were used to estimate indoor and outdoor airborne concentrations a receptor may be exposed to during site-related activities as well as inhalation exposures during showering. Volatile contaminants were defined as those compounds with Henry=s Law Constants greater than 1E-05 atm-m^3/mole (USEPA, 1991a; 2002b) and

molecular weights less than 200 grams/mole (USEPA, 1991a). Consistent with EPA's Draft Subsurface Vapor Intrusion Guidance, the compounds evaluated possessed sufficient volatility and toxicity (USEPA, 2002b) to warrant evaluation, plus included compounds that satisfied the molecular weight criterion (USEPA, 1991a). Suspected indoor air pathways were further evaluated using a site-specific modeling assessment. Appendix C.4 documents the assumptions used in the modeling of indoor and outdoor air concentrations as well as inputs to the model. Appendix C.5 contains the documentation for the shower model. Tables 3-2.5 through 3-2.7 list the soil and groundwater volatile contaminants detected at each exposure point along with their modeled indoor or outdoor air concentrations. Table 3-2.5 lists the groundwater volatile contaminants detected along with their modeled air concentration during showering. Maximum soil and groundwater volatile concentrations were used as inputs to the model. Maximum (i.e., worst-case) air concentrations were derived by summing the contributions from soil and groundwater at each exposure point and are summarized in Tables 3-2.6 and 3-2.7. Because only one set of air concentrations were modeled, only one set of concentrations (i.e., maximum modeled concentrations) appear on Tables 3-2.5 through 3-2.7.

3.2.2.6 Murphy Wetland

Sediment and surface water samples were collected from the Murphy wetland located between the Murphy and Whitney properties. Analytical results of compounds detected in surface water and sediment are presented in the documents referenced in Section 3.2. The results for, and locations of, wetland sediment samples collected and analyzed in 1995 and 1997 by Clean Harbors are presented in Clean Harbors, 1998. Samples collected and analyzed by RETEC in 1993 are presented in the Draft Remedial Investigation Report (RETEC, 1994). Results for samples collected and analyzed in 2002 by RETEC, and split with EPA, are presented in the Supplemental RI (RETEC, 2003), in TRC's Split Report (TRC, 2004), respectively. The data used to prepare this risk assessment are presented in the media-specific tables in Appendix B of this report. Sampling locations for all sampling conducted at Murphy and used in this risk assessment can also be found in Appendix B.

For the purposes of this risk assessment, only surface water results from the 2002 sampling event are used quantitatively for the Murphy wetland. Surface water samples collected prior to 2002 are not considered representative of current conditions due to the mobile nature of surface water.

Humans are likely to encounter only surficial sediment in the wetland. The sediment samples collected by RETEC in 2002 and split with EPA were from the 0 to 0.5 foot depth interval. The sediment samples collected by Clean Harbors in 1995 and 1997 (and presented in the Clean Harbors 1998 source document) were collected from the 0 to 2 foot depth interval. Both sets of samples are considered to represent the surficial interval. Three samples collected from 0 to 3 feet by RETEC in 1993 have also been used in this evaluation since most of the 0 to 3 foot sampling interval overlaps the 0 to 2 foot interval.

Human exposures are likely to occur only to sediments located below two feet or less of standing water. The depth of surface water at the 2002 sediment sampling locations was approximately 2 feet or less. The depth of surface water, where present at a wetland sample location, is not known for the samples collected by Clean Harbors and RETEC prior to the 2002 RETEC/EPA-split sampling event. However, the standing water tends to disappear in the summer months and during dry periods, when human exposures are most likely to occur. Consequently, all sediments are considered accessible. Sediment samples collected from the Murphy wetland include:

Murphy Wetland Sediment Samples (0 to 3 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
P-1	0-2	Clean Harbors 1998, 1995 Sampling Event
P-2	0-2	Clean Harbors 1998, 1995 Sampling Event
P-3	0-2	Clean Harbors 1998, 1995 Sampling Event
P-4	0-2	Clean Harbors 1998, 1995 Sampling Event
P-5	0-2	Clean Harbors 1998, 1995 Sampling Event
P-6	0-2	Clean Harbors 1998, 1995 Sampling Event
P-7	0-2	Clean Harbors 1998, 1995 Sampling Event
P-9	0-2	Clean Harbors 1998, 1995 Sampling Event
P-10	0-2	Clean Harbors 1998, 1995 Sampling Event

Murphy Wetland Sediment Samples (0 to 3 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
P-11	0-2	Clean Harbors 1998, 1995 Sampling Event
P-12	0-2	Clean Harbors 1998, 1995 Sampling Event*
P-13	0-2	Clean Harbors 1998, 1995 Sampling Event
P-14	0-2	Clean Harbors 1998, 1995 Sampling Event
P-15	0-2	Clean Harbors 1998, 1995 Sampling Event
P-17	0-2	Clean Harbors 1998, 1995 Sampling Event
P-18	0-2	Clean Harbors 1998, 1995 Sampling Event
P-19	0-2	Clean Harbors 1998, 1995 Sampling Event
P-20	0-2	Clean Harbors 1998, 1995 Sampling Event
P-21	0-2	Clean Harbors 1998, 1995 Sampling Event
P-22	0-2	Clean Harbors 1998, 1995 Sampling Event
P-23	0-2	Clean Harbors 1998, 1995 Sampling Event
P-24	0-2	Clean Harbors 1998, 1995 Sampling Event*
P-24A	0-2	Clean Harbors 1998, 1997 Sampling Event
P-25	0-2	Clean Harbors 1998, 1995 Sampling Event
P-26	0-2	Clean Harbors 1998, 1995 Sampling Event*
P-27	0-2	Clean Harbors 1998, 1995 Sampling Event
P-28	0-2	Clean Harbors 1998, 1995 Sampling Event
P-29	0-2	Clean Harbors 1998, 1995 Sampling Event
P-30	0-2	Clean Harbors 1998, 1995 Sampling Event
P-31	0-2	Clean Harbors 1998, 1995 Sampling Event
P-32	0-2	Clean Harbors 1998, 1995 Sampling Event
P-33	0-2	Clean Harbors 1998, 1997 Sampling Event
P-34	0-2	Clean Harbors 1998, 1997 Sampling Event
P-35	0-2	Clean Harbors 1998, 1997 Sampling Event
P-36	0-2	Clean Harbors 1998, 1997 Sampling Event
P-37	0-2	Clean Harbors 1998, 1997 Sampling Event
P-38	0-2	Clean Harbors 1998, 1997 Sampling Event
P-39	0-2	Clean Harbors 1998, 1997 Sampling Event
P-40	0-2	Clean Harbors 1998, 1997 Sampling Event
P-41	0-2	Clean Harbors 1998, 1997 Sampling Event

Murphy Wetland Sediment Samples (0 to 3 feet)		
Sample Name	**Sample Depth (feet)**	**Source Reference, Notes**
P-42	0-2	Clean Harbors 1998, 1997 Sampling Event
P-43	0-2	Clean Harbors 1998, 1997 Sampling Event
P-44	0-2	Clean Harbors 1998, 1997 Sampling Event
P-45	0-2	Clean Harbors 1998, 1997 Sampling Event
P-46	0-2	Clean Harbors 1998, 1997 Sampling Event
P-47	0-2	Clean Harbors 1998, 1997 Sampling Event
P-48	0-2	Clean Harbors 1998, 1997 Sampling Event
MW-19	0-2	Clean Harbors 1998, 1997 Sampling Event
SW-1	0-2	Clean Harbors 1998, 1996 Sampling Event
SW-2	0-2	Clean Harbors 1998, 1995 Sampling Event
SW-3	0-2	Clean Harbors 1998, 1996 Sampling Event
SW-4	0-2	Clean Harbors 1998, 1996 Sampling Event
MR-SS5	0-3	RETEC 1994, 1993 Sampling Event
MR-SS6	0-3	RETEC 1994, 1993 Sampling Event
MR-SS7	0-3	RETEC 1994, 1993 Sampling Event
MR-11SS	0-0.5	RETEC 2003, 2002 Sampling Event
MR-11	0-0.5	TRC 2004, 2002 Split Sample Event
MR-11D	0.75-1.75	RETEC 2003, 2002 Sampling Event
MR-11	0.75-1.75	TRC 2004, 2002 Split Sample and Additional Coverage Sample
MR-12SS	0-0.5	RETEC 2003, 2002 Sampling Event
MR-12	0-0.5	TRC 2004, 2002 Split Sample Event
MR-13SST1	0-1	RETEC 2003, 2002 Sampling Event
MR-13SST2	0-1	RETEC 2003, 2002 Sampling Event
MR-14SS	0-0.5	RETEC 2003, 2002 Sampling Event
MR-15SS	0-0.5	RETEC 2003, 2002 Sampling Event
MR-16SS	0-0.5	RETEC 2003, 2002 Sampling Event
MR-17SS	0-0.5	RETEC 2003, 2002 Sampling Event
MR-18SS	0-0.5	RETEC 2003, 2002 Sampling Event
WB-9SS	0-0.5	RETEC 2003, 2002 Sampling Event
WB-9	0-0.5	TRC 2004, 2002 Split Sample Event

* - Sampled twice in 1995 for PCB Aroclors (11/95 and 12/95)

The surface water samples collected by RETEC in 2002 include the following:

Murphy Wetland Surface Water Samples		
Sample Name	**Sample Depth (feet)**	**Source Reference/Notes**
MW-12SW	≤ 2	RETEC 2003, 2002 Sampling Event
MW-13SW	≤ 2	RETEC 2003, 2002 Sampling Event
BW-4SW	≤ 2	RETEC 2003, 2002 Sampling Event

Sampling locations are shown in RETEC's Supplemental RI (RETEC, 2003). A comprehensive tabulation of these data may be found in Appendix B.3 (Surface Water Data Summary Tables) and B.4 (Sediment Data Summary Tables).

Surface water and sediment data for the Murphy wetland are summarized in Tables 3-2.8 and 3-2.9, respectively. These summary tables for chemicals detected in surface water and sediment provide the frequency of detection, range of SQLs for samples where compounds were not detected, range of detected concentrations, and the locations of maximum detected results.

3.2.2.7 Data Evaluation

The following describes data evaluation and data summary conventions utilized during preparation of the human health risk assessment applicable to qualified data, multi-procedure analytical results, and hexavalent chromium data.

Data were qualified by the analytical laboratory and validated as described in Section 2.0 of this report. The qualification and validation of the analytical data included a comparison of the site data to corresponding blank (laboratory, field, equipment, and trip) concentration data. Data rejected by the validation ("R" qualified) were not used. Estimated values (e.g., "J" qualified) were used in the risk assessment without modification. One half the SQL value was used for constituents that were reported as not detected above the quantitation limit (e.g., "U" qualified). Analytical data from duplicate samples were combined as described in Section 2.0. Frequency of detection was calculated as the number of samples in which the chemical was detected over

the total number of samples analyzed for that chemical after the exclusion of rejected ("R" qualified) data. A duplicate sample was not counted as an additional sample.

Where constituents were detected multiple times in one sample because the constituent is common to multiple analytical procedures (e.g., naphthalene is found on VPH, SVOC and EPH analyte lists), the maximum detected value was selected for quantitative use. Where the constituent was not detected by any of the procedures, the lowest laboratory reporting limit was utilized.

The 2002 investigation of the Southwest Properties by RETEC included the sampling of soil, sediment and groundwater for hexavalent chromium using ion chromatography (Method 7199) for soil and sediment, and Ultraviolet/Visible Spectroscopy (Method 7196A) for groundwater. The groundwater monitoring conducted on behalf of Clean Harbors at the Murphy property in 2001 also included the analysis of hexavalent chromium by Method 7196A. These analyses were performed for a subset of samples from each medium, with groundwater having the greatest frequency of analysis. For all media, analyses for total chromium were performed at a greater frequency compared to hexavalent chromium; therefore, total chromium provides the greatest spatial coverage.

The results of hexavalent chromium analysis in soil and sediment suggest that hexavalent chromium does not exist at appreciable levels in these media. The maximum detected hexavalent chromium concentration in sediment was 80.8 mg/kg at location MR-18, which had a total chromium concentration of 14,000 mg/kg. Sediment locations with total chromium concentrations less than 340 mg/kg were non-detect for hexavalent chromium. For soil, the maximum detected concentration of hexavalent chromium was 2.6 mg/kg at WB-10 where the total chromium concentration was 31 mg/kg. Soil sampling locations with total chromium concentrations less than 12.5 mg/kg were non-detect for hexavalent chromium. Since hexavalent chromium analyses were not performed at all sampling location, hexavalent chromium concentrations were estimated at locations with only total chromium results. This approach assumed that a percentage of the total chromium is hexavalent chromium, if total chromium

levels exceed a threshold concentration. The threshold concentration is the medium-specific level of total chromium where hexavalent chromium was not detected.

In soil and sediment, the hexavalent chromium results were compared to the total chromium results in samples where both analyses were performed to estimate the percentage of hexavalent chromium in the medium. The results of this analysis are summarized below:

In the sediments of the Murphy wetland, the percentage of hexavalent chromium/total chromium ranged from 0.39 % to 1.07 %. Hexavalent chromium concentrations were estimated for locations with only total chromium results using the average percentage of hexavalent/total chromium (approximately 0.55%). Sediments with total chromium concentrations less than or equal to 340 mg/kg (the threshold concentration for sediment) are assumed to be non-detect for hexavalent chromium.

In soil, the Whitney property had the greatest number of hexavalent chromium analyses (seven samples). In contrast, Aberjona had one hexavalent chromium analysis in soil and Murphy had two. Based on the Whitney soil data, the percentage of hexavalent chromium/total chromium ranged from 0.35 % to 8.39 %. Hexavalent chromium concentrations were estimated for locations with only total chromium results using the average percentage of hexavalent/total chromium (approximately 3%). Soil with total chromium concentrations less than or equal to 12.5 mg/kg (the threshold concentration for soil) are assumed to be non-detect for hexavalent chromium. The total chromium concentrations at Whitney (maximum of 375 mg/kg) are similar to those at the two other properties (544 mg/kg at Aberjona and 400 mg/kg at Murphy), therefore the hexavalent chromium percentage and threshold concentration derived for Whitney were applied to these properties.

Hexavalent chromium was not detected in groundwater based on the analysis of 45 samples. Therefore, total chromium concentrations in groundwater were qualitatively evaluated as trivalent chromium for the estimation of risk. Since hexavalent chromium analysis was not performed for surface water, total chromium detected in this medium was conservatively assumed to exist entirely as hexavalent chromium.

Since certain soil, groundwater, and sediment samples were collected as splits during the RETEC 2002 sampling event, more than one set of analytical results were available for some sampling locations. For these sampling locations, the multiple results were treated as unique samples rather than as duplicate samples (i.e., the multiple results were not averaged as described in Section 2.0 for duplicates). This is consistent with the approach used in the Wells G&H OU-3 risk assessment, where sediment samples collected during multiple rounds of sampling from the same sampling location were treated as separate samples. The approach was adopted for split-samples collected for this baseline risk assessment and applied to soil, groundwater, and sediment. Therefore, in determining the frequency of detection for split samples, the analytical results from the split samples were considered as separate values.

3.2.3 Identification of COPCs

The scope of the baseline human health risk assessment includes identification of COPCs based on the chemical substances found at the Site. The list of COPCs was developed using the screening process described below. For surface soil, subsurface soil, groundwater, sediment and surface water, all available and appropriate data for the human health exposure points were combined for each medium to select COPCs. Combining all data for a given medium results in a conservative list of COPCs for that medium.

3.2.3.1 Selection Criteria

The maximum detected concentration of a chemical in surface soil, subsurface soil, groundwater, air, sediment and surface water was compared to preliminary remedial goals (PRGs) published by EPA Region 9 (EPA, 2002c). PRGs are risk-based concentrations that are intended to assist risk assessors and others in initial screening-level evaluations of environmental contaminant concentrations. PRGs are chemical concentrations back-calculated using toxicity criteria and either a $1x10^{-6}$ target risk level for potential carcinogens or a hazard quotient (HQ) of 1 for noncarcinogens. For purposes of this screening analysis, a HQ of 0.1 was used to add as a ten-fold measure of safety to reduce the chance of omitting chemicals from the list of COPCs that

could contribute to a total hazard index (HI) of 1. To accomplish this, PRGs for noncarcinogenic chemicals were divided by 10 prior to comparison to maximum detected values. Tap water PRGs were used for comparison to maximum detected surface water and groundwater concentrations. The comparison of surface water concentrations to tap water PRGs provides a conservative screening evaluation. Ambient Water Quality Criteria (AWQCs; EPA, 2002) and Maximum Contaminant Levels (MCLs; EPA, 2003) were also used to screen for COPCs in surface water and groundwater, respectively. Residential soil PRGs were used for comparison to maximum detected surface soil and subsurface soil concentrations, as well as maximum detected sediment concentrations. Ambient air PRGs were used as screening criteria for maximum modeled indoor and outdoor air concentrations as well as maximum airborne concentrations modeled for the showering scenario.

Region 9 does not provide PRGs for petroleum hydrocarbon fraction data obtained from VPH (C5-C8 Aliphatics, C9-C12 Aliphatics, and C9-C10 Aromatics) and EPH (C9-C18 Aliphatics, C19-C36 Aliphatics, and C11-C22 Aromatics) analyses. In lieu of PRGs or other suitable criteria from EPA, the maximum detected hydrocarbon fraction concentrations in soil and sediment were compared to the lowest of the MADEP Massachusetts Contingency Plan (MCP; 310 CMR 40.0000) S-1/GW-1, S-1/GW-2 or S-1/GW-3 Method 1 cleanup criteria for soil. In groundwater, the maximum detected hydrocarbon fraction concentrations in groundwater were compared to the lowest of the GW-1, GW-2, or GW-3 Method 1 cleanup criteria. MADEP cleanup criteria are risk-based concentrations set at a $1x10^{-6}$ target risk level for potential carcinogens or a HQ of 0.2 for noncarcinogens.

A maximum detected chemical concentration less than its screening value indicated that the excess lifetime cancer risk associated with exposure to that chemical concentration would be less than one in one million and the HQ associated with exposure would be less than 0.1 (or 0.2 for the hydrocarbon fractions). Chemicals detected at concentrations below their screening criteria were, therefore, eliminated from further evaluation. All chemicals with maximum concentrations greater than the relevant screening criteria were selected as COPCs. Comparisons of maximum concentrations to screening criteria are presented in the data summary tables for each medium, as summarized below:

COPC Selection Tables				
Table No.	**Medium**	**Exposure Medium**	**Time Frame**	**Note**
3-2.1	Soil	Surface Soil	Current/Future	
3-2.2	Soil	Subsurface Soil	Future	
3-2.3	Groundwater	Groundwater	Current/Future	
3-2.4	Groundwater	Shallow Groundwater	Future	
3-2.5	Groundwater	Indoor Air	Future	Showerhead offsite
3-2.6	Soil/Groundwater	Indoor Air	Current/Future	
3-2.7	Soil/Groundwater	Outdoor Air	Future	
3-2.8	Surface Water	Surface Water	Current/Future	
3-2.9	Sediment	Sediment	Current/Future	

For the future residential groundwater use scenario, COPCs for the dermal exposure pathway were selected using the screening procedure for chemicals in water recommended in RAGS, Part E (EPA, 2001b). This screening procedure examines the relative importance of ingestion and dermal contact exposures for residential groundwater use. Compounds with dermal exposures less than 10% of ingestion exposures were not selected as dermal COPCs. The 10% screening criterion is recommended in RAGS, Part E and documented in Appendix C.6.

For certain analytes that lack compound-specific screening criteria (e.g., endrin aldehyde), a surrogate compound was selected (e.g., endrin) and its screening criteria was used for COPC screening. Specific instances where surrogate assignments were made are identified in footnotes in the COPC selection tables.

For three analytes (mercury, chromium and cyanide) multiple PRGs are available for use as COPC selection criteria. For mercury in soil and sediment, the PRG for methyl mercury in residential soil was compared to the maximum detected result for mercury. For mercury in groundwater and surface water, the PRG for mercury and compounds in tap water was compared to the maximum detected mercury result. For cyanide, the PRG for free cyanide in residential soil was compared to the maximum total cyanide result in soil and sediment. In groundwater, the free cyanide PRG for tap water was compared to the maximum detected total cyanide result in groundwater and surface water. The PRG used for chromium depended on the availability of hexavalent chromium data. In soil and sediment, both total chromium and hexavalent chromium

were detected. In this case, the PRG for chromium VI in residential soil was compared to maximum detected hexavalent chromium result and the PRG for trivalent chromium was compared to the maximum detected total chromium result. In groundwater, analyses were performed for both hexavalent and total chromium. No hexavalent chromium was detected in groundwater. In this case, the PRG for trivalent chromium was compared to the maximum detected result for total chromium in groundwater. In surface water, only total chromium analyses were performed. In this case, the PRG for hexavalent chromium was conservatively compared to the maximum detected total chromium result in groundwater.

For four essential human nutrients that lacked screening criteria (i.e., calcium, magnesium, potassium and sodium), the maximum detected concentrations were compared to concentrations in drinking water and soil that would not significantly increase the dietary Allowable Daily Intakes (ADIs), as follows: for calcium (400,000 µg/l water and 4,000,000 mg/kg soil); for magnesium (805,000 µg/l water and 8,050,000 mg/kg soil); for potassium (100,000 µg/l water and 1,000,000 mg/kg soil); and for sodium (100,000 µg/l water and 1,000,000 mg/kg soil). Derivations of these ADIs are provided in Appendix C.7. If no concentrations exceeded the ADIs, these chemicals were not further evaluated.

Since Region 9 does not provide a PRG for lead, the maximum detected lead concentration in sediment and surface soil was evaluated relative to the residential soil screening level of 400 mg/kg (EPA, 1994a). The maximum lead concentration in surface water and groundwater was evaluated relative to the Safe Drinking Water Act (SDWA) action level of 0.015 mg/l, a criterion protective of blood lead levels in children (EPA, 2002d).

Three additional inorganic chemicals, aluminum, iron and cobalt, were eliminated as COPCs because the PRG values were based on provisional toxicity criteria provided by the Superfund Technical Support Center. EPA Region I does not concur with the use of these values. These metals are abundant in the earth's crust and are unlikely to cause substantial toxicity at concentrations commonly encountered.

3.2.3.2 Chemicals Selected as COPCs

This subsection describes the chemicals selected as COPCs and refers to lists of the selected chemicals.

COPCs in Soil. Constituents detected in the surface and subsurface soil samples collected from the Southwest Properties are summarized in Tables 3-2.1 and 3-2.2, respectively. Tables 3-2.1 and 3-2.2 list all chemicals detected in surface soil and subsurface soil and identify the chemicals selected as COPCs based on comparison to residential soil PRGs. The maximum detected results for 25 contaminants exceed their respective PRGs and MADEP criteria for petroleum carbon ranges and were selected as surface soil COPCs. In subsurface soil the maximum detected results for 41 contaminants exceed their respective residential soil PRGs and MADEP criteria. No essential nutrients were detected at maximum concentrations in excess of their respective ADIs for soil.

The 25 surface soil COPCs are summarized below:

Surface Soil COPCs (0-2 ft)		
vinyl chloride	benzo(g,h,i)perylene	thallium
trichloroethene	antimony	Aroclor 1242
phenanthrene	arsenic	Aroclor 1248
benzo(a)anthracene	cadmium	Aroclor 1254
benzo(b)fluoranthene	copper	Aroclor 1260
benzo(k)fluoranthene	lead	PCB Congener Toxic Equivalent (TEQ)
benzo(a)pyrene	manganese	C11-C22 Aromatic Hydrocarbons
indeno(1,2,3-cd)pyrene	mercury	
dibenz(a,h)anthracene	nickel	

The 41 subsurface soil COPCs are summarized below:

Subsurface Soil COPCs (2-15 ft)		
1,2,4-trimethybenzene	benzo(b)fluoranthene	gamma-chlordane
1,3,5-trimethylbenzene	benzo(k)fluoranthene	4,4'-DDE
naphthalene	benzo(a)pyrene	4,4'-DDT
vinyl chloride	indeno(1,2,3-cd)pyrene	Aroclor 1242
methylene chloride	dibenz(a,h)anthracene	Aroclor 1248
cis-1,2-dichloroethene	antimony	Aroclor 1254
trichloroethene	arsenic	Aroclor 1260
xylenes (total)	barium	PCB Congener TEQ
2-methylnaphthalene	cadmium	C5-C8 Aliphatic Hydrocarbons
2,4,6-trichlorophenol	lead	C9-C10 Aromatic Hydrocarbons
acenaphthylene	manganese	C9-C18 Aliphatic Hydrocarbons
phenanthrene	mercury	C19-C36 Aliphatic Hydrocarbons
benzo(a) anthracene	thallium	C11-C22 Aromatic Hydrocarbons
bis(2-ethylhexyl)phthalate	alpha-chlordane	

COPCs in Groundwater. Constituents detected in the groundwater samples collected from the Southwest Properties are summarized in Tables 3-2.3 and 3-2.4. These tables identify the chemicals selected as COPCs in groundwater based on comparison to screening criteria. Table 3-2.3 lists all chemicals analyzed for in groundwater regardless of depth or formation (i.e., overburden or bedrock) and identifies the COPCs for the off-site residential groundwater use scenario. Table 3-2.4 lists all chemicals analyzed for in shallow groundwater (≤15 feet), which is utilized for certain exposure scenarios in the future timeframe (e.g., construction exposures) and also identifies the COPCs.

The maximum detected results for 41 contaminants for all groundwater regardless of depth exceed their respective screening criteria and were selected as COPCs. In shallow groundwater 40 contaminants exceed criteria (Table 3-2.4). No essential nutrients were detected at maximum concentrations in excess of their respective ADIs for drinking water.

The 41 COPCs in site-wide groundwater regardless of depth are summarized below:

Groundwater COPCs (Regardless of Depth)		
1,1,2-trichloroethane	methylene chloride	dibenz(a,h)anthracene
1,1-dichlorethane	tetrachloroethene	C9-C18 Aliphatic Hydrocarbons
1,1-dichlorethene	toluene	C11-C22 Aromatic Hydrocarbons
1,2,4-trichlorobenzene	trans-1,2-dichloroethene	C19-C36 Aliphatic Hydrocarbons
1,3-dichlorobenzene	trichloroethene	C5-C8 Aliphatic Hydrocarbons
1,4-dichlorobenzene	vinyl chloride	arsenic
benzene	xylenes (total)	chromium
bromomethane	acetophenone	lead
chlorobenzene	4-methylphenol	manganese
chlorodibromomethane	naphthalene	nickel
chloroethane	2-methylnaphthalene	PCB Congener TEQ
cis-1,2-dichloroethene	acenaphthylene	dieldrin
ethylbenzene	phenanthrene	4,4'-DDD
methyl tert butyl ether	benzo(a)pyrene	

The 40 COPCs identified in shallow groundwater are summarized below:

Groundwater COPCs (Shallow Groundwater)		
1,1,2-trichloroethane	methylene chloride	dibenz(a,h)anthracene
1,1-dichlorethane	tetrachloroethene	C9-C18 Aliphatic Hydrocarbons
1,1-dichlorethene	toluene	C11-C22 Aromatic Hydrocarbons
1,2,4-trichlorobenzene	trans-1,2-dichloroethene	C19-C36 Aliphatic Hydrocarbons
1,3-dichlorobenzene	trichloroethene	C5-C8 Aliphatic Hydrocarbons
1,4-dichlorobenzene	vinyl chloride	arsenic
benzene	xylenes (total)	chromium
bromomethane	acetophenone	lead
chlorobenzene	4-methylphenol	manganese
chlorodibromomethane	naphthalene	PCB Congener TEQ
chloroethane	2-methylnaphthalene	dieldrin
cis-1,2-dichloroethene	acenaphthylene	4,4'-DDD
ehylbenzene	phenanthrene	
methyl tert butyl ether	benzo(a)pyrene	

Groundwater COPCs listed above are further evaluated in Appendix C.4 in order to select compounds of significance for the dermal exposure pathway (i.e., dermal COPCs). COPCs are selected for dermal evaluation based on a screening procedure recommended in RAGS Part E. This screening procedure determines the relative significance of the ingestion and dermal exposure pathways. Any compound for which dermal exposure is determined to be greater than 10% of the ingestion exposure is selected as a dermal COPC and is retained for quantitative evaluation of the dermal pathway. Appendix C.4 documents the screening procedure. Compounds have been eliminated from dermal evaluation for the off-site resident scenario where ingestion exposures may predominate over dermal exposures. For the construction worker scenario, all groundwater COPCs are evaluated for dermal exposures since ingestion exposures tend to be minimal for this receptor.

Thirty-six dermal COPCs were identified for the construction worker scenario, which are summarized below:

Groundwater Dermal COPCs		
1,1,2-trichloroethane	ethylbenzene	2-methylnaphthalene
1,1-dichlorethane	methyl tert butyl ether	acenaphthylene
1,1-dichlorethene	methylene chloride	phenanthrene
1,2,4-trichlorobenzene	tetrachloroethene	benzo(a)pyrene
1,3-dichlorobenzene	toluene	dibenz(a,h)anthracene
1,4-dichlorobenzene	trans-1,2-dichloroethene	arsenic
benzene	trichloroethene	chromium
bromomethane	vinyl chloride	lead
chlorobenzene	xylenes (total)	manganese
chlorodibromomethane	acetophenone	PCB Congener TEQ
chloroethane	4-methylphenol	dieldrin
cis-1,2-dichloroethene	naphthalene	4,4’-DDD

Twenty-nine dermal COPCs were identified for the future off-site resident scenario, which are summarized below:

Groundwater Dermal COPCs		
1,1-dichlorethene	trans-1,2-dichloroethene	arsenic
1,2,4-trichlorobenzene	trichloroethene	chromium
1,3-dichlorobenzene	xylenes (total)	lead
1,4-dichlorobenzene	4-methylphenol	manganese
benzene	naphthalene	nickel
chlorobenzene	2-methylnaphthalene	PCB Congener TEQ
cis-1,2-dichloroethene	acenaphthylene	dieldrin
ethylbenzene	phenanthrene	4,4'-DDD
tetrachloroethene	benzo(a)pyrene	
toluene	dibenz(a,h)anthracene	

COPCs in Air. Volatile contamination in indoor and outdoor air can be attributed to migration from source media (soil, groundwater, or both). For a showering scenario, volatile contaminants detected in groundwater can impact air. All contaminants detected in soil and groundwater (or groundwater only for showering) with Henry's Law constants greater than 1E-05 atm-m^3/mole (USEPA, 1991a; 2002b) and molecular weights less than 200 grams/mole (USEPA, 1991a) were selected for modeling. The maximum detections of the selected compounds along with the appropriate compound-specific parameters were used as inputs to dilution/dispersion models to estimate the airborne concentration based on site-wide maximum concentrations in the source media (soil and/or groundwater). The maximum modeled contributions from soil and groundwater were summed to estimate a maximum airborne concentration that might be expected in indoor or outdoor air. The summed results for indoor and outdoor air and the modeled results for the showering scenario were then compared to ambient air PRGs. Those compounds that exceeded ambient air PRGs were retained as COPCs.

Appendix C.4 contains tables that summarize compounds detected in soil and shallow groundwater from the Southwest Properties that meet the Henry's Law and molecular weight criteria described above. Seventy contaminants detected in soil and shallow groundwater were identified as meeting the criteria. These compounds were then modeled using property-specific

parameters such as minimum depth to groundwater and property building dimensions to estimate reasonably conservative indoor and outdoor air concentrations (see Appendix C.4 for the model documentation).

Thirty-four COPCs associated with inhalation while showering are presented in Table 3-2.5 and are summarized below:

Inhalation COPCs During Showering		
1,1,1-trichloroethane	chloroform	naphthalene
1,1,2-trichloroethane	cis-1,2-dichloroethene	2-methylnaphthalene
1,1-dichloroethane	ethylbenzene	acenaphthylene
1,1-dichloroethene	methyl tert butyl ether	phenanthrene
1,2,4-trichlorobenzene	methylene chloride	anthracene
1,2-dichlorobenzene	tetrachloroethene	C9-C18 Aliphatic Hydrocarbons
1,3-dichlorobenzene	toluene	C11-C22 Aromatic Hydrocarbons
1,4-dichlorobenzene	trans-1,2-dichloroethene	C5-C8 Aliphatic Hydrocarbons
benzene	trichloroethene	C9-C10 Aromatic Hydrocarbons
bromomethane	vinyl chloride	C9-C12 Aliphatic Hydrocarbons
chlorobenzene	xylenes (total)	
chloroethane	acetophenone	

Thirty-eight indoor air COPCs are presented in Table 3-2.6 and summarized below.

Indoor Air COPCs		
1,2,4-trimethylbenzene	trans-1,2-dichloroethene	1,4-dichlorobenzene
1,2-dichloroethene (total)	methyl tert butyl ether	1,2-dichlorobenzene
1,3,5-trimethylbenzene	1,1-dichloroethane	2-methynaphthalene
n-butylbenzene	cis-1,2-dichloroethene	acenaphthylene
naphthalene	1,1,1-trichloroethane	dibenzofuran
p-isopropyltoluene	benzene	phenanthrene
chloromethane	trichloroethene	anthracene
vinyl chloride	methyl cyclohexane	C5-C8 Aliphatic Hydrocarbons
bromomethane	toluene	C9-C12 Aliphatic Hydrocarbons
chloroethane	tetrachloroethene	C9-C10 Aromatic Hydrocarbons

Indoor Air COPCs		
1,1-dichloroethene	chlorobenzene	C9-C1 Aliphatic Hydrocarbons
acetone	ethylbenzene	C11-C22 Aromatic Hydrocarbons
methylene chloride	1,3-dichlorobenzene	

Five outdoor air COPCs are presented in Table 3-2.7 and are summarized below.

Outdoor Air COPCs		
C5-C8 Aliphatic Hydrocarbons	C9-C10 Aromatic Hydrocarbons	C11-C22 Aromatic Hydrocarbons
C9-C12 Aliphatic Hydrocarbons	C9-C18 Aliphatic Hydrocarbons	

COPCs in Sediment. Constituents detected in the sediment samples collected from the Murphy wetland quantitatively evaluated in the human health risk assessment are summarized in Table 3-2.8. Table 3-2.8 lists all chemicals detected in sediment samples from the Murphy wetland as well as the chemicals selected as COPCs based on comparison to residential soil PRGs. The maximum detected results for 30 contaminants exceed their respective residential soil PRGs and were selected as sediment COPCs. No essential nutrients were detected at maximum concentrations in excess of their respective soil ADIs. The sediment COPCs for the Murphy wetland are summarized below:

Sediment COPCs – Murphy Wetland		
napththalene	benzo(a)pyrene	cadmium
vinyl chloride	indeno(1,2,3-cd)pyrene	chromium (total)
trichloroethene	dibenz(a,h)anthracene	lead
ethylene dibromide	C11-C22 Aromatic Hydrocarbons	manganese
ethylbenzene	C19-C36 Aliphatic Hydrocarbons	mercury
xylenes (total)	C9-C18 Aliphatic Hydrocarbons	vanadium
acetophenone	hexavalent chromium	PCB Congener TEQ
2-methylnaphthalene	antimony	gamma-chlordane
benzo(a)anthracene	arsenic	Aroclor 1254
benzo(b)fluoranthene	barium	Aroclor 1260

COPCs in Surface Water. Surface water was sampled only for inorganics (metals and cyanide). Previous surface water sampling results were non-detect for organic constituent COPCs detected in site soils; therefore organic analyses of surface water samples were not warranted. Constituents detected in unfiltered Murphy wetland surface water samples are summarized in Table 3-2.9. Table 3-2.9 lists all chemicals detected in surface water from the Murphy wetland as well as the chemicals selected as COPCs based on comparison to tap water PRGs and AWQCs. The maximum detected results for total chromium and manganese exceed their respective PRGs and were selected as surface water COPCs. No essential nutrients were detected at maximum concentrations in excess of their respective ADIs for surface water.

3.2.4 Determination of Exposure Point Concentrations

To evaluate the magnitude of potential human exposures, the concentration of each COPC in each exposure medium must be estimated. An estimate of this concentration is referred to as an EPC. EPCs were determined for the COPCs in each medium for each exposure point.

EPA requires calculation of the 95% UCL on the arithmetic mean concentration for the estimation of both the CT and RME risk (EPA, 1989; 1992; and 1994d). Therefore, whenever possible, the 95% UCL has been calculated and used as the EPC for both the RME and CT exposure cases, except when the 95% UCL was greater than the maximum detected value, in which case the maximum was used. The 95% UCLs were calculated using EPA's program ProUCL Statistical Software Version 2.1 (EPA, 2002a). The 95% UCL values could be calculated by this program if four or more samples were available from an exposure point. When less than four samples were available, the program was unable to calculate a 95% UCL value.

The 95% UCL was calculated differently depending upon the statistical distribution of the data. The ProUCL program was developed to test normality or log-normality of the data distribution, and to compute a conservative and stable UCL of the population mean. ProUCL tests the normality of raw and log-transformed data (natural logarithm to the base e) using three different

procedures (Quantile-Quantile Plots, Shapiro-Wilk W Test, and Lilliefors Test), depending upon the size of the data set.

ProUCL selects from ten procedures based on the sample size, skewness, and data distribution to compute the 95% UCL. For normally distributed data sets, a 95% UCL based upon the Student's t-statistic provides the optimal 95% UCL. For lognormal and skewed data sets, ProUCL provides results from four 95% UCL calculation procedures. Depending on the data set, the 95% UCL calculated by one of these methods was used. For data distributions that are neither normal nor lognormal, ProUCL provides results from five non-parametric 95% UCL calculation procedures. As with lognormal data sets, the 95% UCL calculated by one of these methods was used.

Appendix C.8 contains documentation for the calculation and selection of the 95% UCL values.

When less than four samples were available for an exposure point, the maximum detected COPC concentrations was used as the EPC for the RME exposure case and the arithmetic mean concentration was used as the EPC for the CT exposure case. When the 95% UCL value for a COPC exceeded the maximum detected concentration because of small sample sizes or high variability, the maximum detected COPC concentration was used as the EPC for the RME scenario, and the arithmetic mean value was used as the EPC for the CT exposure case (EPA 1989 and 1994d). In cases where the arithmetic mean value exceeded the maximum detected COPC concentration, which is possible in situations where the data includes slightly elevated non-detect concentration values, the maximum detected COPC concentration was used as the EPC for both the RME and CT cases.

Surface Soil. For surface soil, each of the three Southwest Properties (Aberjona, Whitney and Murphy) were quantitatively evaluated as separate exposure points using COPCs that were selected using all surface soil data combined from the three main data sources: RETEC 1994; RETEC 2003; and TRC 2004, plus additional non-composite sample data for the Murphy property from Clean Harbors 1996 and 1998 (see Table 3-2.1). For current scenarios, Tables 3-3.1 RME and 3-3.1 CT list the surface soil COPCs detected along with the EPCs determined for

the RME and CT scenarios, respectively. Arithmetic mean and 95% UCL values have been calculated because more than four surface soil samples were collected from each of the properties.

Subsurface Soil. Subsurface soil was evaluated for the future scenario under the assumption that Site development results in the disturbance and movement of soils to a location where exposures may occur. Subsurface soil data from each of the three Southwest Properties were quantitatively evaluated as separate exposure points using COPCs that were selected using all subsurface soil data (2-15 feet) from the three main data sources, plus additional non-composite sample data for the Murphy property from Clean Harbors 1996 and 1998 (see Table 3-2.2). Tables 3-3.2 RME and 3-3.2 CT list the subsurface soil COPCs detected along with the EPCs determined for the future case RME and CT scenarios, respectively. Arithmetic mean and 95% UCL values have been calculated because more than four subsurface soil samples were collected from each of the properties.

Groundwater. Exposure to groundwater was evaluated in both the current (for indoor air only) and future scenarios. Groundwater data collected from each of the Southwest Properties (Aberjona, Whitney and Murphy) were quantitatively evaluated using COPCs that were selected using all 2001 and 2002 groundwater data combined (see Table 3-2.3). For the future scenario, Tables 3-3.3 RME and 3-3.3 CT list the groundwater COPCs detected along with the EPCs determined for the RME and CT residential groundwater use scenarios, respectively. Tables 3-3.4 RME and 3-3.4 CT list the shallow groundwater COPCs detected and EPCs determined for future RME and CT scenarios, respectively, for certain receptors (e.g., construction worker). Arithmetic mean and maximum detected values have been used in the estimation of risk for the residential groundwater use scenario. 95% UCLs have been calculated for groundwater contribution to the indoor and outdoor air pathways and for the construction worker direct contact scenario.

Exposure to groundwater associated with showering was evaluated for the future scenario only. Tables 3-3.5 RME and 3-3.5 CT list the shower-related COPCs detected along with the EPCs determined for the RME and CT shower exposure point for an off-site residential receptor.

Indoor Air/Inhalation Exposures During Showering. Soil and groundwater data from the Southwest Properties were quantitatively evaluated using COPCs identified as previously described in subsection 3.2.3.2 (Chemicals Selected as COPCs). Only those compounds with Henry's Law constants greater than 1E-05 atm-m^3/mole (USEPA, 1991a; 2002b) and molecular weights less than 200 grams/mole (USEPA, 1991a) were used to model indoor air/shower concentrations and select indoor air/shower COPCs.

Ninety-five percent UCLs have been calculated for soil and groundwater contributions to the indoor air/shower pathway. Tables 3-3.6 RME and 3-3.6 CT list the air COPCs along with the modeled EPC for RME and CT scenarios, respectively for soil. Tables 3-3.7 RME and 3-3.7 CT list the indoor air/shower COPCs along with the modeled EPC for the RME and CT scenarios, respectively, for groundwater.

Outdoor Air. Soil data from Southwest Properties were quantitatively evaluated for outdoor air impacts separately for the surface soil (0 to 2 feet) and subsurface soil (2 to 15 feet) interval. Groundwater data was also evaluated for outdoor air impacts for the COPCs. Only those compounds detected in soil with Henry's Law constants greater than 1E-05 atm-m^3/mole (USEPA, 1991a; 2002b) and molecular weights less than 200 grams/mole (USEPA, 1991a) were used to model outdoor air concentrations and select outdoor air COPCs (see subsection 3.2.3.2).

Tables 3-3.8 RME and 3-3.8 CT list the air COPCs along with the modeled EPC for the RME and CT scenarios, respectively, for the shallow soil interval. Tables 3-3.9 RME and 3-3.9 CT list the air COPCs along with the modeled EPCs for the RME and CT scenarios, respectively, for the subsurface soil interval. 95% UCLs have been calculated for soil contribution to the outdoor air pathway. Tables 3-3.10 RME and 3-3.10 CT list the air COPCs along with the modeled EPCs for the RME and CT scenarios, respectively for groundwater.

Sediment. Exposures to sediment was evaluated for both the current and future scenarios. For sediment, as with surface water, the risk assessment quantitatively evaluates only one exposure point (i.e., the Murphy wetland). COPCs were selected using all sediment data from the four

main data sources combined (see Table 3.2-11). For the current and future exposure scenarios, Tables 3-3.11 RME and 3-3.11 CT list the sediment COPCs detected and the EPCs determined for the RME and CT scenarios, respectively. The 95 % UCL values have been provided because more than four sediment samples of appropriate depth were collected from the wetland.

Surface Water. Exposures to surface water were evaluated for both the current and future scenarios. For surface water, the risk assessment quantitatively evaluates only one human health exposure point (i.e., the Murphy wetland). COPCs were selected using unfiltered 2002 data (see Table 3-2.12). For current and future scenarios, Tables 3-3.12 RME and 3-3.12 CT list the surface water COPCs detected and the EPCs determined for the RME and CT scenarios, respectively. Since only three surface water samples were collected from the Murphy Wetland, 95% UCL values were not calculated. Thus, the maximum detected concentrations and arithmetic mean concentrations were used as EPCs for the RME and CT scenarios.

3.3 Exposure Assessment

The purpose of the exposure assessment is the quantification of the extent, frequency and duration of actual or potential exposure to chemicals by pathways relevant to the Site and activities of the potential receptors.

3.3.1 Identification of Potentially Exposed Populations and Potential Exposure Pathways

As part of the exposure assessment, current and potential future exposure pathways were determined through which identified populations may be exposed to the COPCs at the Southwest Properties. A detailed historical account and physical description of the Southwest Properties can be found in the Supplemental RI.

An exposure pathway describes the course a chemical follows while moving through environmental media to a receptor. An exposure pathway may consist of a mechanism of release of contaminants to an environmental medium (e.g., soil), an exposure route (e.g., ingestion) and a receptor (e.g., trespasser). An exposure pathway is considered complete when contact by a

receptor with contaminated media may occur currently or in the future. For purposes of this risk assessment, only potentially complete exposure pathways were quantitatively evaluated.

EPA (1989 and 1991b) guidance requires that plausible exposures under both current and future land-use scenarios be evaluated in a baseline risk assessment. Accordingly, potential human exposure pathways were identified for both current and potential future land-use scenarios at the Site. The current land-use scenario examines the potential for human exposure under current site conditions, while the future land-use scenario evaluates potential exposures following possible changes in site land use (assuming no remedial action occurs).

3.3.1.1 Potential Exposure Pathways and Receptors Under Current Land Use Conditions

The Site consists of three properties (Aberjona Auto Parts, Whitney Barrel, and Murphy's Waste Oil). Current land use is commercial/industrial at all three sites. However, a residence exists on the southeast portion of the Aberjona property. The Southwest Properties are zoned industrial (City of Woburn, 1997). Properties surrounding the Site are also zoned industrial. Many of the on-site areas of known contamination are currently fenced and/or paved. Commercial workers may access these secured areas. A complete exposure pathway does not currently exist for the paved portions of the properties, however, no data used in the evaluation of current risk is impacted by the presence of pavement. Table 3-1 presents a summary of the current exposure routes qualitatively and quantitatively evaluated in the baseline risk assessment as well as the human health exposure points and receptors. The following justifies the selection or exclusion of exposure points, receptors and exposure routes under current land-use conditions.

Resident. The Aberjona Property is the only property with a residence. Exposures of adult and young child (i.e., 1 to 6 years old) residents to surface soil, sediment, and surface water in the backyard and adjacent wetland area were previously evaluated as part of the Wells G&H OU-3 risk assessment (EPA 2003a) and, therefore, are not quantitatively evaluated in this report. Because access to the salvage yard is limited by a fence, locked gates, and a concrete wall, residential exposures to surface soil in the salvage yard is not quantitatively evaluated.

Because there are no known potable wells on-site and the residence is connected to the municipal water supply, current residential exposures to groundwater are not addressed. However, the residence is downgradient of a monitoring well containing contaminants with the potential to impact indoor air and inhalation exposures during showering. Because the direction of groundwater flow is toward the residence and additional groundwater data close to the residence is not available, residential indoor air/shower exposures (i.e., inhalation) have been evaluated. Soil impacts to indoor air were not included since soils contaminated with compounds warranting evaluation (e.g., VOCs) are not located near the residence.

Commercial Worker. Adult commercial workers are present at all three of the Southwest Properties. Contact with exposed surface soils may occur as part of job-related activities. Potential exposure routes for contaminated surface soil include incidental ingestion and dermal contact. Inhalation of contaminants in fugitive dust is expected to be negligible since these workers are not performing invasive activities.

Because commercial buildings exist on the Murphy and Aberjona properties, exposure of commercial workers to impacted indoor air is possible. As discussed previously, the central building on the Whitney property is currently unoccupied. Occupied buildings on the Murphy property and along Salem Street are not in close proximity to or downgradient of groundwater monitoring wells containing compounds with the potential to impact indoor air. Therefore, this pathway was only quantitatively evaluated at the Aberjona property. Soil impacts to indoor air were not included since soils contaminated with compounds warranting evaluation (e.g., VOCs) are not located near the occupied commercial buildings.

On the Murphy and Whitney properties, commercial operations would result in little, if any, contact by human receptors with surface water and sediment of the Murphy wetland; therefore the exposure of commercial workers to these media was not quantitatively evaluated. The evaluation of the trespasser (see below) is likely to be a conservative representation of commercial exposures, should they be occurring.

Trespasser. Many of the known contaminated areas are either secured by fencing or below pavement. Consequently, exposure pathways involving trespassers (older children) and contaminated surface soil (0 to 2 feet) are limited. Areas of the Site where trespassers may contact contaminated surface soil include the Aberjona Triangle and the Whitney property. Even though these areas are fenced, the gate at Whitney is frequently left unsecured and the fencing present at the triangular Aberjona parcel does not prevent human entry. Trespasser exposure to contaminated Murphy wetland surface water and sediment were also evaluated since the wetland is accessible to trespassing through the unsecured Whitney property. Due to the presence of shallow surface waters, wading in likely to be the primary activity in the wetland.

The exposure routes quantitatively evaluated for trespassers include incidental ingestion of and dermal contact with contaminated surface soil. For surface water, only dermal exposures are evaluated. Ingestion of surface water for wading-related exposures was not assessed since it is unlikely that a wader would ingest more than a negligible amount of surface water. For sediment, the exposure pathways include incidental ingestion and dermal contact.

3.3.1.2 Potential Exposure Pathways and Receptors Under Future Land Use Conditions

Table 3-1 presents a summary of the future exposure routes quantitatively and qualitatively evaluated in the baseline risk assessment along with the human health exposure points and receptors. To evaluate potential future exposures, it was assumed that no remedial action was taken, and that the levels of contamination currently existing at the site would remain the same in the future. However, since future activities on-site may result in the movement of soils currently at depth to the surface, certain future receptors are assumed to be exposed to subsurface soil (2 to 15 feet below ground surface) as well (e.g., construction worker).

For the purposes of this baseline risk assessment, the exposures described under current land-use conditions for commercial workers may remain unchanged in the future. Future trespasser exposures may also occur. However, it is assumed that the properties may become more accessible by the removal of current access obstacles (paving, fencing, locked gates). Based on

potential redevelopment plans for the Site, it was also assumed that land use may change at the Southwest Properties, resulting in the construction of recreational facilities on the Southwest Properties. The potential change from commercial to recreational land use is considered most likely for the Aberjona and Whitney properties, but is also possible for the Murphy property. Consequently, future recreational use of the Southwest Properties is included in this evaluation. Given the potential for the construction of new commercial or recreational facilities, a construction worker scenario has also been included.

The following justifies the selection or exclusion of exposure points, receptors and exposure routes under assumed future land-use conditions.

Resident. The Aberjona Property is currently the only property with a residence. This residence is assumed to continue to exist in the future. Future residential development on the Murphy and Whitney properties, or at the Aberjona salvage yard, is considered highly unlikely because the site and surrounding area is zoned industrially and is highly commercial/industrial and thus uninviting for residential development. As with the current scenario, future residents are not assumed to access the fenced salvage yard to the rear (north) of the residence. Therefore, residential exposure to surface or subsurface soil is not evaluated. Soils in the salvage yard will be evaluated as part of the future recreational scenario.

Future exposures at the Aberjona residence will include the indoor air pathway because the residence is downgradient of a monitoring well containing contaminants with the potential to impact indoor air. Because the direction of groundwater flow is toward the residence and additional groundwater data close to the residence is not available, residential indoor air exposures (i.e., inhalation) have been evaluated. Soil impacts to indoor air were not included since soils contaminated with compounds warranting evaluation (e.g., VOCs) are not located near the residence.

Because Site groundwater is categorized as a potentially productive area (i.e., GW-1) by MADEP, a future residential groundwater use scenario has been included. Exposure to contaminated groundwater will be addressed on a site-wide basis for the hypothetical off-site

resident population, in contrast to the property-by-property approach used for the other scenarios. This approach is based on the assumption that groundwater, as a mobile medium, can be drawn to a property by pumping, or can migrate to another property under natural gradients. Consequently, a future resident could be exposed to contaminated groundwater from all three of the properties with equal likelihood. Exposures to contaminated groundwater for adult and young child (i.e., 1 to 6 years old) residents are through the routes of ingestion, dermal contact, and inhalation assuming tap water consumption and water contact during showering and bathing.

Commercial Worker. In the future, commercial use is assumed to continue at all three of the Southwest Properties. Potential commercial workers exposures evaluated in the risk assessment include surface soil incidental ingestion and dermal contact. Inhalation of contaminated fugitive dust is expected to be negligible since commercial workers are not assumed to perform invasive activities. Subsurface soil exposures are not evaluated for commercial receptors since commercial land use may continue into the future without soil disturbance. Should soils at depth be disturbed in the future by construction/excavation, the disturbance is likely to be short-term and pavement is likely to be placed upon completion of the work, thus limiting commercial exposures to subsurface contaminants.

Commercial worker exposures to impacted indoor air attributable to contaminated groundwater is quantitatively evaluated for all three properties. Impacts of soil on indoor air quality is also evaluated since new buildings could be constructed in areas of VOC-contaminated soil.

Trespasser. Contaminated soil on all three properties that are currently fenced are considered accessible in the future. Consequently, future older child trespassers are assumed to be exposed to contaminated surface soil via ingestion and dermal contact at all three Southwest Properties. Subsurface soil exposures are not evaluated since current land use may continue into the future without soil disturbance. Should soils at depth be disturbed in the future by excavation, the disturbance is likely to be short-term and pavement is likely to be placed upon completion of the work, thus limiting trespasser exposures to subsurface contaminants.

Exposure of the trespasser to contaminated surface water and sediment in the Murphy wetland are also quantitatively evaluated. As in the current timeframe, exposure to surface water is assumed to occur through dermal contact only and exposure to sediment by both ingestion and dermal contact.

Recreational Users. Each of the properties may be developed as recreational facilities. Recreational users are assumed to include adults and a young children (i.e., 1 to 6 years old). Exposure pathways evaluated for recreational use include incidental ingestion of and dermal contact with contaminated soil at all three properties. Future recreational land use will require extensive reworking of the land with the possible movement of subsurface contamination to the surface. In addition, future recreational land use may not require extensive paving of the surface, therefore longer term exposure to subsurface soils will be possible. Hence, future recreational receptors are likely to be exposed to both surface and subsurface soil contamination. Contact with contaminated surface water and sediment in the Murphy wetland is also possible for the recreational user via a wading scenario. Future exposure pathways evaluated for recreational use include incidental ingestion of, and dermal contact with, contaminated sediments, and dermal contact with contaminated surface water during wading.

Future recreational development may include the construction of recreational buildings. Therefore, recreational user exposure to impacted indoor air attributable to contaminated soil and groundwater is evaluated for all three properties.

Construction Worker. Since changes in land use may occur, it is reasonable to assume that construction workers may be exposed to contaminants in soil and groundwater during the construction of new facilities or installation of utility connections. Construction work is assumed for all three of the Southwest Properties. Future construction workers may be exposed to surface and subsurface soils through incidental ingestion and dermal contact. Inhalation of contaminated fugitive dust is expected to be potentially significant due to the types of invasive activities being performed and has been evaluated on a quantitative basis. Future exposure to groundwater includes incidental ingestion of, and dermal contact with, contaminated groundwater during

dewatering operations. Construction workers are likely to contact shallow groundwater only (0 to 15 feet below ground surface).

Construction workers may also be exposed to fugitive contaminant vapors (i.e., outdoor air) that migrate to the air space of construction excavations. Exposure to impacted outdoor air attributable to contaminated groundwater and soil is quantitatively evaluated for all three properties.

3.3.1.3 Summary of Pathways and Receptors Selected for Consideration

The following items summarize the pathways quantitatively evaluated for each exposure scenario. Indoor and outdoor air attributable to soil is identified with an "(s)" and indoor/outdoor air attributable to groundwater is identified with a "(gw)". The use of the term "Southwest Properties" in this subsection is meant to indicate each of the three properties (Aberjona, Whitney, and Murphy) for the purposes of the following summary, otherwise the properties are cited individually. Exceptions are noted where warranted. Please refer to Table 3-1, which summarizes scenarios addressed quantitatively and qualitatively, provides assumptions related to media depth, and presents the rationale for the selection or exclusion of exposure pathways.

- **Residential scenario, Aberjona residence, current/future**

  Inhalation pathway: Indoor air (gw)

- **Residential scenario, Off-site residence, future**

  Ingestion pathway: Groundwater (tapwater)
  Inhalation pathway: Groundwater (showerhead)
  Dermal contact pathway: Groundwater (showerhead)

- **Commercial worker scenario, Southwest Properties, current**

  Ingestion pathway: Surface soil
  Inhalation pathway: Indoor air (gw) – Aberjona property only

Dermal contact pathway: Surface soil

- **Commercial worker scenario, Southwest Properties, future**

  Ingestion pathway: Surface soil
  Inhalation pathway: Indoor air (gw)
  Indoor air (s)
  Dermal contact pathway: Surface soil

- **Trespasser, Whitney and Aberjona Triangle, current**

  Ingestion pathway: Surface soil
  Dermal contact pathway: Surface soil

- **Trespasser, Murphy Wetland, current/future**

  Ingestion pathway: Sediment
  Dermal contact pathway: Surface water, sediment

- **Trespasser, Southwest Properties, future**

  Ingestion pathway: Surface soil
  Dermal contact pathway: Surface soil

- **Recreational user scenario, Southwest Properties, future**

  Ingestion pathway: Surface and subsurface soil
  Inhalation pathway: Indoor air (s)
  Indoor air (gw)
  Dermal contact pathway: Surface and subsurface soil

- **Recreational user scenario, Murphy Wetlands, future**

Ingestion pathway:	Sediment
Dermal contact pathway:	Surface water, sediment

- **Construction worker scenario, Southwest Properties, future**

Ingestion pathway:	Surface and subsurface soil, shallow groundwater
Inhalation pathway:	Outdoor air (s)
	Outdoor air (gw)
Dermal contact pathway:	Surface and subsurface soil, shallow groundwater

3.3.2 Calculation of Dose

Part of the exposure assessment is to identify exposure equations to be used in the risk assessment and to document assumptions made for each of the parameters used in these equations. The selection of exposure equations and assumptions is based both on available guidance and professional judgment.

EPA Region 1 *Risk Updates, No. 2* (EPA 1994b) requires the calculation of CT exposure and RME estimates and provides default exposure parameters for each of these estimations. The risk assessment used the default CT exposure parameters to evaluate average exposures and RME exposure parameters to evaluate high-end exposure parameters. EPA guidance or documents used in the exposure assessment include *RAGS, Part A* (EPA, 1989); *Exposure Factors Handbook* (EPA, 1997a); *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c) and *Risk Updates, No. 2* (EPA, 1994b).

3.3.2.1 Selection of Exposure Equations

Tables 3-4.1 through 3-4.14 provide the medium-specific equations used for the calculation of carcinogenic and noncarcinogenic chronic daily intake (CDI) values. The equations are used for calculating a lifetime average daily dose (LADD) relevant to cancer risk (i.e., cancer intake) or

for calculating an average daily dose (ADD) relevant to noncancer risk (i.e., noncancer intake). Additional equations used in calculating dose following dermal and inhalation exposures in site media are contained in Appendices C.4, C.5, and C.6.

3.3.2.2 Exposure Parameters

The exposure parameters used for each of the receptors evaluated in the risk assessment are described below and are presented in Tables 3-4.1 through 3-4.14. Since exposure parameters vary depending on the exposure pathway and receptor being evaluated, the exposure parameters are presented by pathway in the tables and are discussed by receptor.

Commercial Worker Exposure Parameters. The exposure parameters for the adult commercial worker are shown in Tables 3-4.1 (surface soil, current land use), 3-4.2 (surface soil, future land use), 3-4.4 (soil/indoor air, future land use), 3-4.7 (groundwater/indoor air, current land use), and 3-4.9 (groundwater/indoor air, future land use). These exposure parameters rely partially on default CT and RME exposure parameters presented in *Risk Updates, No. 2* (EPA, 1994b) and *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c).

For the soil ingestion pathway, the default CT and RME soil ingestion rate of 50 mg/day was used (EPA, 1997a). This ingestion rate is the recommended value for an adult in an industrial setting. It was assumed that commercial workers may be exposed to soil for 125 days/year for both the RME case CT cases based on professional judgment. This exposure frequency represents 5 days of exposure each week for the warmest 6 months of the year. Soil exposures during the colder months when the ground is frozen or covered by snow have not been assumed to occur. The fraction of soil ingested from the site was conservatively assumed to be 100% for both the CT and RME cases, which assumes that the worker remains on-site for the entire work day.

The default high-end exposure duration of 25 years was used for the RME case, while an average exposure duration of 9 years was used for the CT exposure case (EPA, 2001c). The default

value of 70 kg for an adult body weight was used for both CT and RME exposures (EPA, 1997a). As recommended in RAGS (EPA 1989), the averaging time for non-carcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard EPA lifetime duration (70 years).

For the soil dermal pathway, skin surface areas were calculated for the body parts that could contact soil, using statistical distributions of surface areas provided in *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c). Commercial workers were assumed to contact soils with 3,300 cm^2 of body surface area for both the CT and RME cases (50^{th} percentile value; EPA, 2001c). This surface area assumes exposure to face, forearms, trunk (including neck) and hands. A weighted soil-to-skin adherence factor of 0.2 mg/cm^2-day was used for both the CT and RME cases (95^{th} percentile value; EPA, 2001c), consistent with landscapers and gardeners, an activity selected to represent a conservative high end activity for an adult commercial work at the site.

Dermal absorption factors provided in Exhibit 3-4 of *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA 2001c) were used to evaluate risk associated with dermal contact with soil. Dermal absorption factors of 3% (arsenic), 0.1% (cadmium), 4% (chlordane), 3% (DDT), 3% (TCDD TEQ), 13% (benzo(a)pyrene and other PAHs), 14% (Aroclors and other PCBs), and 10% (SVOCs) were used in both the RME and CT cases. In the absence of recommended dermal absorption factors, dermal exposure to the remaining soil COPCs were not assessed as recommended by EPA (EPA, 2001c). The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same as the values described for the soil ingestion pathway for this receptor.

For the inhalation pathway, the exposure time was assumed equivalent to a typical 8-hour work day for both the CT and RME cases (EPA, 1997). The remaining exposure parameters used for the inhalation exposure pathway (i.e., exposure frequency, exposure duration, and averaging time) were the same as the values described for the soil ingestion pathway for this receptor.

Trespasser Exposure Parameters. The exposure parameters for the trespasser, assumed to be an older child (12 to 18 years of age), are shown on Table 3-4.1 (surface soil, current land use), Table 3-4.2 (surface soil, future land use), Table 3-4.11 (sediment, current land use), Table 3-4.12 (sediment, future land use), Table 3-4.13 (surface water, current land use), and Table 3-4.14 (surface water, future land use). These exposure parameters rely partially on default CT and RME exposure parameters presented in *Risk Updates, No. 2* (EPA, 1994b) and *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c).

The weather at Site is not conducive to outdoor activities for about 6 months of the year. Under this assumption, the older child trespasser may venture onto the Site 1 to 2 days per week for the warmest 6 months of the year (26 to 52 days/year). It was assumed that the current trespasser may venture onto the site and engage in activities resulting in soil, sediment and surface water exposures 26 days/year for both the CT and RME cases. Exposure frequency values under future land are 26 days/year for CT and 52 days/year for RME. The increased frequency under future land use assumes that access obstacles are removed in the future resulting in increased accessibility to trespassers.

The fraction of sediment or surface soil ingested was assumed to be 50% for both the CT and RME cases. Use of a fraction-ingested term assumes that a receptor ingests a portion of the daily sediment/soil intake from the Site and a portion from wetland/upland areas not impacted by the Site (i.e., background areas). This assumption is reasonable since receptors are likely to spend a portion of the day in residential yards or other background areas and incur a portion of their daily sediment/soil ingestion from these background areas. Using a 50% fraction ingested term assumes that half of the daily sediment/soil ingested is from the Site.

For the soil and sediment ingestion pathways, the default CT and RME soil ingestion rates (50 mg/kg and 100 mg/kg, respectively; EPA, 1997a) for adult residents were used since older children will likely ingest similar quantities to those ingested by adults. Surface water exposure time was set at 0.5 hour/event and 1 hour/event for the CT and RME case, respectively.

Exposure duration is assumed to be 2 years for the CT case and 6 years for the RME case (EPA, 1997a). The value of 57 kg for the body weight of an older child was used for both CT and RME exposures (EPA, 1997a). The averaging time for non-carcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard EPA lifetime duration (70 years; EPA, 1989).

For the dermal pathway, skin surfaces were calculated for the body parts that could contact surface soil, sediment and surface water, using statistical distributions of surface areas provided in *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c). The trespasser is assumed to contact environmental media with 4,500 cm^2 of body surface area for both the RME and CT cases (EPA, 2001c). This surface area assumes exposure to face, forearms, hands and lower legs. A soil-to-skin adherence factor of 0.2 mg/cm^2-day was used for both the CT and RME cases (approximate 95^{th} percentile value; EPA, 2001c). This value is a 50^{th} percentile weighted value for children playing in wet soil, an activity selected to represent a reasonable high-end activity for an older child trespasser. The same surface area and soil-to-skin adherence factors selected for soil have also been used for sediment since EPA suggests using the same approach for sediment as that used for soil (EPA, 2001b).

Dermal absorption factors provided in Exhibit 3-4 of *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA 2001c) were used to evaluate risk associated with dermal contact with soil and sediment. In the absence of recommended dermal absorption factors, dermal exposure to the remaining soil and sediment COPCs were not assessed as recommended by EPA (EPA, 2001c).

The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same values described for the ingestion pathways.

Resident Exposure Parameters. The exposure parameters for the adult and child resident are shown in Tables 3-4.7 (groundwater/indoor air, current land use), 3-4.8 (groundwater, future land use), and 3-4.9 (groundwater/indoor air and inhalation exposures during showering, future

land use). These exposure parameters rely partially on default CT and RME exposure parameters presented in *Risk Updates, No. 2* (EPA 1994b) and *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA 2001c).

For inhalation exposure to indoor air attributable to groundwater under current and future land use, the Aberjona residence is evaluated based on its proximity to upgradient monitoring wells with known VOC contamination. Due to the GW-1 classification of site groundwater, ingestion of, dermal contact with, and inhalation of VOCs from contaminated groundwater are evaluated under a future off-site residential scenario.

For the groundwater ingestion pathway, adult CT and RME ingestion rates of 1.4 liters/day and 2.0 liters/day, respectively, were used (EPA, 1997a). For the young child, CT and RME ingestion rates of 0.87 liters/day and 1.5 liters/day, respectively, were used (EPA 1997a). Exposures were assumed to occur 350 days/year in both the CT and RME cases (EPA, 2001c). This value assumed that residents are away from the home (e.g., on vacation) for two weeks of the year.

For the adult, the default high-end exposure duration of 24 years was used for the RME case, while an average exposure duration of 7 years was used for the CT exposure case (EPA, 2001c). The default value of 70 kg for an adult body weight was used for both CT and RME exposures (EPA, 1997a). For the young child, a high-end exposure duration of 6 years was used for the RME case, while an average exposure duration of 2 years was used for the CT exposure case (EPA 2001c). The default value of 15 kg for young child body weight was used for both CT and RME exposures (EPA 1997a). For both adult and young child, the averaging time for non-carcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard EPA lifetime duration (70 years).

The calculation of the air concentration in the shower is based upon an integrated household exposure model (IHEM) developed by Sara A. Foster and Paul C. Chrostowski (Foster and Chrostowski, 1986 and 1987). This is a kinetic model that estimates exposures to VOCs in the shower; both while showering and after the shower has been turned off. This model takes into

account many of the variable factors that influence the release of VOCs from water and their subsequent buildup in shower room air. Chemical specific concentrations from groundwater data, along with standard assumptions were used to calculate the air concentration. The calculations assume that an individual takes one 15-minute shower and spends 5 minutes in the shower room after the shower is turned off per day for a 70-year lifetime. The results of the model are provided in Appendix C.5.

For the dermal pathway, skin surface areas were selected for the body parts that could contact contaminated groundwater water while showering, using statistical distributions of surface areas provided in *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c). The adult off-site resident was assumed to contact groundwater during showering with 18,000 cm^2 of body surface area for both the CT and RME cases (EPA, 2001c). The young child off-site resident was assumed to contact groundwater during showering with 6600 cm^2 of body surface area for both the CT and RME cases (EPA, 2001c). These surface areas assume exposure to the whole body. For the dermal exposure pathway, absorbed doses were calculated for each chemical using equations and chemical-specific factors provided by EPA 2001c. The dermal absorbed dose was calculated using chemical-specific permeability coefficients and, for organic compounds, molecular weight and octanol-water partition coefficients, as detailed in Appendix C.6 (Dermal Appendix). For this exposure, event times of 0.58 hours was assumed for both the CT and RME cases (EPA, 2001c). This event time includes time in the shower as well as time after showering when the skin remains damp and absorption of contaminants through the skin continues. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight and averaging time) were the same as the values described for the groundwater pathways discussed above.

For the indoor air inhalation pathway, the exposure time was assumed to be 16 hours/day for both the CT and RME cases based on professional judgment. This exposure time assumes that residents are away from the home 8 hours per day while at work or school. The remaining exposure parameters used for the inhalation pathway associated with indoor air (i.e., exposure frequency, exposure duration, and averaging time) were the same as the values described for the groundwater ingestion pathway for this receptor.

Recreational User Exposure Parameters. The exposure parameters for the adult and child recreational user are shown in Table 3-4.2 (surface soil, future land use), Table 3-4.3 (subsurface soil, future land use), Table 3-4.4 (surface soil/indoor air, future), Table 3-4.9 (groundwater/indoor air, future), Table 3-4.12 (sediment; future land use), and Table 3-4.14 (surface water, future land use). These exposure parameters rely partially on default CT and RME exposure parameters presented in *Risk Updates, No. 2* (EPA, 1994b) and *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c).

As previously mentioned, the weather at the Site is not conducive to outdoor activities for about 6 months of the year. Therefore, it was assumed that the adult and young child recreational user may venture onto the site and engage in activities resulting in surface water, sediment, surface soil and subsurface soil exposure for 1 to 3 days per week for the warmest 6 months of the year. The exposure frequency values used for the CT and RME exposure cases for sediment, soil and surface water exposures were 1 or 3 days per week for the warmest 6 months of the year (i.e., 26 and 78 days/year), respectively. For indoor activities where exposure to impacted indoor air is assessed, it was assumed that indoor activities would take place during the coldest six months of the years since one possible future use of the Aberjona property is as an ice skating facility. Under this assumption, the adult recreational user would engage in indoor activities resulting in indoor air exposures for 26 and 78 days/year for the CT and RME exposure case, respectively. These exposure frequency values represent 1 or 3 days per week for the coldest 6 months of the year.

For surface water, incidental ingestion was assumed to not occur during wading. For the soil and sediment ingestion pathways, the default CT and RME soil ingestion rates (50 mg/kg and 100 mg/kg, respectively; EPA, 1997) for adult residents were used. For the sediment and surface soil ingestion pathway, the default CT and RME soil ingestion rates (100 mg/kg and 200 mg/kg, respectively; EPA 1997a) for young child residents were used. Use of these values provides a conservative evaluation of soil and sediment exposure in a recreational setting.

The fraction of sediment or surface soil ingested from the Southwest Properties was assumed to be 50% for both the CT and RME cases. Use of a fraction-ingested term assumes that a receptor ingests a portion of the daily sediment/soil intake from the Site and a portion from wetland and upland areas not impacted by the site (i.e., background areas). This assumption is reasonable for the Site since recreational receptors are likely to spend a portion of the day in unimpacted areas and incur a portion of their daily sediment/soil ingestion from these background areas. Using a 50% fraction ingested term assumes that half of the daily sediment/soil ingested is from the Site.

For the dermal pathway, skin surface areas were selected for the body parts that could contact surface water, sediment or soil, using statistical distributions of surface areas provided in *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c). Adult recreational users were assumed to contact sediments, surface soils and surface water during wading with 5,700 cm^2 of body surface area for both the CT and RME cases (50^{th} percentile value; EPA, 2001c). The surface area assumes exposure to the face, forearms, hands and lower legs. A soil-to-skin adherence factor of 0.07 mg/cm^2-day was used for both the CT and RME cases (EPA 2001c). This value is a 50^{th} percentile weighted adherence factor for gardeners, the activity selected to represent a reasonable high-end activity for the adult. Young child recreational users were assumed to contact sediments, soils and surface water during wading also with 2,800 cm^2 of body surface area for both the CT and RME cases (50^{th} percentile value; EPA 2001c). The surface area assumes exposure to the face, forearms, hands, lower legs and feet of the young child. A soil-to-skin adherence factor of 0.2 mg/cm^2-day was used for both the CT and RME cases (EPA 2001c). This value is a 50^{th} percentile weighted adherence factor for children playing in wet soil, the activity selected to represent a reasonable high-end activity for the child. The same surface area and soil-to-skin adherence factors selected for soil have also been used for sediment since EPA suggests using the same approach for sediment as that used for soil (EPA, 2001d).

Dermal absorption factors provided in Exhibit 3-4 of *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Intermim* (EPA, 2001c) were used to evaluate risk associated with dermal contact with soil. In the absence of recommended dermal absorption factors, dermal

exposure to the remaining soil COPCs were not assessed as recommended by EPA (EPA, 2001c).

For the surface water dermal exposure pathway, absorbed doses were calculated for each chemical using equations and chemical-specific factors provided by EPA, 2001c. The dermal absorbed dose was calculated using chemical-specific permeability coefficients and, for organic compounds, molecular weight and octanol-water partition coefficients, as detailed in Appendix C.6 (Dermal Appendix). For this exposure, event times of 0.5 hours and 1 hour were assumed for the CT and RME cases, respectively, based on professional judgment. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight and averaging time) were the same as the values described for the soil and sediment ingestion pathways.

For the adult, the default high-end exposure duration of 24 years was used for the RME case (EPA 1994b). For the CT exposure case, 7 years was selected as the average exposure duration (EPA 1994b). The default value of 70 kg for an adult body weight was used for both CT and RME exposures (EPA 1994b). For the young child, the default high-end exposure duration of 6 years was used for the RME case, while an average exposure duration of 2 years was used for the CT exposure case (EPA 1994b). The value of 15 kg for a young child body weight was used for both CT and RME exposures (EPA 1994b). Finally, as recommended in *RAGS* (EPA 1989), the averaging time for non-carcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard EPA lifetime duration (70 years) for both adult and young child residents.

Construction Worker Exposure Parameters. The exposure parameters for the construction worker are shown in Table 3-4.2 (surface soil, future land use), Table 3-4.3 (subsurface soil, future land use), Table 3-4.5 (surface soil/outdoor air, future land use), Table 3-4.6 (subsurface soil, future land use), Table 3-4.8 (shallow groundwater, future land use), and Table 3-4.10 (shallow groundwater/outdoor air, future land use). These exposure parameters rely partially on default CT and RME exposure parameters presented in *Risk Updates, No. 2* (EPA, 1994b) and *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c).

Construction workers are expected to experience direct exposure to surface soil, subsurface soil, and groundwater via incidental ingestion and direct dermal contact. Inhalation of fugitive dusts from surface and subsurface soil may also occur. Construction workers may also be exposed to contaminated outdoor air in the breathing zone during excavation and trenching attributable to volatile contaminants in surface soil, subsurface soil, and groundwater.

For the soil ingestion pathway, the default contact intensive soil ingestion rate of 200 mg/day (EPA, 1997) was used for both RME and CT cases to provide a conservative evaluation of exposure. For groundwater, an ingestion rate 0.05 liters/day of groundwater was assumed for both the RME and CT case based on professional judgment. This value represent the ingestion of approximately one mouthful of water per day. For both soil and groundwater, it was assumed that construction workers may be exposed for 125 days/year (5 days per week for a 6-month construction project) for the RME scenario and 40 days/year (5 days per week for an 8-week construction project) for the CT scenario. The fraction of soil ingested from the Site was assumed to be 100% for both the CT and RME cases.

The exposure duration of 1 year was assumed for both the RME and CT cases. The default value of 70 kg for an adult body weight was used for both RME and CT exposures (EPA, 1997a). As recommended in *RAGS* (EPA, 1989), the averaging time for non-carcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard EPA lifetime duration (70 years).

For the dermal pathway, skin surface areas were calculated for the body parts that could contact soil or groundwater using statistical distributions of surface areas provided in *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Interim* (EPA, 2001c). Construction workers were assumed to contact soil and/or groundwater with 3,300 cm^2 of body surface area for both the RME and CT cases (50^{th} percentile value; EPA 2001c). The surface area assumes exposure to the face, forearms, hands and lower legs. A soil-to-skin adherence factor of 0.2 mg/cm^2-day was used for both the CT and RME cases (50^{th} percentile value for utility workers; EPA, 2001c), an activity selected to represent a reasonable high-end activity for this receptor.

Dermal absorption factors provided in Exhibit 3-4 of *RAGS, Part E Supplemental Guidance for Dermal Risk Assessment, Intermim* (EPA, 2001c) were used to evaluate risk associated with dermal contact with soil. In the absence of recommended dermal absorption factors, dermal exposure to the remaining soil COPCs were not assessed as recommended by EPA (EPA, 2001c).

For the inhalation pathway, construction workers were assumed to engage in activities resulting in the inhalation of fugitive dusts and volatile compounds from the subsurface for 8 hours/day. Air EPCs were modeled from soil and groundwater COPC concentrations as described in Section 3.2.2.2. Exposure frequencies were the same as those selected for ingestion/dermal contact related exposures. The remaining exposure parameters for the inhalation pathway (i.e., exposure duration and averaging time) were the same values described for the soil ingestion pathway

3.4 Toxicity Assessment

The toxicity assessment presented here was conducted in accordance with EPA guidance (EPA 1989). The methodology used for classifying health effects from exposure to chemicals is recommended by EPA, 1989. The toxicity assessment considers chronic (long-term) exposures. For potentially carcinogenic chemicals, less than chronic exposures (i.e., subchronic exposures) would result in less risk than chronic exposure. Therefore, if chronic risk is below a regulatory limit, risk from subchronic exposures will also be below the regulatory limit. In other words, as exposure decreases, so does the risk for potential carcinogens.

The chronic toxicity criteria were obtained from EPA's Integrated Risk Information System (IRIS) (EPA 2003b) and Health Effects Assessment Summary Tables (HEAST) (EPA 1997b). These sources list the most recent toxicity values recommended by EPA for use in human health risk assessments. In addition, some toxicity criteria values were obtained from the National Center for Environmental Assessment (NCEA), a division of EPA. Values from IRIS are the preferred criteria, if available.

3.4.1 Toxicity Information for Noncarcinogenic Effects

Systemic toxic effects other than cancer can be associated with exposures to chemicals. The reference doses (RfDs) and reference concentrations (RfCs) are the toxicity values that are used to evaluate the potential of developing noncarcinogenic effects as a result of exposure to potentially toxic chemicals. The RfDs and RfCs have been developed on the premise that there are protective mechanisms that must be overcome before an appreciable risk of adverse health effects is manifested during a defined exposure period. It is assumed that there is a threshold dose that must be exceeded before adverse effects can occur.

Chemicals classified as carcinogens may also produce other systemic effects. These chemicals were also evaluated for potential noncarcinogenic toxic effects and were included in the determination of chronic toxicity HQs, which characterize noncancer hazards. Carcinogenic effects, however, are usually manifested at levels that are lower than those associated with systemic toxic effects; thus, cancer is usually the predominant adverse effect for contaminants that may elicit carcinogenic as well as noncarcinogenic responses. Table 3-5.1 summarizes the noncarcinogenic toxicity values (i.e., RfDs) for oral and dermal exposure routes and the corresponding critical effects for the COPCs at the site. Table 3-5.2 summarizes the inhalation noncarcinogenic toxicity values (i.e., RfCs) and the corresponding critical effects for volatile COPCs at the site. Both chronic and subchronic toxicity values are listed on these tables. When the chronic Reference Dose (RfD) or chronic Reference Concentration (RfC) is based on a subchronic study, a subchronic RfD has been developed by the elimination of the 10-fold uncertainty factor.

Oral RfDs for manganese were developed based on EPA Region I guidance (EPA 1996a) as recommended in IRIS (EPA 2003b). These RfDs were based on a total allowable manganese intake of 10 mg/day (EPA 2003b). After adjusting for background intake (the average dietary manganese intake in the U.S. population; 5 mg/day), the remaining intake (5 mg/day) was then normalized for body weight (70 kg) to arrive at the manganese RfD for sediment and soil (0.07 mg/kg-day).

For mercury, the RfD for inorganic mercury was used to evaluate surface water and groundwater exposures. However, since mercury in soil and sediments is likely to exist as organic mercury compounds, the RfD for organic mercury was used to evaluate soil and sediment exposures.

Due to a lack of reliable chromium speciation data for surface water, all chromium in this medium was evaluated using the hexavalent chromium RfD. For soil, sediment and groundwater and surface water, total chromium was evaluated using the trivalent chromium RfD, except in cases where hexavalent chromium was detected. In these cases, the hexavalent chromium RfD was used.

The certain constituents lacking compound-specific screening criteria (e.g., 2-methylnaphthalene), a surrogate compound was selected (e.g., naphthalene). Specific instances where surrogate assignments were made are identified in footnotes on Tables 3-5.1, 3-5.2, 3-6.1 and 3-6.2. In addition, toxicity values for the VPH and EPH carbon ranges were obtained from MADEP's Characterizing Risk Posed by Petroleum Contaminated Sites: Implementation of the MADEP VPH/EPH Approach, Final Policy (MADEP, 2002).

Additional information on the noncarcinogenic effects for each COPC is presented in the toxicity profiles in Appendix C.9. Chemical-specific permeability coefficients (K_ps), used to evaluate the surface water dermal pathway, are provided in Appendix C.10.

3.4.2 Toxicity Information for Carcinogenic Effects

The potential for human carcinogenic effects is evaluated based on the chemical-specific slope factors (SFs) and Unit Risk (UR) values along with the weight-of-evidence classification of the EPA. The SF and UR values are the toxicity values that quantitatively define the dose-response relationship of a known or suspected carcinogen. The SF and UR are estimates of an upper-bound lifetime probability of an individual developing cancer following exposure to a potential cancer-causing agent over his or her lifetime. The SFs and URs for chemicals are generally expressed as the 95-percent UCL of the slope of the dose-response curve and are derived by assuming low-dose linearity and applying a computer model to extrapolate from the relatively high doses administered to animals (or the exposures observed in epidemiological studies) to the

lower environmental exposure levels that generally occur in humans. The EPA has developed SFs and URs for chemicals classified as carcinogens, based on the premise that there is no threshold, i.e., there is no level of exposure below which there is no risk of a carcinogenic effect.

Because the SF and UR are generally the 95-percent UCL of the probability of a response per unit intake of a chemical over a lifetime exposure, the use of such SFs and URs is expected to result in a conservative (i.e., upper-bound) estimate of potential cancer risk. The true risk to humans is not likely to exceed the upper-bound estimate but could be lower and may even be zero. Further, because the dose-response curve is assumed to be linear in the low-dose region, the accuracy of the SF and UR may be limited if this region should, in reality, exhibit nonlinearity.

Table 3-6.1 summarizes the carcinogenic toxicity values (i.e., SFs) and the corresponding weight-of-evidence classifications. Table 3-6.2 summarizes the inhalation carcinogenic toxicity values (URs) for volatile COPCs. For PAHs, the SF for B(a)P, along with the appropriate relative potency factors (EPA, 1993a), have been used to evaluate the potency of the individual carcinogenic PAHs. Additional discussion on each COPC is provided in toxicity profiles presented in Appendix C.9.

Prior to carcinogenic evaluation, the detected concentrations of dioxin-like PCBs were adjusted to Toxic Equivalent (TEQ) concentrations using methodology and Toxicity Equivalency Factors (TEFs) provided by EPA 2000e and Van den Berg *et al*. (1998). The concept of TEFs has been developed and introduced to facilitate risk assessment and regulatory control of exposure to complex environmental mixtures of classes of compounds. TEFs are used to represent the toxicity of isomers, congeners and homologues of dioxin-like PCBs relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), which is assigned a TEF of unity. For example, an isomer assigned a TEF of 0.1 indicates that the isomer is approximate 10-fold less potent than 2,3,7,8-TCDD. The environmental concentrations of the isomers and congeners are multiplied by their respective TEFs and then summed together to derive an adjusted environmental concentration (the TEQ) that factors in the relative toxicity of the compounds. The TEQ is then used, along with the slope factor for 2,3,7,8-TCDD, to estimate cancer risk for dioxin-like PCBs

as a group. Because the Scientific Advisory Board is currently re-evaluating the carcinogenic potency of 2,3,7,8-TCDD, the draft dioxin slope factor has also been used in risk estimation and is further discussed in subsection 3.5.2.2.

EPA is currently re-evaluating the carcinogencity of trichloroethene. Under EPA's interim (1999) cancer guidelines, trichloroethene can be characterized as likely to be carcinogenic to humans. Currently, there is no consensus on appropriate SF or UR toxicity values with which to evaluate trichloroethene's non-threshold effects, although EPA's National Center for Environmental Assessment has issued an external review draft of the *Trichloroethylene Health Risk Assessment: Synthesis and Characterization* (EPA, 2001e). Because of the lack of consensus, four trichloroethene oral slope factors and corresponding unit risks, including two oral slope factors and unit risks from NCEA's external review draft are used for risk estimation, as summarized below:

Trichloroethene Non-Threshold Toxicity Factors

Source	Oral Slope Factor (per mg/kg/day)	Unit Risk (per ug/m^3)	Reference
NCEA high-end	0.4	1.1E-04	USEPA, 2001e
NCEA low-end	0.02	5.7E-06	USEPA, 2001e
California EPA OEHHA	0.007	2.0E-06	OEHHA, 2002
EPA HEAST	0.006	1.7E-06	USEPA, 1993b

Notes:
NCEA – National Center for Environmental Assessment
OEHHA – Office of Environmental Health Hazard Assessment
HEAST – Health Effects Assessment Summary Table

The above slope factors and associated URs are further discussed in subsection 3.5.2.2.

Additional discussion on each carcinogenic COPC is provided in toxicity profiles presented in Appendix C.9.

3.4.3 Adjustment of Toxicity Factors

No RfDs or SFs are available for evaluating dermal exposure. Therefore, cancer risks and HIs associated with dermal exposure may be evaluated using an oral SF or RfD, adjusted such that the toxicity value is appropriate for the dermal pathway. As detailed by EPA, for purposes of evaluating dermal exposure, it is generally necessary to adjust an oral toxicity factor (i.e., RfD or SF) from an administered (i.e., applied) dose to an absorbed (i.e., internal) dose (EPA 1989). Because the toxicity values for the COPCs at the study area are expressed as orally administered doses (i.e., applied or intake-based), it is necessary to adjust both the RfDs and SFs for these substances in estimating exposure on an absorbed-dose basis when assessing dermal exposure.

The oral RfDs and oral SFs for each COPC were modified according to the following equations for use in assessing dermal exposure (EPA 1989):

$$ERfD_o = RfD_o \times BF_{o,a}$$

$$ESF_o = SF_o / BF_{o,a}$$

where:

- $ERfD_o$ = effective absorbed-dose oral RfD for each chemical (i.e., adjusted dermal RfD)
- RfD_o = oral RfD for each chemical
- $BF_{o,a}$ = absolute oral bioavailability factor for each chemical (i.e., oral to dermal adjustment factor)
- ESF_o = effective absorbed-dose oral SF for chemical (i.e., adjusted dermal SF)
- SF_o = oral SF for each chemical

Tables 3-5.1 and 3-6.1 present the oral to dermal adjustment factors used to adjust the oral toxicity criteria for the COPCs evaluated in the dermal exposure pathways. Oral bioavailability values were derived from data presented in RAGS, Part E. No adjustment for oral absorption efficiency has been applied to any COPC with an absorption efficiency of greater than 50%.

These COPCs include all VOCs, PAH compounds, pesticides, PCBs, arsenic, organic mercury, thallium and zinc. Additional information on compound-specific oral to dermal adjustment factors is provided in Appendix C.9.

3.4.4 Toxicity Information for Arsenic in Sediment

To more accurately assess the oral toxicity of arsenic in sediments at the site, the site-specific oral bioavailability study conducted for the Wells G&H Superfund Site, OU-3 Aberjona River Study was utilized. This study was initiated for the Aberjona River Study because current default information on the oral bioavailability of arsenic from environmental media indicates that arsenic may be absorbed from the gastrointestinal tract with an efficiency approaching 100%. However, oral bioavailability studies at other sites have indicated that the actual oral bioavailability of arsenic from some soils is significantly less than 100%.

The report entitled *Relative Bioavailability of Arsenic in Sediments from the Aberjona River* (Castell, et al 2002), details the methods and results of the study conducted for the Aberjona River Study Area and is included in its entirety in Appendix C.11. In this study, young swine were fed sediments from the Aberjona River study area that contained arsenic at various known levels. Data were collected to calculate the relative bioavailability (RBA) of arsenic from these sediments. RBA is an estimate of the oral bioavailability of arsenic from study area sediments compared to that of a reference arsenic compound administered in drinking water. "Best Estimate" RBA values determined in this study ranged from 37 to 51%, indicating that arsenic from sediments is absorbed less extensively than arsenic from drinking water. These site-specific RBA estimates are also less than the default value of 100% for oral absorption efficiency of arsenic. The most conservative RBA value determined for study area sediments (51%) was selected as the most appropriate to evaluate the oral toxicity of arsenic in sediments at the Murphy wetland.

The site-specific RBA value of 51% was used to adjust the oral RFD and SF for arsenic to derive a site-specific estimate of oral toxicity of arsenic in sediments. The oral RfD and oral SF for

arsenic were modified according to the following equations from Castell, et al 2002 (see Appendix C.11 for use in assessing oral sediment exposures for arsenic:

$$RfD_{adjusted} = RfD_{IRIS} / RBA$$

$$SF_{adjusted} = SF_{IRIS} \times RBA$$

where:

$RfD_{adjusted}$	=	adjusted oral RfD for arsenic in sediment
RfD_{IRIA}	=	oral RfD for arsenic as listed in IRIS (EPA 2003b)
RBA	=	site-specific relative bioavailability factor for arsenic (i.e., 0.51)
$SF_{adjusted}$	=	adjusted oral SF for arsenic in sediment
SF_{IRIS}	=	oral SF for arsenic as listed in IRIS (EPA 2003b)

Tables 3-5.1 and 3-6.1 present the adjusted oral RfD and adjusted oral SF for arsenic, respectively. These adjusted toxicity values were used to evaluate ingestion exposures to arsenic in sediment only. Arsenic toxicity values were not changed for the evaluation of arsenic in other media or by the dermal route of exposure.

3.4.5 Toxicity of Lead

Lead was selected as a COPC in soil, groundwater, surface water and sediment. Lead in soil and sediment exceeded the residential soil screening value of 400 mg/kg (EPA, 1994a). No RfD or SF is available for lead. Therefore, EPA has recommended some alternative approaches to evaluate lead exposures. For soil and sediment, childhood lead exposures were evaluated through the use of the Integrated Exposure Uptake Biokinetic (IEUBK) Model (EPA, 2002a). Appendix C.12 (Lead Model CALCs) contains summary information showing the IEUBK model inputs. This model uses algorithms to calculate a soil lead concentration protective of a childhood blood lead level of 10 micrograms per deciliter (μg/dL). The average time-weighted soil or sediment lead concentration was used as the soil or sediment concentration in the model. Default values, as recommended in the model, were used for all other inputs (see Table C.12a).

Lead sediment exposures were evaluated for the adult commercial, adult recreational, adult construction worker, and older child trespasser through the use of methodology provided in Recommendations of the Technical Workgroup for Lead for an Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil (EPA 2003c). This methodology uses algorithms to relate soil lead intake to blood lead concentrations in women of childbearing age. The model calculates a soil lead concentration protective of a site-specific maternal blood lead level that will be protective of a 95th percentile fetal blood level of 10 μg/dL. Appendix C.12, Tables C.12b through C.12e, document the calculation of a site-specific maternal blood lead level for each scenario using a geometric standard deviation (GSD) in intake and biokinetics of 1.8, which is typical of populations in small areas dominated by a single source of lead exposure. A typical blood lead concentration in women of child-bearing age in the absence of study area exposures was assumed to be 2.0 μg/dL, which is a mid-range default assumption (EPA 2003c). All other model inputs are presented on Tables C.12-7 through C.12-12.

The ingestion rate was adjusted based on the scenario being evaluated. For the adult commercial worker, adult recreational user and older child trespasser, the ingestion rate was assumed to be 50 mg/day and for the construction worker, 200 mg/day. The time-weighted average soil or sediment lead concentration was used as the soil or sediment concentration in the model.

3.5 Risk Characterization

Risk characterization combines estimates of exposure with toxicity data to develop estimates of the probability that an adverse effect will occur under the specified conditions of exposure. The risk characterization was divided into three phases: 1) risk estimation; 2) risk description; and 3) uncertainty analysis.

Risk estimation is undertaken by combining the toxicity factors and exposure assessment equations to calculate estimates of risks. Noncarcinogenic risks are reported as pathway-specific HIs, which are the sum of individual COPC HQs for that pathway. Only HQs from COPCs that affect the same target organ are summed to generate HIs. Estimates of carcinogenic risks are

reported as incremental (above background) lifetime cancer risks (ILCRs). Current practice considers carcinogenic risks to be additive when assessing exposure to a mixture of hazardous substances. Risk description entails several discussions, including the relative contributions of individual exposure pathways to the total risk for each medium. The significance of the risk estimates are relative to risk management criteria set forth in EPA policy. The uncertainty analysis describes and quantifies, where possible, the impact of data uncertainty and variability, exposure assumptions, and toxicity values on estimates of risk.

3.5.1 Risk Estimation

Noncancer risk is estimated by means of a HQ. To calculate noncarcinogenic HQs, the ADDs, calculated as described in subsection 3.3.2, were divided by the RfDs as follows:

$$HQ = ADD / RfD$$

The sum of this ratio for all chemicals within a property/area and pathway that have the same target organ or type of toxicity is termed the pathway HI. The HI is useful as a reference point for gauging potential effects of environmental exposures to complex mixtures. In general, HIs that are less than 1 are not of regulatory concern; however, a HI of greater than 1 does not automatically indicate that an adverse effect will occur and should not automatically be interpreted as posing an unacceptable risk to the exposed population.

The total pathway HI for each property/area was calculated by summing the HQs for the COPCs having similar systemic effects. Total HIs for each receptor, by medium, were calculated by summing the total pathway HIs across pathways within media (e.g., summing dermal and ingestion sediment risks). As a first approximation, all COPCs are assumed to have additive effects. Total pathway HIs, assuming additivity of effects, are presented on Tables 3-7.1 through 3-7.13. However, in cases where the total pathway HI for a receptor exceeded 1, only COPCs having similar systemic effects (i.e., target organs) were summed for each pathway and medium. Target organ HIs are presented on Tables 3-9.1 through 3-9.29.

The cancer risk of each receptor is estimated for each medium by means of an ILCR. EPA (1991b) states that where the cumulative incremental current or future carcinogenic risk to a receptor is less than 10^{-4}, and where the noncarcinogenic HI is less than 1, action generally is not warranted unless there are adverse environmental impacts (EPA, 1991b).

To calculate ILCR, the chemical- and pathway-specific LADDs, calculated as described in subsection 3.3.2, were multiplied by SFs as follows:

$$ILCR = SF \times LADD$$

The resulting value represents the upper-bound probability that an individual could develop cancer over his or her lifetime due to exposure to potential carcinogens under the conditions specified in the exposure scenario. For example, carcinogenic risk levels of 10^{-6} and 10^{-4} represents a one-in-one-million chance and a one-in-ten-thousand chance, respectively, that an individual could develop cancer over a lifetime.

The cancer risk for each pathway (e.g., the sediment ingestion pathway) was calculated by summing the risks from each COPC at each property/area within the pathway, while receptor risks for each medium were calculated by summing ILCRs for each pathway within the medium (e.g., the sediment ingestion and dermal contact pathways). Receptor cancer risk from exposure to soil, groundwater, air, surface water and sediment within a property/area was determined by adding the risk from each medium and pathway, as appropriate. ILCRs were further summed for child and adult receptors to derive a total receptor cancer risk for the recreational and residential receptors. The total receptor ILCRs are presented on Tables 3-9.1 through 3-9.29.

Total receptor cancer risk from each medium is presented by property/area. Risk was not summed across the properties since the parameter values used assume maximal exposure within each exposure area. This approach assumes that an individual would not be maximally exposed to media at more that one property.

3.5.2 Risk Description

This subsection summarizes the human health risks potentially associated with exposures to environmental media (surface/subsurface soil, groundwater, indoor air, outdoor air, surface water and sediment). Individual chemical-specific carcinogenic risks are expressed as probabilities of developing cancer (i.e., ILCRs), while noncarcinogenic risks are expressed as HIs. All carcinogenic and noncarcinogenic risks were calculated using both CT and RME methods. The RME represents the reasonable maximum exposure and risk a receptor may receive from a property/area. The CT represents the average exposure and risk at a property/area.

The risk description for the Southwest Properties is provided below in two parts. First, the relative contributions of the various exposure pathways within each medium are analyzed for each receptor. Second, the relative contributions of each contaminant are analyzed for each receptor.

Tables 3-9.1 through 3-9.29 present target-organ specific HIs, which are discussed if a medium-specific HI exceeds 1. For the recreational and residential receptors, child and adult ILCRs have been summed to present the total receptor cancer risk. However, because the child receptor is the most sensitive receptor for the estimation of noncarcinogenic risks, only the child receptor HIs have been presented on these tables for these receptors.

3.5.2.1 Description of HI Estimates

HI estimates represent the risk of health effects other than cancer from exposure to contaminants within the Southwest Properties, as described in subsection 3.5.1. Tables 3-7.1 through 3-7.13 present the non-carcinogenic risks by receptor and medium for each of the three properties, the Murphy wetland and the off-site resident. When a receptor-specific HI for an exposure medium exceeded 1, HIs were segregated by target organ and discussed as to whether target organ-specific HIs exceed the risk management criterion. These target organ HIs are presented on Tables 3-9.1 through 3-9.29.

The following summarizes the estimated HIs for the evaluated pathways and media for each of the three properties, the Murphy wetland and the off-Site resident. HQs for contaminants that contributed significantly to HIs in excess of the risk management criterion are noted, where appropriate. The Murphy wetland is evaluated as a separate exposure point for the current/future trespasser and future recreational user. The additive effect of exposure to the Murphy wetland and soil at the Murphy and Whitney properties is evaluated qualitatively where appropriate.

Aberjona Property

Adult Commercial Receptor. The estimated HIs for the adult commercial receptor at the Aberjona property are presented in Tables 3-7.1 and 3-7.2 for current and future land use, respectively. The cumulative risks for the media evaluated are presented in Tables 3-9.1 and 3-9.8 for current and future land use, respectively. Current HIs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor volatiles attributable to contaminated groundwater. Future HIs are calculated assuming incidental ingestion of, and dermal contact with surface soil and inhalation of indoor volatiles attributable to contaminated soil and groundwater. The RME and CT HIs are below the target HI of 1.

Older Child Trespasser. The estimated HIs for the older child trespasser at the Aberjona property are provided in Tables 3-7.3 and 3-7.4 for current and future land use, respectively. The cumulative risks for the media evaluated are presented in Tables 3-9.2 and 3-9.9 for current and future land use, respectively. The HIs are calculated assuming incidental ingestion of and dermal contact with surface soil. The current trespasser was evaluated for exposures on the triangular portion of the Aberjona property only due to current access limitations. The future trespasser was evaluated for exposures on the entire Aberjona property assuming unlimited access to the property in the future. The RME and CT HIs are below the target HI of 1.

Adult Resident Receptor. The estimated HIs for the adult resident at the Aberjona property are provided in Tables 3-7.5 and 3-7.6 for current and future land use, respectively. HIs are calculated assuming inhalation of indoor volatiles from groundwater only. Exposures to other

contaminated media for this receptor were previously evaluated as part of the Wells G&H OU-3 risk assessment (EPA, 2003a). The RME and CT HIs are below the target HI of 1.

Young Child Resident Receptor. The estimated HIs for the young child resident at the Aberjona property are provided in Tables 3-7.7 and 3-7.8 for current and future land use, respectively. HIs are calculated assuming inhalation of indoor volatiles from groundwater only. Exposures to other contaminated media for this receptor were previously evaluated as part of the Wells G&H OU-3 risk assessment (EPA, 2003a). The cumulative risks for the media evaluated are presented in Tables 3-9.3 and 3-9.10 for current and future land use, respectively. The RME and CT HIs are below the target HI of 1.

Adult Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater.

The estimated HIs for the future adult recreational user exposed to media including surface soil and subsurface soil at the Aberjona property are provided in Table 3-7.11. For this scenario, HIs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT HIs are below the target HI of 1.

Young Child Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater.

The estimated HIs for the future young child recreational user exposed to media including surface soil and subsurface soil at the Aberjona property are provided in Table 3-7.12. For this

scenario, HIs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The cumulative risks for the media evaluated are presented in Table 3-9.11, for surface soil. Table 3-9.12 presents the cumulative risks including subsurface soil. The RME and CT HIs are below the target HI of 1.

Construction Worker Receptor. The future construction worker was evaluated for exposures to surface soil and subsurface soil. Direct contact surface soil risk was evaluated in combination with the inhalation of outdoor air attributable to contaminants in surface soil. Subsurface soil risk was evaluated in combination with inhalation of outdoor air attributable to contaminated subsurface soil and groundwater, as well as incidental ingestion of and dermal contact with shallow groundwater.

The estimated HIs for the future construction worker exposed to surface soil and other media at the Aberjona property are provided in Table 3-7.13. For this scenario, HIs are calculated assuming incidental ingestion of and dermal contact with surface soil, inhalation of particulates from surface soil, and the inhalation of outdoor air attributable to contaminants in surface soil. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.13. The cumulative HIs are below the target HI of 1.

The estimated HIs for the future construction worker exposed to subsurface soil and other media at the Aberjona property are provided in Table 3-7.13. For this scenario, HIs are calculated assuming incidental ingestion of and dermal contact with subsurface soil; inhalation of particulates from subsurface soil; incidental ingestion of and dermal contact with shallow groundwater; and the inhalation of outdoor air attributable to contaminants in soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.14. The cumulative HIs are below the target HI of 1.

Whitney Property

Adult Commercial Receptor. The estimated HIs for the adult commercial receptor at the Whitney property are provided in Tables 3-7.1 and 3-7.2 for current and future land use, respectively. Current HIs are calculated assuming incidental ingestion of and dermal contact with surface soil. Future HIs are calculated assuming incidental ingestion of and dermal contact with surface soil and the inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Tables 3-9.4 and 3-9.15 for current and future land use, respectively. For the current scenario, the RME HI of 2 exceeds the target HI due to direct contact with surface soil. Major contributors to the surface soil risk include PCB Aroclors. For the future scenario, the RME and CT HI also exceeds 1 due to direct contact with surface soil and the inhalation of indoor air attributable to groundwater contaminants. Major contributors to the surface soil risk include PCB Aroclors. The indoor air risk is attributable to the C5-C8 Aliphatic and C9-C18 Aliphatic fractions in groundwater.

Older Child Trespasser. The estimated HIs for the older child trespasser at the Whitney property are provided in Tables 3-7.3 and 3-7.4 for current and future land use, respectively. The current and future HIs are calculated assuming incidental ingestion of and dermal contact with surface soil. The cumulative risks for the media evaluated are presented in Tables 3-9.5 and 3-9.16 for current and future land use, respectively. The estimated RME HI for the current older child trespasser at Whitney is below the target HI of 1. The future RME HI equals the target HI. The current and future CT HIs are both below the target HI.

Adult Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater.

The estimated HIs for the future adult recreational user exposed to media including surface soil at the Whitney property are provided in Table 3-7.11. HIs are calculated assuming incidental ingestion of and dermal contact with surface soil, and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT HIs are below the target HI.

The estimated HIs for the future adult recreational user exposed to media including subsurface soil at the Whitney property are provided in Table 3-7.11. HIs are calculated assuming incidental ingestion of and dermal contact with subsurface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT HIs of 20 and 6, respectively, exceed the target HI of 1 due to direct contact with subsurface soil. Major contributors to the RME and CT risk include PCB Aroclors.

Young Child Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater.

The estimated HIs for the future young child recreational user exposed to media including surface soil at the Whitney property are provided in Table 3-7.12. HIs are calculated assuming incidental ingestion of and dermal contact with surface soil, and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in 3-9.17. The RME HI of 7 exceeds the target HI of 1, due to direct contact with surface soil. Major contributors to surface soil risk include PCB Aroclors. The CT HI is below the target HI.

The estimated HIs for the future young child recreational user exposed to media including subsurface soil at the Whitney property are provided in Table 3-7.12. HIs are calculated assuming incidental ingestion of and dermal contact with subsurface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in 3-9.18. The RME and CT HIs of 200 and 40, respectively,

exceed the target HI of 1 due to direct contact with subsurface soil. Major contributors to the RME risk include alpha-chlordane, and PCB Aroclors. Major contributors to the CT risk include PCB Aroclors.

Construction Worker Receptor. The future construction worker was evaluated for exposures to surface soil and subsurface soil. Direct contact surface soil risk was evaluated in combination with the inhalation of outdoor air attributable to contaminants in surface soil. Subsurface soil risk was evaluated in combination with inhalation of outdoor air attributable to contaminated subsurface soil and groundwater, as well as incidental ingestion of and dermal contact with shallow groundwater.

The estimated HIs for the future construction worker exposed to media including surface soil at the Whitney property are provided in Table 3-7.13. The HIs are calculated assuming incidental ingestion of and dermal contact with surface soil; inhalation of particulates associated with surface soil; and inhalation of outdoor air attributable to contaminants in surface soil. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.19. The RME HI of 4 exceeds the target HI of 1 due to direct contact with surface soil. Major contributors to the surface soil risk include PCB Aroclors. The CT HI is below the target HI.

The estimated HIs for the future construction worker exposed to media including subsurface soil are provided in Table 3-7.13. The HIs are calculated assuming incidental ingestion of and dermal contact with subsurface soil; inhalation of particulates associated with subsurface soil; incidental ingestion of and dermal contact with shallow groundwater; and inhalation of outdoor air attributable to contaminants in subsurface soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.20. The RME and CT HIs of 100 and 30, respectively, exceed the target HI of 1, due to direct contact with subsurface soil. Major contributors to the RME and CT risk include PCB Aroclors.

Murphy Property

Adult Commercial Receptor. The estimated HIs for the adult commercial worker are provided in Tables 3-7.1 and 3-7.2, for current and future land use, respectively. The current HIs are calculated assuming incidental ingestion of and dermal contact with surface soil. The future HIs are calculated assuming incidental ingestion of and dermal contact with surface soil, and the inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Tables 3-9.6 and 3-9.21 for current and future land use, respectively. The current RME and CT HIs are below the target HI of 1. The future RME and CT HIs are equal to 2 and 1, respectively, but cumulative risks to individual target organs are below the target HI.

Older Child Trespasser. The estimated HIs for the future older child trespasser are provided in Table 3-7.4. The future HIs are calculated assuming incidental ingestion of and dermal contact with surface soil. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.22. The estimated RME and CT HIs are below the target HI of 1.

Adult Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater.

The estimated HIs for the future adult recreational user exposed to media including surface soil at the Murphy property are provided in Table 3-7.11. The HIs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT HIs are below the target HI of 1.

The estimated HIs for the future adult recreational user exposed to media including subsurface soil are provided in Table 3-7.11. HIs are calculated assuming incidental ingestion of and

dermal contact with subsurface soil, and the inhalation of indoor air attributable to contaminated soil and groundwater. The RME and CT HIs are below the target HI of 1.

Young Child Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater.

The estimated HIs for the future young child recreational user exposed to media including surface soil at the Murphy property are provided in Table 3-7.12. The HIs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.24. The RME and CT HIs are below the target HI of 1.

The estimated HIs for the future young child recreational user exposed to media including subsurface soil are provided in Table 3-7.11. HIs are calculated assuming incidental ingestion of and dermal contact with subsurface soil, and the inhalation of indoor air attributable to contaminated soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.26. The RME and CT HIs are below the target HI of 1.

Construction Worker Receptor. The future construction worker was evaluated for exposures to surface soil and subsurface soil. Direct contact surface soil risk was evaluated in combination with the inhalation of outdoor air attributable to contaminants in surface soil. Subsurface soil risk was evaluated in combination with inhalation of outdoor air attributable to contaminated subsurface soil and groundwater, as well as incidental ingestion of and dermal contact with shallow groundwater.

The estimated HIs for the future construction worker exposed to media including surface soil are provided in Table 3-7.13. HIs are calculated assuming incidental ingestion of and dermal contact

with surface soil, inhalation of particulates associated with surface soil; and the inhalation of outdoor air attributable to contaminants in surface soil. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.27. The RME and CT HIs are below the target HI of 1.

The estimated HIs for the future construction worker exposed to media including subsurface soil are provided in Table 3-7.13. HIs are calculated assuming incidental ingestion of and dermal contact with subsurface soil; inhalation of particulates associated with subsurface soil; incidental ingestion of and dermal contact with shallow groundwater; and inhalation of outdoor air attributable to contaminants in subsurface soil and groundwater. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.28. The RME and CT HIs are below the target HI of 1.

Murphy Wetland

The Murphy wetland is evaluated as a separate exposure point for the current and future trespasser and for the future recreational user. Typically, risks associated with surface water and sediment would be evaluated in combination with other Site media. However, due to the location of the Murphy wetland (i.e., located between the Whitney and Murphy properties), the wetland area is being evaluated as a separate exposure point. Nonetheless, the calculated risk due to surface soil at either of the neighboring properties (Whitney or Murphy) is significantly less than the risk estimated for sediment.

Older Child Trespasser. The estimated HIs for the older child trespasser are provided in Tables 3-7.3 and 3-7.4 for current and future land use, respectively. HIs are calculated assuming dermal contact with surface water and incidental ingestion of and dermal contact with sediment. The RME and CT cumulative risks for the media evaluated are presented in Tables 3-9.7 and 3-9.23 for current and future land use, respectively. The current RME HI does not exceed the target HI when risks were summed only for COPCs with similar target organs. The future RME HI of 3 exceeds the target HI of 1 due to exposure to sediment. Major contributors to future HI include PCB Aroclors. The current and future CT HIs equal the target HI.

Adult Recreational User. The estimated HIs for the future adult recreational user are provided in Table 3-7.11. The HIs are calculated assuming dermal contact with surface water and incidental ingestion of and dermal contact with sediment. The cumulative RME HI of 2 exceeds the target HI of 1 due direct contact with sediment. Major contributors to the HI include PCB Aroclors. The CT HI is below the target HI.

Young Child Recreational User. The estimated HIs for the future young child recreational user are provided in Table 3-7.12. The HIs are calculated assuming dermal contact with surface water and incidental ingestion of and dermal contact with sediment. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.25. The cumulative RME and CT HIs of 20 and 4, respectively, exceed the target HI of 1 due direct contact with sediment. Major contributors to the HIs include PCB Aroclors.

Off-Site Resident

Adult Receptor. The estimated HIs for the future off-Site adult resident are provided in Table 3-7.9. For this scenario, HIs are calculated assuming ingestion of groundwater, dermal contact with groundwater while showering, and inhalation of volatiles while showering. The RME HI of 60 is above the target HI of 1 due to all routes of exposure. The CT HI of 3 is above the target HI due to ingestion of groundwater. The largest contributors to the RME HI in excess of 1 are cis-1,2-dichloroethene, trichloroethene, vinyl chloride, C11-C22 Aromatic fraction, arsenic, and manganese. The largest contributor to the CT HI in excess of 1 is trichloroethene.

Young Child Receptor. The estimated HIs for the future off-Site young child resident are provided in Table 3-7.10. For this scenario, HIs are calculated assuming ingestion of groundwater, dermal contact with groundwater while showering, and inhalation of volatiles while showering. The RME and CT cumulative risks for the media evaluated are presented in Table 3-9.29. The RME HI of 200 is above the target HI of 1 due to all routes of exposure. The CT HI of 8 is above the target HI due to ingestion of groundwater. The largest contributors to the RME HI in excess of 1 are 1,3-dichlorobenzene, benzene, cis-1,2-dichloroethene,

trichloroethene, vinyl chloride, C9-C18 Aliphatic fraction, C11-C22 Aromatic fraction, arsenic, and manganese. The largest contributor to the CT HI in excess of 1 is trichloroethene.

3.5.2.2 Description of ILCR Estimates

Estimates of ILCR represent the incremental risk of cancer from the Site, as described in subsection 3.5.1. Tables 3-7.1 through 3-7.13 present the cancer risks by receptor and medium. ILCRs were summed for the young child and adult receptors to derive a total receptor risk for the recreational and residential receptors. The total receptor cancer risks, summed for the adult and child receptors where appropriate, are presented on Tables 3-9.1 through 3-9.29. Note also that because the Scientific Advisory board is currently re-evaluating the carcinogenic potency of 2,3,7,8-TCDD, the draft dioxin slope factor has also been used in risk estimations for PCB dioxin-like congeners. Also, since there is currently no consensus on appropriate SF or UR toxicity values to evaluate trichloroethene's non-threshold effects, trichloroethene cancer risk has been evaluated using the NCEA high-end oral slope factor, and three additional trichloroethene non-threshold toxicity values (NCEA low-end oral slope factor, California EPA oral slope factor, and the withdrawn HEAST oral slope factor). These oral slope factors serve as the basis for the UR values. Therefore, four UR values have also been used for risk estimation. The results of the draft dioxin slope factor and the three additional trichloroethene toxicity values are provided at the bottom of Tables 3-9.1 through 3-9.29, as appropriate.

Aberjona Property

Adult Commercial Receptor. The estimated RME and CT ILCRs for the adult commercial worker at the Aberjona property are presented in Tables 3-7.1 and 3-7.2 for current and future land use, respectively. The current ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil and the inhalation of indoor air attributable to contaminants in groundwater. Future ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ILCRs are presented in Tables 3-9.1 and 3-9.8 for current and future land use, respectively. The total receptor RME ILCRs for the current and

future adult commercial worker are estimated to be within the target risk range of 10^{-6} to 10^{-4}. The total receptor CT ILCRs for the current and future adult commercial worker are both estimated to be below 10^{-6}.

Older Child Trespasser. The estimated ILCRs for the older child trespasser at the Aberjona property are provided in Tables 3-7.3 and 3-7.4 for current and future land use, respectively. Current and future ICLRs are calculated assuming incidental ingestion of and dermal contact with surface soil. The current trespasser was evaluated for exposures on the triangular portion of the Aberjona property only due to current access limitations. The future trespasser was evaluated for exposures on the entire Aberjona property assuming unlimited access to the property in the future. The total receptor ICLRs are presented in Tables 3-9.2 and 3-9.9 for current and future land use, respectively. The total receptor RME and CT ILCRs for the current and future older child trespasser are below 10^{-6}.

Young Child/Adult Resident Receptor. The estimated ILCRs for the current and future adult and young child resident at Aberjona are provided in Tables 3-7.5 through 3-7.8, respectively. ILCRs are calculated assuming inhalation of indoor air attributable to contaminants in groundwater. The child and adult ILCRs have been summed to present the total receptor cancer risk. The total receptor RME and CT ICLRs are presented in Tables 3-9.3 and 3-9.10 for current and future land use, respectively. The total receptor RME and CT ILCRs for the current and future young child and adult resident are estimated to be within the target risk range of 10^{-6} to 10^{-4}.

Young Child/Adult Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater. Also, estimated adult and young child ILCRs are summed to present total receptor cancer risk.

The estimated ILCRs for the future adult and young child recreational user exposed to media including surface soil are provided in Tables 3-7.11 and 3-7.12, respectively. ILCRs are

calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ICLRs for the media evaluated are presented in Table 3-9.11. The total receptor RME and CT ILCRs for the future young child and adult recreational user for surface exposure is within the target risk range of 10^{-6} to 10^{-4}.

The estimated ILCRs for the future adult and young child recreational user exposed to subsurface soil are provided in Table 3-7.11 and 3-7.12. ILCRs are calculated assuming incidental ingestion of and dermal contact with subsurface soil, and the inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ICLRs for the media evaluated are presented in Table 3-9.12. The total receptor RME and CT ILCRs for the future young child and adult recreational user for subsurface exposure is within the target risk range of 10^{-6} to 10^{-4}.

Construction Worker Receptor. The future construction worker was evaluated for exposures to surface soil and subsurface soil. Direct contact surface soil risk was evaluated in combination with the inhalation of outdoor air attributable to contaminants in surface soil. Subsurface soil risk was evaluated in combination with inhalation of outdoor air attributable to contaminated subsurface soil and groundwater, as well as incidental ingestion of and dermal contact with shallow groundwater.

The estimated ILCRs for the future construction worker exposed to surface soil and other media are provided in Table 3-7.13. ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil, inhalation of particulates from surface soil, and inhalation of outdoor air attributable to contaminants in surface soil. The total receptor RME and CT ILCRs are presented in Table 3-9.13. The total receptor RME and CT ILCRs for the future construction worker exposed to surface conditions are below 10^{-6}.

The estimated ILCRs for the future construction worker exposed to subsurface soil and other media are provided in Table 3-7.13. ILCRs are calculated assuming incidental ingestion of and dermal contact with subsurface soil; inhalation of particulates associated with subsurface soil;

inhalation of outdoor air attributable to contaminants in subsurface soil and groundwater; and incidental ingestion of and dermal contact with shallow groundwater. The total receptor RME and CT ILCRs are presented in Table 3-9.14. The total receptor RME and CT ILCRs for the future construction worker are within, and below, the target risk range of 10^{-6} to 10^{-4}, respectively.

Whitney Property

Adult Commercial Receptor. The estimated ILCRs for the adult commercial worker are provided in Tables 3-7.1 and 3-7.2 for current and future land use, respectively. Current ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil. Future ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ILCRs are presented in Tables 3-9.4 and 3-9.15 for current and future land use, respectively. The RME ILCR for current land future and use is 10^{-4}. The current and future CT ILCRs are within the target risk range of 10^{-6} to 10^{-4}.

Older Child Trespasser. The estimated ILCRs for the older child trespasser are provided in Tables 3-7.3 and 3-7.4 for current and future land use, respectively. Current and future ICLRs are calculated assuming incidental ingestion of and dermal contact with surface soil. The total receptor RME and CT ILCRs are presented in Tables 3-9.5 and 3-9.16, respectively. The total receptor RME and CT ILCRs for the current and future receptor are within or below the target risk range of 10^{-6} to10^{-4}.

Young Child/Adult Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater. Also, estimated adult and young child ILCRs are summed to present total receptor cancer risk.

The estimated ILCRs for the future adult and young child recreational user exposed to surface soil and other media are provided in Tables 3-7.11 and 3-7.12, respectively. ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ILCRs are presented in Table 3-9.17. The total receptor RME and CT ILCRs for the future child and adult recreational user exposed to surface conditions are within the target risk range of 10^{-6} to 10^{-4}.

The estimated ILCRs for the future adult and young child recreational user exposed to subsurface soil and other media are provided in Tables 3-7.11 and 3-7.12, respectively. ILCRs are calculated assuming incidental ingestion of and dermal contact with subsurface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ILCRs are presented in Table 3-9.18. The total receptor RME ILCR of 1×10^{-3} for the future child and adult recreational user exposed to subsurface conditions exceeds 10^{-4} due to direct contact with subsurface soil. Compounds that contribute significantly to the RME ILCR in excess of 10^{-4} include: benzo(a)pyrene, arsenic, alpha-chlordane, gamma-chlordane, 4,4'-DDE, 4,4'-DDT, PCB Aroclors, and PCB congeners. The CT ICLR is within the target risk range.

Construction Worker Receptor. The future construction worker was evaluated for exposures to surface soil and subsurface soil. Direct contact surface soil risk was evaluated in combination with the inhalation of outdoor air attributable to contaminants in surface soil. Subsurface soil risk was evaluated in combination with inhalation of outdoor air attributable to contaminated subsurface soil and groundwater, as well as incidental ingestion of and dermal contact with shallow groundwater.

The estimated ILCRs for the future construction worker exposed to surface soil and other media are provided in Table 3-7.13. ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil; inhalation of particulates associated with surface soil; and inhalation of outdoor air attributable to contaminants in surface soil. The total receptor RME and CT ILCRs

are presented in Table 3-9.19. The total receptor RME and CT ILCRs for the future construction worker exposed to surface conditions are within or below the target risk range of 10^{-6} to 10^{-4}.

The estimated ILCRs for the future construction worker exposed to subsurface soil and other media are provided in Table 3-7.13. ILCRs are calculated assuming incidental ingestion of and dermal contact with subsurface soil; inhalation of particulates associated with subsurface soil; incidental ingestion of and dermal contact with shallow groundwater; and inhalation of outdoor air attributable to contaminants in subsurface soil and groundwater. The total receptor RME and CT ILCRs are presented in Table 3-9.20. The total receptor RME and CT ILCRs for the future construction worker exposed to subsurface conditions are within target risk range of 10^{-6} to 10^{-4}.

Murphy Property

Adult Commercial Receptor. The estimated ILCRs for the adult commercial worker are provided in Tables 3-7.1 and 3-7.2 for current and future land use, respectively. Current land use ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil. Future ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ILCRs are presented in Tables 3-9.6 and 3-9.21 for current and future land use, respectively. The total receptor RME and CT ILCRs for current and future adult commercial worker are within the target risk range of 10^{-6} to 10^{-4}.

Older Child Trespasser. The estimated ILCRs for the future older child trespasser are provided in Table 3-7.4. Future ICLRs are calculated assuming incidental ingestion of and dermal contact with surface soil. The total receptor ILCRs are presented in Table 3-9.22. The total receptor RME and CT ILCRs for the future older child trespasser are within or below the target risk range of 10^{-6} to 10^{-4}.

Young Child/Adult Recreational User. The future recreational user was evaluated for exposures to surface soil and subsurface soil. Surface soil exposures assume that the soils are not disturbed in the future. Subsurface soil exposures assume that future site use results in the relocation of

subsurface soil to the surface. This receptor was also evaluated for risks associated with exposure to indoor air attributable to contaminated soil and groundwater. Also, estimated adult and young child ILCRs are summed to present total receptor cancer risk.

The estimated ILCRs for the adult and young child future recreational user exposed to surface soil and other media are provided in Tables 3-7.11 and 3-7.12, respectively. ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor ILCRs are presented in Table 3-9.24. The total receptor RME and CT ILCRs for the future recreational user exposed to surface conditions are within or below the target risk range of 10^{-6} to10^{-4}.

The estimated ILCRs for the future adult and young child recreational user exposed to subsurface soil and other media are provided in Tables 3-7.11 and 3-7.12, respectively. ILCRs are calculated assuming incidental ingestion of and dermal contact with subsurface soil and inhalation of indoor air attributable to contaminants in soil and groundwater. The total receptor RME and CT ILCRs are presented in Table 3-9.26. The total receptor RME and CT ILCRs for the future recreational user exposed to subsurface conditions are within or below the target risk range of 10^{-6} to 10^{-4}.

Construction Worker Receptor. The future construction worker was evaluated for exposures to surface soil and subsurface soil. Direct contact surface soil risk was evaluated in combination with the inhalation of outdoor air attributable to contaminants in surface soil. Subsurface soil risk was evaluated in combination with inhalation of outdoor air attributable to contaminated subsurface soil and groundwater, as well as incidental ingestion of and dermal contact with shallow groundwater.

The estimated ILCRs for the future construction worker exposed to surface soil and other media are provided in Table 3-7.13. ILCRs are calculated assuming incidental ingestion of and dermal contact with surface soil; inhalation of particulates associated with surface soil; and inhalation of outdoor air attributable to contaminants in surface soil. The total receptor RME and CT ILCRs

are presented in Table 3-9.27. The total receptor RME and CT ILCRs for the future construction worker exposed to surface conditions are less than the target risk range.

The estimated ILCRs for the future construction worker exposed to subsurface soil and other media are provided in Table 3-7.13. ILCRs are calculated assuming incidental ingestion of and dermal contact with subsurface soil; inhalation of particulates associated with subsurface soil; incidental ingestion of and dermal contact with shallow groundwater and inhalation of outdoor air attributable to contaminants in subsurface soil and groundwater. The total receptor RME and CT ILCRs are presented in Table 3-9.28. The total receptor RME and CT ILCRs for the future construction worker exposed to subsurface conditions are within the target risk range of 10^{-6} to 10^{-4}.

Murphy Wetland

The Murphy wetland is evaluated as a separate exposure point for the current and future trespasser and for the future recreational user. Typically, risks associated with surface water and sediment would be evaluated in combination with other Site media. However, due to the location of the Murphy wetland (i.e., located between the Whitney and Murphy properties), the wetland area is being evaluated as a separate exposure point. Note that only two COPCs were selected for surface water (chromium and manganese), both of which are not considered to be carcinogenic by the ingestion and dermal routes. Thus, ILCRs were not calculated for surface water.

Older Child Trespasser. The estimated ILCRs for the older child trespasser exposed to sediment in the Murphy wetland are provided in Tables 3-7.3 and 3-7.4 for current and future land use, respectively. ILCRs are calculated assuming incidental ingestion of and dermal contact with sediment. The total receptor RME and CT ILCRs are presented in Tables 3-9.7 and 3-9.23. The total receptor RME and CT ILCRs for the current and future trespasser are within the target risk range of 10^{-6} to 10^{-4}.

Young Child/Adult Recreational User. The estimated ILCRs for the future adult and young child recreational user exposed to sediment in the Murphy wetland are provided in Tables 3-7.11 and 3-7.12, respectively. ILCRs are calculated assuming incidental ingestion of and dermal contact with sediment. The total receptor RME and CT ILCRs are presented in Table 3-9.25. The total receptor RME ILCR of 3×10^{-4} for the future recreational user exceeds the target risk range. Compounds that contribute significantly to the RME ILCR in excess of 10^{-4} include: ethylene dibromide, benzo(a)pyrene, dibenz(a,h)anthracene, arsenic, chromium, PCB congeners and PCB Aroclors. The CT ILCR was within the target risk range of 10^{-6} to 10^{-4}.

Off-Site Resident

The estimated ILCRs for the future adult and young child off-Site resident are provided in Tables 3-7.9 and 3-7.10, respectively. ILCRs are calculated assuming ingestion of groundwater, dermal contact with groundwater while showering, and inhalation of volatiles while showering. The total receptor RME and CT ILCRs are presented in Table 3-9.29. The adult and child ILCRs are summed to present the total receptor cancer risk. The RME and CT ILCRs of 2×10^{-2} and 7×10^{-4}, respectively, for the future off-Site resident are above 10^{-4} due to all pathways of exposure Compounds that contribute significantly to the RME ILCR in excess of 10^{-4} include: benzene, chlorodibromomethane, methyl tert-butyl ether, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, benzo(a)pyrene, dibenz(a,h)anthracene, arsenic, PCB congeners, dieldrin, 4,4'-DDD, and 1,1,2-trichloroethane. Compounds that contribute significantly to the CT ILCR in excess of 10^{-4} include: benzene, trichloroethene, vinyl chloride, benzo(a)pyrene, dibenz(a,h)anthracene, arsenic, PCB congeners, 4,4'-DDD, and 1,1,2-trichloroethane.

3.5.2.3 Risks Associated with Exposure to Lead

Lead was selected as a COPC for soil and sediment. Childhood lead exposures were evaluated through use of the IEUBK model (EPA 2002a). Adult lead exposures were evaluated using the methodology provided by EPA (2003b). The results of the lead evaluation for all three properties are contained in Appendix C.12. For adult exposures, the calculated central estimate of the blood lead concentration in women of childbearing age did not exceed the goal of 4.2

μg/dL for current and future land use. Likewise, assumed childhood lead exposures were not estimated to result in blood lead levels exceeding the goal of 10 μg/dL. Appendix C.12 provides inputs and outputs for both of these models. Since the average concentrations of lead in groundwater was below the Safe Drinking Water Act (SDWA) action level of 15 ug/L, the model default value was used. This results in a more conservative evaluation. Note however, the maximum concentration of lead detected in groundwater (148 ug/L) does exceed the SDWA action level and further evaluation may be required.

Six background surface and subsurface soil samples (AB-5, AB-10, AB- 17, WB-14, MR-19, and MR-18) were collected from locations that were outside of the areas of impact at the three properties. In addition, two background groundwater samples (MW-1 and MW-2) were collected from a location upgradient of the three properties. Soil samples were analyzed for metals only and groundwater samples were analyzed for VOCs, SVOCs, VPH, EPH, PCB congeners, metals (including hexavalent chromium), and cyanide. Background data were compared to applicable screening criteria, and the screening resulted in the selection of arsenic as a COPC for background surface soil, and arsenic and manganese for subsurface soil. No COPCs were selected for the groundwater background since all analytical results were below applicable screening criteria.

Cancer and non-cancer risk calculations for background conditions are provided in Appendix C.2. The results indicate that the calculated risks associated with arsenic in background surface soil, and arsenic and manganese in background subsurface soil, are either greater than, or are on the same order of magnitude of those calculated for site related soil exposures. Thus, background conditions contribute to the calculated site-related risks associated with exposure to arsenic and manganese at the Southwest Properties.

3.5.3 Description of Uncertainties

Estimation of risks to human health that may result from exposure to chemicals in the environment is a complex process that often requires the combined efforts of multiple disciplines. Each assumption, whether regarding the toxicity value to use for a particular

chemical or the value of a parameter in an exposure equation, has a degree of variability and uncertainty associated with it. In each step of the risk assessment process, beginning with the data collection and analysis and continuing through the toxicity assessment, exposure assessment, and risk characterization, conservative assumptions are made that are intended to be protective of human health and to ensure that risks are not underestimated. The following subsections provide a discussion of the key uncertainties that may affect the final estimates of human health risk in this risk assessment. Uncertainties are arranged by topic.

3.5.3.1 Environmental Sampling and Analysis

The process of environmental sampling and analysis results in uncertainties from several sources, including errors inherent in sampling procedures or analytical methods. One area of uncertainty is sampling procedures. Since it is not possible to sample the entire area of interest at a given site, several samples are taken from each medium within each area of a site, and the results are considered to be representative of the chemicals present throughout the area. At the Southwest Properties, however, this uncertainty is likely to be minimal since the primary area of contamination has been well characterized, past operations at the Southwest Properties are reasonably well documented and sampling efforts were intentionally biased to select samples from most highly impacted areas.

In addition, soil concentrations may vary by orders of magnitude over short intervals. The greatest uncertainty in this regard for the samples collected at the Southwest Properties is that surface soil samples, which typically represent the first 0 to 6 inches of soil were sometimes collected from more shallow intervals. This could result in an over- or under estimation of risk. If the deeper interval (6” to 2’) contains higher concentrations, then surface soil risks are overestimated. If the deeper interval is cleaner, then risks are underestimated.

This risk assessment incorporated the results of the site-specific relative bioavailability study performed for the Wells G&H Superfund Site, OU-3 Aberjona River Study. The bioavailability study was done to decrease the uncertainty associated with ingestion of arsenic-containing sediment. The study involved the feeding of arsenic to swine in a sediment matrix. The oral

absorption of arsenic from sediment matrix was quantified and determined to be less than the absorption of arsenic from a water medium. This relative bioavailability estimate was then used in the human health risk assessment to more accurately characterize the risk associated with sediment ingestion at the Site.

Another measure taken to reduce the uncertainty associated with site data was the collection of site-specific chromium speciation (chromium VI) data for soil, sediment and groundwater. This data was used to more accurately characterize risk associated with chromium exposures at the Site.

With respect to determining exposure point concentrations for this evaluation, one assumption was that the concentrations of chemicals in the medium evaluated would remain constant over time. Depending on the properties of the chemical and the medium in which it was detected, this assumption may overestimate risks, depending on the degree of chemical degradation or transport to other media. Conversely, biodegradation of chemicals to more toxic chemicals was also not considered.

3.5.3.2 Analytical Data Quality

Errors (e.g., misidentification of constituents; over-or underestimation of constituent concentrations) can occur during sample analysis. Data were qualified during validation due to various quality control nonconformances. The data validation reports that summarize these nonconformances, and the potential biases on the data, are included in RETEC's Draft RI Report (RETEC, 1994), the Supplemental RI (RETEC, 2003) and TRC's Split Sample Report (TRC, 2004).

The biases which existed in the Southwest Properties data set are summarized below:

2002 Soil/Sediment and Groundwater Data

High Biases:

- Equipment blank contamination.
- Elevated quantitation limits due to method blank, trip blank, or equipment blank contamination.
- High recoveries in calibration verification standards.
- High recoveries in the linear range standard.
- Positive interference in the interference check sample analyses.
- High recoveries in the matrix spike analyses.
- High recoveries in the Laboratory Control Sample (LCS) and/or LFB analyses.
- High recoveries in the Performance Evaluation (PE) sample analyses.
- High surrogate recoveries in sample analyses.
- High recoveries in the Gel Permeation Chromotography (GPC) calibration standard analyses.
- High recoveries in the Contract Required Detection Limit (CRDL) standard analyses.

Low Biases:

- Holding time exceedances.
- Negative bias in the instrument blank analysis.
- Low recoveries in the interference check sample analyses.
- Low recoveries in the matrix spike analyses.
- Low recoveries in the LCS and/or LFB analyses.
- Low surrogate recoveries in sample analyses.
- Low recoveries in the CRDL standard analyses.
- Negative interference in the interference check sample analyses.
- Low recoveries in the post digestion spike analyses.
- Low recoveries in the PE sample analyses.
- Exceedance of DDT breakdown criteria.
- Low recoveries in the GPC calibration standard analyses.

Historical Data (Clean Harbors)

High Biases:

- High recoveries in the LCS analyses.
- Elevated quantitation limits due to method blank, trip blank, or equipment blank contamination.
- High surrogate recoveries in sample analyses.
- High recoveries in the matrix spike analyses.

Low Biases:

- Low surrogate recoveries in sample analyses
- Holding time exceedances.
- Low recoveries in the CRDL standard analyses.

It should be noted that fewer biases exist for the historical data set due to the lower level of validation performed on this data set and the lack of full laboratory deliverables for this data set.

Due to uncertainty of quantification, individual chemicals were sometimes listed as detected, but with the value qualified as estimated by laboratory qualification or validation procedures. The estimated value was used in the risk assessment. In some cases, analytical errors or sampling errors resulted in the rejection of data, which decreased the amount of data available and increased uncertainty associated with the representativeness of the detected chemical concentrations.

In addition, the values reported as non-detected may actually range from non-detect (i.e., not present) up to the value of the SQL. The replacement of non-detects with a value equal to one-half the SQL is intended to be reasonably conservative, but could over- or underestimate the actual constituent concentrations present in the environmental media. Finally, elevated SQLs

were reported for some constituent analytical results, which may mask the presence of that constituent in the affected samples. This may result in an underestimation of risk. Note that elevated SQLs were often associated with analysis conducted in early years. Over time, analytical techniques have been improved and the occurrences of elevated SQLs have decreased.

3.5.3.3 Selection of Chemicals for Evaluation

The maximum detected chemical concentrations and modeled concentrations in surface soil, subsurface soil, groundwater, air, sediment and surface water were compared to one or more of the following screening criteria: EPA Region 9 PRGs, AWQC and MCLs. Chemicals whose maximum concentrations were below their respective cancer screening value or 10-percent of their noncancer screening value were not carried through the assessment. It is unlikely that this risk-based screening excluded chemicals that would be of concern, based on the conservative exposure assumptions and conservatively derived toxicity criteria that are the basis of the screening criteria. Although following this methodology does not provide a quantitative risk estimate for all chemicals, it focuses the assessment on the chemicals accounting for the greatest risks (i.e., chemicals whose maximum concentrations exceeded their respective screening value), and, although the overall risk estimates are uncertain, it is not expected that actual risks will be significantly greater than estimated risks.

3.5.3.4 Toxicological Data

Uncertainty is associated with the toxicity values and toxicity information available to assess potential adverse effects. For the study area, there is a probability of overestimating health risks or hazards for a number of reasons.

One of the major contributors to uncertainty is the accuracy of the toxicity values used. The assumptions used by the EPA in the dose-response extrapolation model for carcinogens were based on a 95-percent UCL of the maximum likelihood estimate. Other assumptions include the following: 1) the extrapolation of data from high-dose exposures in human and animal studies to the low-dose exposure region of the general population is linear and does not have a threshold;

2) there is an interspecies (i.e., animal to man) correlation, based on body surface area; and 3) there is a conditional probability that cancer incidence demonstrated in animal studies will be similar to the incidence in potentially exposed humans. 4) cross-assignment of toxicity values and absorption factors for those compounds without assigned values (e.g., the Unit Risk for Aroclor 1242, 1248, and 1260, is based on Aroclor 1254). To the extent these assumptions are incorrect, the extrapolated risks may be over- or underestimates.

One chemical for which there is some evidence of a nonlinear dose-response is arsenic (Chen *et al*., 1992; Tseng, 1977; Tseng *et al*., 1968). Since arsenic is a primary contributor to potential cancer risks to Site receptors from the ingestion of groundwater, the interpretation of whether there is a non-toxic threshold for arsenic could affect whether arsenic levels in sediment result in risks in excess of risk management criteria. The quantitative estimates of risk presented in this risk assessment assumes no threshold for carcinogenicity from arsenic, which may overestimate risks.

One COPC currently undergoing re-evaluation for carcinogenic potency is 2,3,7,8-TCDD. An interim revised cancer slope factor for 2,3,7,8-TCDD indicates that the cancer risk associated with 2,3,7,8-TCDD exposure may be as much as 6.2 times greater than the risks estimated in this risk assessment. Footnotes on Table 3-9.1 through 3-9.29, as applicable, present revised cancer risk estimates using the revised slope factor.

Trichloroethene is also being re-evaluated for carcinogenic potency by EPA. Estimates of carcinogenic potency for this compound range over two orders of magnitude. The high-end of the range of oral slope factors and unit risk values has been used for carcinogenic risk estimation in Tables 3-9.1 through 3-9.29. Footnotes on these tables also present the cumulative receptor cancer risks using the less conservative oral slope factors and unit risk values.

3.5.3.5 Exposure Assessment

The primary areas of uncertainty affecting exposure parameter estimation involve the assumptions regarding exposure pathways, the estimation of exposure point concentrations, and

the parameters used to estimate chemical doses. The uncertainties associated with these various sources are discussed below.

For dermal exposure pathways, the absence of dermal toxicity criteria necessitated the use of oral toxicity data. To calculate risk estimates for the dermal pathway, absolute oral bioavailability factors that reflect the toxicity study conditions were used to modify the oral toxicity criteria. For the chemicals with oral absorption exceeding 50-percent (i.e., the PAHs), a default oral absorption factor of 100-percent was used. The risk estimates for the dermal pathways may be over- or underestimated depending on how closely these values reflect the difference between the oral and dermal routes.

To better quantify exposure point concentrations, EPA's software program, Pro UCL version 2.1, was used to determine 95-percent UCLs. This software has been extensively reviewed and provides the best available science for the statistical determination of EPCs. The use of this program is believed to result in the more accurate estimation of EPCs than previously used methods.

In the absence of monitoring data for indoor and outdoor air quality, the Johnson and Ettinger Model for subsurface vapor intrusion into buildings, version 3.0 February 2003, and a modified version of the J&E Model for the evaluation of exposure to outdoor air for the construction worker were used to estimate volatilization of COPCs from soil and groundwater. Both versions of the Johnson and Ettinger model used property-specific information such as the minimum observed depth to groundwater and building dimensions. Nonetheless, the assumptions used in the model are conservative and tend to overestimate health risks.

In addition, the Foster and Chrostowski Shower Model (Foster and Chrostowski, 1986 and 1987) was used in order to evaluate the risk associated with the inhalation of volatiles while showering. Use of these models introduces uncertainty into the risk evaluation. However, the assumptions that were used in the model are conservative assumptions that tend to over estimate health risks.

The exposure assumptions selected for this evaluation were based on CT and RME case exposures. RME risks are conservative since estimated risks are based on upper-bound exposure assumptions. The RME individual is assumed to be exposed to the 95-percent UCL concentration of every chemical in a medium each time they visit the area. Note that the maximum concentration of different COPCs often occurs in different locations within the exposure area. Additionally, exposure frequencies assumed for the various scenarios in this analysis may occur less frequently than assumed. Each of these assumptions may result in an overestimate of risk.

The parameter values used to describe the extent, frequency, and duration of exposure are associated with some uncertainty. Actual risks for some individuals within an exposed population may vary from those predicted depending upon their actual intake rates (e.g., sediment ingestion rates) or body weights. The exposure assumptions were selected to produce an upper-bound estimate of exposure in accordance with EPA guidelines regarding evaluation of potential exposures at Superfund sites. Therefore, exposures and estimated potential risks for the majority of the evaluated receptors are likely to be overestimated.

3.5.3.6 Risk Characterization

The uncertainties associated with the risk characterization may be categorized into two groups: 1) those related to the other components of the risk assessment (i.e., the hazard identification, dose response assessment, and exposure assessment) and 2) those inherent in the risk characterization methodologies. The key uncertainty associated with the latter category is the assumption that constituent-specific risks are additive (i.e., act independently (1 + 1 = 2)). This oversimplifies the fact that constituents may also act synergistically (1 + 1 > 2) or antagonistically (1 + 1 < 2). The nature of the impact of the assumption of additivity on the risk estimates for the Site is unknown. However, as a guide, if compounds act synergistically, then assuming additivity would underestimate risk; if they act antagonistically, then it's overestimated.

Cancer risks and HIs for each receptor were not summed across all media. For example, the risks to the recreational and trespasser receptors from surface water and sediment were not summed with those from soil ingestion and dermal contact for the Whitney and Murphy Properties. This may have resulted in an underestimation of cumulative risk for these receptors. However, summing the risks for all pathways in this circumstance will not have a significant impact on the overall calculated risks because the risk associated with exposure to sediments is significantly greater than for exposure to soil. In addition, risks from a given medium were not summed across exposure areas (i.e., properties). That is, for any given receptor, risks were calculated assuming that exposure occurs at only one property. This assumption is uncertain since a given recreational receptor may spend half his/her time in one exposure area and half in another. Risks to such an individual would be intermediate between the risks to individuals exposed solely within each exposure area.

Use of the range of oral slope factors and inhalation unit risks for trichloroethene results in the calculation of a range of cancer risk estimates for soil, sediment and groundwater. The high-end of the range was used to calculate RME and CT risks presented in the main text and tables of the report. Risk estimates using the less conservative carcinogenic toxicity values are presented in footnotes on Tables 3-9.1 through 3-9.29. The cumulative receptor risks presented for soil and sediment, based on the range of oral slope factors and unit risks, do not significantly differ from each other because trichloroethene is not a significant risk contributor for these media. In groundwater, use of carcinogenic toxicity values at the high-end of the range results in the conclusion that trichloroethene is a major risk contributor should groundwater be used as a source of potable water in the future. Use of the less conservative carcinogenic toxicity values would result in the conclusion that trichloroethene is not a major risk contributor for carcinogenic effects. However, because of the noncarcinogenic toxicity of this compound, trichloroethene would still be selected as a major risk contributor for noncarcinogenic effects for groundwater. Therefore, should the carcinogenic potency of trichloroethene be determined to be less than assumed in this report, the overall conclusions of the report would not be altered.

Arsenic was selected as a major contributor to the cancer risk for the Future Recreational User at the Whitney property due to ingestion of, and dermal contact with subsurface soil. The total

RME cancer risk for this scenario was 1E-03. Arsenic's contribution to the total cancer risk is 9E-06. Based on the forgoing background evaluation, potential historical releases of arsenic at the Whitney property cannot be distinguished from background and therefore are not considered to be a major contributor of risk for this property. Manganese was not selected as a major contributor of risk for any of the scenarios evaluated in this risk assessment.

Reference/background surface water and sediment samples were collected as part of the Wells G&H OU-3 risk assessment. The results of background risk calculations are presented in Appendix C.3. Risks were evaluated for the RME and CT exposure to reference (background) wetland samples assuming a one day and 4 day exposure frequency respectively. The cancer and non-cancer risks calculated for the background samples were within the target risk range of 10^{-6} to 10^{-4} for cancer and below the HI of 1 for non-cancer effects.

The ILCR for the Future Adult/Child Recreational user at the Murphy Wetland area exceeded the target risk range for carcinogenic effects due to ingestion of, and dermal contact with, sediment. The calculated risk of each constituent that was selected as a risk driver were compared to the background risks values that were calculated for the Wells G&H OU3 for sediment.

Risks compared were for arsenic and benzo(a)pyrene contamination since these contaminants were identified as risk drivers in the Murphy Wetland and were also assessed in OU-3 wetland sediment background. This comparison is provided below:

Contaminant	Risk Basis	Murphy Wetland Recreational User	OU-2 Wetland 4-Day Recreational User*
Arsenic	ILCR	2E-06	8E-06
Benzo(a)pyrene	ILCR	8E-06	6E-06

* Adjusted from 104 days per year to 78 days per year for equal comparison to the Murphy Wetland Recreational User.

3.5.3.7 Overall Uncertainty

This risk assessment contains many layers of conservative assumptions. For example, in the RME case, the value selected for each parameter in each equation used to calculate risks to the RME individual is a maximum or upper-bound assumption. Therefore, the estimated risk is likely to be greater than the 95-percent UCL of all potential risks. If the risk assessment was able to capture the uncertainty and variability associated with each parameter, it is likely that the actual potential risk to the RME individual would be less than the risks estimated in this assessment.

3.5.4 Summary of Human Health Risks

Overall summaries of cancer and noncancer risks estimates for each of the evaluated scenario and pathway and for each property/area are presented in Tables 3-9.1 through 3-9.29. Risks are summarized for both the RME and CT receptors. When risks were estimated for a child and adult receptor, the child HIs are presented as the most conservative, while incremental lifetime cancer risks (ILCRs) are the sum of the child and adult risks (i.e., a total receptor cancer risk). For all media except surface water and sediment, the risks presented by property/area have been summed together under the assumption that each receptor is exposed to all media during site activities, with the exception of the trespasser, who is only exposed to soil, not air and groundwater. The Murphy wetland was evaluated as a separate exposure point because of its location (i.e., located between both the Whitney and Murphy properties).

When a receptor-specific HI for an exposure medium exceeded 1, HIs were segregated by target organ and discussed as to whether target organ-specific HIs exceed the risk management criterion. Estimated ILCRs were compared to the EPA target risk range of 10^{-6} to 10^{-4}. Risks were not summed across the properties since the parameter values used assume maximal exposures within each exposure area. This approach assumes that an individual would not be maximally exposed to media at more than one property.

The following summarizes the major risk drivers (HI >1, ILCR >10^{-4}) for the evaluated pathways and media for each of the three properties, the Murphy wetland, and the off-Site resident. Other contaminants that contribute to risk at the site below these thresholds are discussed in 3.5.2. This summary focuses on the major risk contributors.

Aberjona. The ILCRs and HIs are all below risk management criteria for all scenarios evaluated.

Whitney. The RME and/or CT ILCR and/or HI exceed the target risk range for the Current and Future Commercial Worker, Future Recreational User, and Future Construction Worker. Major risk drivers contributing to the exceedances for the Commercial Worker include direct contact with PCB Aroclors in surface soil as well as C5-C8 Aliphatic and C9-C18 Aliphatic Hydrocarbons in indoor air attributable to subsurface soil. Major risk drivers contributing to the exceedance for the Recreational User are direct contact with PCB Aroclors in surface soil and PCB Aroclors/PCB congeners in subsurface soil. The major risk drivers for the Construction Worker exceedances are PCB Aroclors in both surface soil and subsurface soil.

Murphy. The ILCRs and HIs are all below risk management criteria for all scenarios and pathways evaluated.

Murphy Wetland. The RME ILCR exceeds the target risk range for the Future Young Child/Adult Recreational User. The RME and CT HIs were above the target HI of 1 for the Future Older Child Trespasser and the Future Young Child/Adult Recreational User. The major risk driver associated with the exceedance for the Future Trespasser is PCB Aroclors in sediment. The major risk drivers contributing to the exceedance for the Future Recreational receptor are PCB Aroclors in sediment for the RME case and PCB Aroclors in sediment for the CT case.

Off-Site Resident. The RME and CT cancer and non-cancer risks exceed risk management criteria for the future off-site resident exposed to groundwater during household use. The major risk drivers associated with RME exceedances are direct contact with 1,3,-dichlorobenzene,

benzene, cis-1,2-dichloroethene, trichloroethene, vinyl chloride, C9-C18 Aliphatic hydrocarbons, C11-C22 Aromatic hydrocarbons, C19-C36 Aliphatic Hydrocarbons, C5-C8 Aliphatic Hydrocarbons, arsenic and manganese. In the CT case, trichloroethene and vinyl chloride were the major risk drivers. The inhalation pathway also had RME exceedances of the cancer and non-cancer target risk ranges with tetrachloroethene, trichloroethene, and vinyl chloride as major risk drivers.

Lead in soil and sediment was evaluated through the use of EPA models for children and adults. The lead evaluation indicated that exposures to lead in current and future scenarios would not result in adult or childhood blood lead levels in excess of blood lead level goals. Therefore, lead in soil and sediment was determined not to be of concern for human receptors at the Southwest Properties. Since the average concentrations of lead in groundwater was below the Safe Drinking Water Act (SDWA) action level of 15 ug/L, the model default value was used. This results in a more conservative evaluation. Note however, the maximum concentration of lead detected in groundwater (148 ug/L) does exceed the SDWA action level and further evaluation may be required. Across the Southwest Properties site, lead was detected in 10 out of 48 wells sampled. Nine out of the ten detections were located in the Murphy Property. Five samples exceed the action level, all of which were obtained for wells installed at the Murphy Property. Only one non-detect sample from a well on the Aberjona Property had an SQL in excess of the action level.

4.0 ECOLOGICAL RISK ASSESSMENT

4.1 Introduction

This ecological risk assessment (ERA) describes existing habitats and ecological receptor species that have been noted or are expected to be present at the Southwest Properties Wells G&H Operable Unit 2 Superfund Site (the "Site") and evaluates the potential risks associated with the exposure of these biota to surface water and sediment contaminants detected during the site characterization. Site reconnaissance was conducted by TRC ecologists and supplements data provided in the RETEC Sampling and Analysis Plan, Supplemental Remedial Investigation. The objective of this risk assessment is to evaluate whether contaminants present within the Southwest Properties Study Area may pose adverse impacts to biota inhabiting the Site. The Site includes the three properties consisting of the Aberjona Auto Parts parcel (Aberjona property), Whitney Barrel parcel (Whitney property), and Murphy Waste Oil parcel (Murphy property). However, the only significant area that provides habitat for ecological receptor is the Murphy Wetland located between the Murphy and Whitney properties.

This ecological risk assessment was conducted in accordance with the following U.S. Environmental Protection Agency (U.S. EPA) guidance:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. EPA/540/R-97-006. June 1997 (U.S. EPA, 1997a).
- Guidelines for Ecological Risk Assessment. EPA/630/R-958/002Fa. May 1998 (U.S. EPA, 1998).

Following the guidelines prepared by the EPA, the basic components of the ecological risk assessment for the site is composed of the following parts:

- Problem Formulation
  - Description of the Ecological Resource (Resource Characterization);
  - Hazard Identification;

- Site Conceptual Model;
- Assessment Endpoints and Measurement Endpoints;

- Analysis
  - Exposure Assessment;
  - Ecological Effects Assessment; and

- Risk Characterization

This ERA provides introductory information in Section 4.1. Section 4.2 describes the ecological resources present at the Site, formulates the risk assessment problem including the presentation of a site conceptual model that includes the proposed assessment endpoints and measurement endpoints. Environmental samples used in the ERA and constituents of potential concern (COPCs) are also selected in this section as is a brief review of the ecotoxicity data for these constituents. Section 4.3 provides the ERA analysis including the evaluation of biota exposed to Site COPCs and an assessment of potential effects of these contaminants to various receptor organisms. Section 4.4 characterizes risk to ecological receptors inhabiting the Site and a summary and conclusions are presented in Section 4.5. References cited in the ERA are provided in Section 5.4.

This ERA was organized and conducted in a manner that is consistent with the Baseline Ecological Risk Assessment (BERA) conducted for the adjacent Wells G&H Superfund Site Operable Unit 3 that consists of the Aberjona River and associated wetlands (M&E, 2003). Applicable assessment endpoints used in the BERA as well as the analyses components (i.e., estimated exposure of biota to COPCs and toxicity effects data) used in the BERA were also incorporated into this ERA, which focuses on the Murphy Wetland.

4.2 Problem Formulation

Problem Formulation is comprised of two primary components: Resource Characterization and Hazard Identification. Resource Characterization describes habitats present at the Site and

identifies potential receptor species. Hazard Identification discusses exposure pathways and identifies contaminants of ecological concern. The results of these components are then used to develop a site conceptual model including the selection of assessment endpoints and measurement endpoints.

4.2.1 Resource Characterization

The 33-acre Site is located adjacent to Salem Street in the City of Woburn, Massachusetts and encompasses three distinct properties consisting of the Aberjona, Whitney and Murphy parcels. Brief descriptions of the ecological resources present within each of these three properties are provided below.

4.2.1.1 Habitat Characterization

The Aberjona property abuts the Aberjona River and associated wetlands to the northeast and northwest while developed areas are present to the southeast and southwest. There are three existing buildings on the property and a small parking area along Salem Street is also present. The remainder of the property is also highly disturbed and currently contains scrapped autos and auto parts.

The soils present within this property consist of fill material while vegetation cover is sparse and consists primarily of non-native plants. Due to the highly disturbed nature of this property, it does not provide significant habitat for ecological receptors. The adjacent wetlands that border on the Aberjona River were previously evaluated in the BERA conducted for the Aberjona River (M&E, 2003).

To the west of the Aberjona property is the Whitney property. Currently, several companies occupy a long rectangular building that still is present on the property while other operations consisting primarily of firewood and landscaping businesses are evident over most of remaining portions of the property. The open areas around the building are heavily cluttered with brick, wood, and metal debris. A small forested/scrub-shrub wetland area and an intermittent stream

are also present within the northern portion of this property while a seasonally ponded area is located immediately adjacent and southwest of the property. The primary wildlife habitat present on the Whitney property consists of the forested/scrub-shrub wetland community. This wetland is referred to as the Murphy Wetland and is discussed in greater detail below.

The Murphy property lies to the east of the B & M Railroad right-of-way and west of the Whitney property. An active waste oil handling and transfer facility and associated parking areas occupy most of the upland portion of the property and a remnant dike wall from a former tank farm occupies the northern portion of the property. A chain-link fence is present around the periphery of the facility. Two buildings outside the fence are used for storage and office space. A wetland (Murphy Wetland) is present within the eastern and northern portions of this property and extends east on to the Whitney property.

With the exception of the Murphy Wetland that is present on both the Murphy and Whitney properties, no other significant habitat exists on the Site. The remaining portions of these parcels and the Aberjona property consist of occupied buildings, scrapped automobiles, wood/metal debris, and pavement/barren dirt areas. These non-significant habitat areas were not evaluated as part of this ERA.

The Murphy Wetland present within the northwestern portion of the Site contains areas of forested/scrub-shrub wetland and a seasonally ponded area. The forested/scrub-shrub wetland areas are present within the southern and the eastern portions of the wetland while the seasonally ponded cover type is present within the western portion of the Murphy Wetland (primarily on the Murphy property). The locations of these cover types are depicted in Figure 4-1. The seasonally ponded cover type extends over an area of approximately 0.8 acres while the forested/scrub-shrub wetland totals approximately 0.9 acres in extent.

Surface water within the seasonally ponded area was observed to range from several inches to several feet in depth in spring although no surface water was noted during the summer. Surface water within the Murphy Wetland is attributable to stormwater runoff from the Site as well as an additional area to the west that discharges to the Murphy Wetland via an existing culvert under

the railroad right-of-way. During period of high water, overflow from the seasonally ponded area is discharged to a small intermittent stream. This stream flows to the east through the forested/scrub-shrub cover type and enters an 18-inch concrete pipe located beneath an existing unpaved road (the access road to the Wildwood Property that is located between the Whitney and Aberjona properties). Flow then continues to the east for approximately 400 feet where it is discharged to the Aberjona River.

Vegetation present within the seasonally ponded wetland cover type consists predominately of herbaceous species with tree and shrub vegetation present along the periphery of the ponded area as well as on some elevated mounded areas. The predominant herbaceous species present include purple loosestrife (*Lythrum salicaria*), common cat-tail (*Typha latifolia*), common reed (*Phragmites australis*), tussock sedge (*Carex stricta*) and duckweed (*Lemma* sp.). Woody vegetation present along the periphery of the seasonally flooded areas include cottonwood (*Populus deltoides*), red maple (*Acer rubrum*) and American elm (*Ulmus americana*) in the tree overstory with glossy-leaved buckthorn (*Rhamnus frangula*) and silky dogwood (*Cornus amomum*) present in the shrub understory.

Plant species noted in the forested/scrub-shrub wetland cover type include a tree overstory comprised primarily of cottonwood and red maple. The average diameter at breast height (dbh) of the overstory trees ranges from 6 to 12 inches. Understory vegetation consists of glossy-leaved buckthorn, silky dogwood, common buckthorn (*Rhamnus cathartica*) in the shrub understory with poison ivy (*Toxicodendron radicans*), purple loosestrife, sensitive fern (*Onoclea sensibilis*) and soft rush (*Juncus effusus*) present within the ground layer.

4.2.1.2 Wildlife Receptor Species Characterization

A variety of wildlife receptors have either been observed at the Site or are expected to inhabit the various wetland cover types identified on the Site. As discussed above, the upland habitats have been extensively disturbed and do not currently provide significant habitat for ecological receptors. A list of potential amphibian, avian, mammalian and reptilian wildlife receptors noted or expected to utilize the identified wetland cover types is presented in Table 4-1. Brief

discussions of wildlife receptors expected to be present within each habitat cover type are provided below.

The cover types identified within the Murphy Wetland consist of a seasonally ponded area (pond/shallow marsh/wet meadow) and forested/scrub-shrub wetland communities. These wetlands may support a variety of aquatic, semi-aquatic, and terrestrial species. These species would include invertebrates, amphibians, reptiles, birds and mammals. However, due to the seasonal nature of the standing water, fish would not normally be expected to inhabit the Murphy Wetland.

Several amphibian and reptilian species may potentially use the aquatic habitats associated with the seasonally ponded area. However, no amphibians or reptiles have been previously observed by TRC within this area. Amphibians that may potentially use the seasonally ponded aquatic habitat as breeding or foraging habitat include the American toad (*Bufo americanus*), green frog (*Rana clamitans*) and northern leopard frog (*Rana pipiens*). Amphibians are generally insectivores consuming insects and other invertebrates although larger species such as the bullfrog (*Rana catesbeiana*) may also feed on small vertebrates. Several species of snakes and turtles are also expected this cover type. Snake species that may be present are generally carnivorous and include the northern water snake (*Nerodia sipedon*) and eastern ribbon snake (*Thamnophis sauritus*), two species that are often associated with aquatic/wetland habitats. Turtle species potentially present include the common snapping turtle (*Chelydra serpentina*) and eastern painted turtle (*Chrysemys picta*) are generally omnivorous species that forage on the water bottom.

The forested/scrub-shrub cover type would provide potential habitat for the more terrestrial amphibian and reptilian species that may only use the seasonally ponded area as a breeding area. These species include anurans such as the American toad and gray treefrog (*Hyla versicolor*) as well as snakes such as the northern brown snake (*Storeria dekayi*) and eastern garter snake (*Thamnophis sirtalis*).

A variety of avian species representing diverse feeding guilds may use the habitats provided by the Murphy Wetland. Aquatic bird species that may forage within the seasonally ponded area include waterfowl such as the mallard (*Anas platyrhynchos*) and wood duck (*Aix sponsa*). Several insectivorous bird species such as the tree swallow (*Tachycineata bicolor*) and eastern phoebe (*Sayornis phoebe*) are likely to hawk insects above the ponded area cover type as emerging insects are particularly abundant above an aquatic environment. Several omnivorous ground gleaners such as the red-winged blackbird (*Agelaius phoeniceus*) and song sparrow (*Melospiza melodia*) are also likely to nest and/or forage within this area after water levels recede in the summer or along its periphery during the spring and summer. Additional songbirds are expected to inhabit the vegetation present along the periphery of the seasonally ponded area. These species would include shrub nesters such as the common yellowthroat (*Geothlypis trichas*) and tree nesters such as the yellow warbler (*Dendroica petechia*), insectivores that may consume terrestrial insects and recently emerged aquatic insects.

Birds noted within or likely to use the forested/scrub-shrub wetland cover type include various tree and shrub nesters/foragers. These species include insectivorous species such as the black-capped chickadee (*Parus atricapillus*), blue-winged warbler (*Vermivora pinus*), and downy woodpecker (*Picoides pubescens*). Other omnivorous species including the American robin (*Turdus migratorius*), gray catbird (*Dumatella carolinensis*) and northern cardinal (*Cardinalis cardinalis*) may also use this habitat for nesting and/or foraging.

Several mammal species representing different foraging guilds are expected to use the seasonally ponded cover type (see Table 4-1). Bats are likely to forage for insects above the ponded area as aquatic habitats are generally very productive sites for invertebrates including a variety of aquatic insects. Emerging insects would provide an important food resource for bats in the vicinity of the site. Species such as the little brown bat (*Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*) are often associated with structures/ buildings located near aquatic habitats. Herbivorous mammals such as the muskrat (*Onodatra zibethicus*) and various small mammals may also forage on vegetation within the seasonally ponded area. The muskrat would primarily use this area during portions of the year when surface water is present while small mammals such as the white-footed mouse (*Peromyscus leucopus*) and meadow vole (*Microtus*

pennsylvanicus) are only likely to be found within this cover type after surface water is absent. Mammalian predators such as the raccoon are expected to forage within or along the periphery of the ponded area. The raccoon is an omnivorous feeder that consumes a wide variety of items including macroinvertebrates and amphibians that may be associated with this habitat. The insectivorous short-tailed shrew (*Blarina brevicauda*) may also forage on insects and other invertebrates within this area during times when surface water levels are absent.

A diversity of small mammals including white-footed mice, short-tailed shrews, and red-backed voles (*Clethrionomys gapperi*) may inhabit the forested/scrub-shrub wetland cover type while larger mammals including the Virginia opossum (*Diadelphis virginiana*) and white-tailed deer (*Odocoileus virginianus*) also forage within this habitat (see Table 4-1).

Based on available information from the Massachusetts Natural Heritage and Endangered Species Program (MANHESP, 1999), no state-listed rare species are known to inhabit the Site or immediate vicinity. Federal-listed threatened or endangered species are also not known to inhabit the vicinity of the site (M&E, 2003).

4.2.2 Hazard Identification

For the characterization of ecological risk, the primary media of concern at the Site are surface water and sediment associated with the Murphy Wetland. Possible exposure pathways for ecological receptors present at the Site include the direct ingestion of contaminated surface water and sediments and the indirect ingestion of contaminated biota in the food chain. Exposure of biota to subsurface soils and airborne contaminants (through volatization or fugitive dust emissions) via inhalation or dermal contact are not expected to represent as significant a pathway as direct ingestion of contaminated media or ingestion of contaminated biota in the food chain. In addition, methods to evaluate exposure of ecological receptors via the inhalation and dermal exposure pathway generally contain considerable uncertainties. Ecological receptors are also not anticipated to be directly exposed to groundwater contaminants although the evaluation of surface water and sediment within the Aberjona River BERA (M&E, 2003) indirectly evaluate contaminants transported through groundwater discharge.

4.2.2.1 Data Management

Analytical data used in the risk assessment include recent surface water and sediment sampling results from the Spring 2003 sampling as well as sediment samples collected from the Site wetland in previous investigations. The following section describes which samples were grouped together for risk analysis. Summary statistics detailing contaminant concentrations (mean, 95 % upper confidence limit of the mean, and maximum) and frequency of detection for each media grouping are presented in Appendix D.1.

Environmental data used for the hazard identification were collected during several sampling events conducted by property owners, potentially responsible parties (PRPs), and split samples collected on behalf of USEPA by TRC. The following discussion identifies the data deemed suitable for use in this ERA.

Background samples for sediment and surface water from wetland reference areas that were used by the Aberjona River BERA (M&E, 2003) as part of Operable Unit 3 (OU-3) were considered to be the most appropriate source of data to assess background conditions for the Murphy Wetland. Reference samples for surface water and sediment were collected as part of investigation activities conducted for OU-3 and were augmented by additional surface water and sediment reference samples collected in support of the Industri-Plex Superfund Site Investigation. Reference samples were collected from areas considered to be unaffected by OU-3 site activities and displaying no visual evidence of contamination. Analytical data for surface water and sediment wetland reference samples are presented in Appendix C.1. Wetland reference data were not used quantitatively in this ERA and do not impact the selection of COPCs (subsection 4.2.2.2).

As discussed previously, environmental data used in this risk assessment were collected during several sampling events. Detailed discussions of sampling approaches and the quality assurance and control activities implemented during the collection of the data, where available, are provided in the source documents. Data obtained as part of the Supplemental RI and associated TRC split data (RETEC 2003; TRC 2004) were validated according to USEPA's Contract

Laboratory Program (CLP) procedures and guidelines, as described in the Supplemental RI and the TRC Split Report, with one exception. Samples analyzed by the MADEP Volatile Petroleum Hydrocarbon (VPH) and Extractable Petroleum Hydrocarbon (EPA) protocols were not validated because USEPA validation protocols do not apply to these procedures. The respective analytical results are discussed in the Supplemental RI and the TRC Split Report.

Data obtained from the Clean Harbors 1998 Corrective Action Investigation Report (Part II) were not validated when published. USEPA determined that within the limited circumstances of this project, validation of a representative subset of the analytical data may provide reasonable confidence in the quality of the data. USEPA required that validation be conducted of a minimum of 25 percent of the total samples analyzed using EPA Tier II protocols, and 5 percent of the samples using EPA Tier III protocols, in accordance with USEPA Region I data validation guidelines.

The analytical data were summarized by environmental medium and grouped into exposure areas. For the ERA, the following media and exposure areas were selected for quantitative evaluation:

- Surface water at the Murphy Wetland located between the Whitney and Murphy properties;
- Sediment within the seasonally ponded portion of the Murphy Wetland; and,
- Sediment within the forested/scrub-shrub portion of the Murphy Wetland.

The following sections summarize the environmental data available for use in the quantitative risk assessment for each of the exposure areas.

Sediment and surface water samples were collected from the Murphy Wetland located between the Murphy and Whitney properties. Figure 4-1 depicts the location of surface water and sediment samples used in the ERA. Analytical results of compounds detected in surface water and sediment are presented in the Supplemental RI and in the documents referenced in this section. The locations and results of wetland sediment samples collected and analyzed in 1995 and 1997 are presented in Clean Harbors, 1998. Results for samples collected and analyzed in

2002 by RETEC, and split with USEPA, are presented in the Supplemental RI and in TRC's Split Report. For the purposes of this ERA, only surface water results from the 2002 sampling event are used quantitatively for the Murphy Wetland. Surface water samples collected prior to 2002 (i.e., 1994 and 1995) are not considered representative of current on-site conditions and are discussed qualitatively. The surface water samples collected by RETEC in 2002 are provided in Table 4-2.

The depth of sediment generally considered for ecological exposure is 0 to 6 inches. The sediment samples collected by RETEC in 2002 and split with USEPA were from the 0 to 0.5 foot depth interval. The sediment samples collected by Clean Harbors in 1995 and 1997 were collected from the 0 to 2 foot depth interval and were also used in the ERA. Three samples collected from 0 to 3 feet by RETEC in 1993 were not used in this ERA as most ecological exposure is expected to occur in the surficial sediments. The sediment sampling locations include areas that are inundated seasonally (ponded portion of Murphy Wetland) or are only saturated (hydric soils in forested scrub-shrub portion of Murphy Wetland). Sediment samples collected from the Murphy Wetland and used in the ERA are listed in Table 4-3.

Surface water and sediment analytical results for the Murphy Wetland are summarized in Appendix D.1. The summary tables for chemicals detected in surface water and sediment provide the frequency of detection, range of laboratory reporting limits for samples where compounds were not detected, mean concentration, 95% upper confidence limit (UCL) of the mean, range of detected concentrations, and the location of maximum detected results.

4.2.2.2 Data Evaluation

Data were qualified by the analytical laboratory and validated as described previously. The qualification and validation of the analytical data, where performed, included a comparison of the site data to corresponding blank (laboratory, field, equipment, and trip) concentration data. Data rejected by the validation ("R" qualified) were not used. Estimated values (e.g., J qualified) were used in the risk assessment without modification. Analytical data from duplicate samples were combined as described in Section 2.0. Frequency of detection was calculated as the

number of samples in which the chemical was detected over the total number of samples analyzed after the exclusion of rejected ("R" qualified) data. A duplicate sample was not considered a separate sample.

Where constituents were detected multiple times in one sample because the constituent is common to multiple analytical procedures (e.g., naphthalene is found on VPH, SVOC and EPA analyte lists), the maximum detected value was used. Where non-detect, the lowest reporting limit was utilized.

Since certain sediment samples were splits collected during the RETEC 2002 sampling event, more than one set of analytical results were available for some sampling locations. For these sampling locations, the multiple results were treated as unique samples rather than as duplicate samples (i.e., the multiple results were not averaged as duplicates). This is consistent with the approach used in the Wells G&H OU-3 risk assessment where sediment samples collected during multiple rounds of sampling from the same location were treated as separate samples. Therefore, in determining the frequency of detection for split samples, the analytical results from the split samples were considered as separate values.

Analytical reporting limits for some sediment samples were elevated with respect to applicable ecological criteria or benchmarks. In order to reduce uncertainties associated with non-detected concentrations of analytes with high reporting limits, data for analytes with reporting limits that exceeded their applicable criterion or benchmark by a factor of two or greater (i.e., one-half the non-detect value would exceed the applicable benchmark) were not included in this ERA. A summary of the analyses used in the ERA for each sediment sample collected from the Murphy Wetland is provided in Table 4-4. It should be noted that considerably less data are available within the forested/scrub-shrub portion of the Murphy Wetland than in the seasonally ponded area. There are no VOC or SVOC data available and only one inorgainic sample (other than chromium and lead) available for the forested scrub-shrub wetland cover type.

4.2.2.3 COPC Selection

The selection of constituents of potential concern (COPCs) for this ERA is based on a comparison of maximum detected contaminant concentrations from the media-specific Site environmental samples to conservative, media-specific, ecological criteria or benchmarks. Combining all data for a given medium results in a conservative list of COPCs for that medium. Constituents lacking ecological criteria or benchmarks were also retained as COPCs except for essential nutrients (i.e., calcium, magnesium, potassium and sodium).

Surface Water

Three surface water samples were collected from the Murphy Wetland in 1994 and 1995 and analyzed for VOCs, PAHs and several inorganics (Clean Harbors, 1998). Detected analytes included acetone, arsenic, chromium, lead and zinc. A total of three surface water samples were collected within the seasonally ponded area present within the Murphy Wetland in 2002. Each of these samples was analyzed for total and dissolved metals (and total cyanide). The locations of the surface water samples are depicted in Figure 4-1. The maximum concentration detected for each constituent was compared to USEPA (2002a) freshwater chronic Ambient Water Quality Criteria (AWQC), or, if unavailable, Lowest Observed Effect Levels (LOELs) (USEPA, 1996). If no freshwater chronic criterion or LOEL was available for a particular analyte, the Tier II screening values presented in Suter and Tsao (1996) were used. Tier II values were calculated using the Great Lakes Water Quality Initiative Tier II methodology (USEPA, 1993a) and are analogous to the methodology to derive AWQC. Constituents with maximum concentrations that exceed these benchmarks were selected as COPCs.

AWQC for chromium and nickel were normalized for the lowest reported water hardness (46 mg/L) within the filtered surface water samples. Frequency of detection was not utilized as a screening tool for surface water due to the limited number of surface water samples collected. Data from reference locations were also not used as a screening tool to avoid eliminating any potential COPCs based on reference data collected within an urban watershed.

The surface water screening comparison is presented in Table 4-5. Five inorganics (aluminum, barium, cyanide, iron, and manganese) were detected in unfiltered (total recoverable concentration) surface water samples at concentrations above their respective benchmarks and subsequently retained as COPCs. None of the analytes with dissolved benchmarks available were detected above their respective dissolved benchmarks for the filtered (i.e., dissolved) surface water samples collected from the Murphy Wetland.

Sediment

A total of 64 sediment samples were collected within the Murphy Wetland (48 samples within the seasonally ponded area and 16 samples within the forested/scrub-shrub cover type). The locations of the sediment samples are depicted in Figure 4-1. For the purpose of selecting sediment COPCs, all sediment data from the two wetland cover types were combined. In order to maintain consistency with the OU-3 BERA (M&E, 2003), the maximum concentration detected for each constituent was compared to sediment quality benchmarks (Table 4-6). Although the substrate present within the forested/scrub-shrub portion of the Murphy Wetland is more characteristic of a hydric soil than sediment, it should be noted that, other than essential nutrients, only aluminum and silver were not selected as COPCs within this cover type. The concentrations of these constituents were detected at lower concentrations in the forested scrub-shrub wetland than in either the seasonally ponded wetland or the reference wetland. In addition, wildlife benchmarks for these two constituents are unavailable. The sets of benchmarks used in the screening, in the order of selection, included:

- USEPA Office of Solid Waste and Emergency Response Ecotox Thresholds (ETs) - Sediment Quality Criteria (SQCs), Sediment Quality Benchmarks (SQBs), or NOAA- Effects Range Low (ERLs) were used preferentially (USEPA, 1996);
- Ontario Ministry of Environment and Energy (OMEE) Lowest Effect Levels (LELs) (Persaud *et al.*, 1993), were used when a screening value from above was not available;
- Oak Ridge National Laboratory (ORNL) Sediment Secondary Chronic Values (SCVs) (Jones *et al.*, 1997); were used when a screening value from above was not available; and

- National Oceanic and Atmospheric Administration (NOAA) Threshold Effects Level (TEL) (Buchman, 1999) were used when a screening value was not available in any of the above.

SQBs, SCVs, and SQCs, as presented in their respective documents, are based on a sediment organic carbon content of 1%. The organic carbon content of all sediment samples collected within the Murphy Wetland was greater than 1%. However, to maintain a conservative screening process, no screening criterion was adjusted upward to account for an organic carbon content of greater than 1%.

Ecological sediment screening criteria were unavailable for several chemicals. In all cases, chemicals lacking screening criteria were included as COPCs in the ERA. Calcium, magnesium, potassium and sodium were not selected as COPCs because they are essential nutrients and occur naturally at high concentrations.

Over 70 analytes were detected in study area sediments, including a number of VOCs, SVOCs, pesticides/PCBs, and inorganics (Table 4-6). Although detected less frequently than other chemical classes, six VOCs were detected in the sediment samples. Three VOCs were retained as COPCs. Acetone and carbon disulfide were each detected at concentrations above their respective benchmarks while methyl tert-butyl ether (MTBE) was also retained as a COPC because a screening benchmark is unavailable (Table 4-6).

Twenty-four SVOCs were detected in the Murphy Wetland sediments. The detection percentage for many of the PAHs was greater than 80%. Locations of maximum detections varied, but a number of maximum levels were found in samples collected within the seasonally ponded area at sample MR-12. SVOCs detected at levels exceeding screening criteria included 2-methylphenol, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, phenol and pyrene. These compounds were selected as COPCs. No screening criteria were available for acenaphthylene, acetophenone, benzaldehyde, benzo(b)fluoranthene, carbazole or pentachlorophenol. These contaminants were also retained as COPCs.

Five pesticides, two PCB Aroclors and 12 PCB congeners were also detected in the Murphy Wetland sediments. Pesticides and PCB Aroclors with maximum detected levels exceeding screening criteria included 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, *alpha*-chlordane, *gamma*-chlordane, and Aroclors 1254 and 1260. These compounds were selected as COPCs. There were no criteria available for the PCB congeners. These congeners were also retained as COPCs.

A total of 25 inorganics were detected in site-related sediments, with the majority detected in over 80% of the samples. Maximum levels of all analytes except aluminum and manganese exceeded their respective screening criteria. These inorganics as well as essential nutrients (i.e., calcium, magnesium, phosphorous and sodium) were not retained as COPCs. Inorganics selected as COPCs included antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, hexavalent chromium, iron, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc.

4.2.2.4 Ecotoxicity Literature Review

An ecotoxicity literature review has been performed for selected COPCs and is discussed in the following subsections.

Volatile Organic Compounds (VOCs)

VOCs were detected in several sediment samples collected at the Murphy Wetland. VOCs were not analyzed in the three surface water samples. VOCs are often not found within surficial sediment and surface water due to their tendency to volatilize into the air. At high concentrations, VOCs in surface water and sediment may impact aquatic receptors. These volatile compounds, when present at high concentrations, may also present an inhalation hazard to animals that inhabit confined areas (*e.g.*, burrows or lodges). VOCs do not bioaccumulate to any significant degree, and therefore, do not pose a risk to environmental receptors via trophic transfer.

Acetone. The lowest chronic value (LCV) reported for daphnids in freshwater is 1,560 µg/L (Suter and Tsao, 1996). The estimated LCV for fish is approximately 510,000 µg/L. Using the equilibrium partitioning (EqP) approach to develop a sediment quality criterion, Jones *et al*. (1997) calculated a SCV of 8.7 µg/kg for freshwater aquatic organisms, based on 1% sediment organic carbon content. For acetone, which is a polar organic compound, Jones *et al*. (1997) indicates that the EqP approach is likely to result in a conservative estimate of exposure (*i.e*., the acetone SCV may be lower than the level which would be associated with an impact to ecological receptors).

Carbon Disulfide. As estimated by Suter and Tsao (1996), LCVs for daphnids and fish in freshwater are approximately 244 and 9,538 µg/L, respectively. Using the EqP approach to develop a sediment quality criterion, Jones *et al*. (1997) calculated an SCV of 0.85 µg/kg for freshwater aquatic organisms, based on 1% sediment organic carbon content.

Semi-Volatile Organic Compounds (SVOCs)/Polycyclic Aromatic Hydrocarbons (PAHs)

In aquatic environments, PAHs rapidly become adsorbed to organic and inorganic particulate materials and are deposited in sediments (Neff, 1985). Once adsorbed to sediment, PAHs have limited bioavailability to aquatic organisms (Neff, 1985). However, PAHs deposited in sediments can be toxic to benthic invertebrates. In sediment toxicity tests with the tubificid, *Limnodrilus hoffmeisteri*, Lotufo and Fleeger (1996) observed a median lethal phenanthrene level of 298 mg/kg (sediment organic carbon content = 0.7%). In the same study, pyrene levels up to 841 mg/kg were not acutely toxic. Decreases in tubificid reproduction were observed at much lower levels (IC_{25}s [concentration associated with a 25% inhibition in measured endpoint relative to control] of 40.5 mg/kg and 59.1 mg/kg for phenanthrene and pyrene, respectively).

Sediment-associated PAHs can be accumulated by bottom-dwelling invertebrates and fish (Eisler, 1987a). Great Lakes sediments contaminated with elevated levels of PAHs were reported by Eadie *et al.* (1983 *cited in* Eisler, 1987a) to be the source of body burdens in bottom-dwelling invertebrates. Lake *et al.* (1985 *cited in* Eisler, 1987a) found that marine mussels

(*Mytilus edulis*) and annelids (*Nereis virens*), exposed for 28 days to sediments heavily contaminated with PAHs, accumulated up to 1,000 times more than controls.

In aquatic environments, exposure to ultraviolet light can result in photomodification of some PAHs to products with increased polarity, water solubility, and toxicity compared to the parent compound (Duxbury *et al.*, 1997). Ireland *et al.* (1996) showed that the photoinduced toxicity of PAHs to the daphnid, *Ceriodaphnia dubia*, occurred frequently during low-flow conditions and wet weather runoff, and was reduced in turbid conditions. In studies on the marine amphipod, *Rhepoxynius abronius*, ultraviolet radiation exposure enhanced the toxicity of fluoranthene and pyrene in sediments, but did not affect the toxicity of acenaphthene and phenanthrene (Swartz *et al.*, 1997). Pelletier *et al.* (1997) found that the phototoxicity of individual PAHs (anthracene, fluoranthene, pyrene) to marine bivalves *(Mulinia lateralis)* and marine shrimp *(Mysidopsis bahia*) were 12 to >50,000 times that of conventional toxicity.

The capacity to metabolize PAHs varies among organisms. Varanasi *et al.* (1985 *cited in* ATSDR, 1995b) ranked the extent of benzo(a)pyrene metabolism by aquatic organisms as follows: fish > shrimp > amphipod > crustaceans > mussels. The fact that mussels are ranked last may be because mussels show no or limited mixed function oxidase (MFO) activity. MFO is an enzyme system responsible for the initiation of metabolism of various lipophilic organic compounds, including PAHs (Neff, 1985).

The primary effect of PAH exposure in mammalian laboratory species is tumor development (Eisler, 1987a). USEPA has classified benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene, chrysene, and indeno(1,2,3-cd)pyrene as carcinogens (ATSDR, 1995b). Acenaphthylene, anthracene, benzo(g,h,i)perylene, fluoranthene, fluorene, phenanthrene and pyrene are not classified as carcinogens by USEPA (ATSDR, 1995b).

Carbazole. AQUIRE [Aquatic Toxicity Information Retrieval Database] (USEPA, 1998b) presents the following endpoints for aquatic receptors exposed to carbazole: an EC_{50} (concentration at which 50% of the individuals are affected) of 3,350 µg/L for the water flea,

Daphnia magna (Brooke, 1991); and LC_{50}s ranging from 930 to <1,500 µg/L for the fathead minnow, *Pimephales promelas* (Brooke, 1991). Carbazole bioconcentration factors (BCFs) reported in AQUIRE (USEPA, 1998b) for *D. magna* and *Daphnia pulex* are 113.4 (Newsted and Giesy, 1987) and 65 (Southworth, 1979), respectively. Data on the toxicity of carbazole to wildlife are limited. Dermal treatment with benzo(a)carbazole at a dose of 250 mg/kg resulted in significant reductions in maternal body weight gain and food consumption in pregnant Sprague-Dawley rats (Dutson *et al.*, 1997).

Pentachlorophenol. Pentachlorophenol is a man-made organic biocide that is often contaminated with other toxic organic chemicals such as chlorinated phenols, dioxins, and dibenzofurans (Williams, 1982; U.S. Air Force, 1989; ATSDR, 1992a).

Pentachlorophenol is readily absorbed following oral or inhalation exposure and is widely and rapidly distributed throughout the body (Wagner et al., 1991; ATSDR, 1992a; Jorens and Schepens, 1993). Animal data regarding the noncancer effects of chronic oral exposure to pentachlorophenol appear to be limited to studies with rats (U.S. Air Force, 1989; ATSDR, 1992a). In a study by Schwetz et al. (1978), rats given Dowicide EC-7 (90% pentachlorophenol with lower levels of dioxins and dibenzofurans than most technical grade pentachlorophenol preparations) in the diet for 24 months exhibited some signs of hepatotoxicity (elevated serum enzyme levels, histopathological alterations) and a decrease in body weight gain was noted in both male and female rats at a dose level of 30 mg/kg/day.

Pesticides/Polychlorinated Biphenyls (PCBs)

DDD, DDE, and DDT. LC_{50} values between 0.2 and 1,230 µg/L have been reported for aquatic invertebrates exposed to DDT and its breakdown products, DDD and DDE (USEPA, 1980). Other 96-hr LC_{50}s, reported in Mayer and Ellersieck (1986), include 1 µg/L for the freshwater amphipod, *Gammarus lacustris*, and 4 µg/L for the isopod, *Asellus brevicaudus*, as well as 70, 10 and 7 µg/L for mosquito larvae (*Culex fatigans* and *Anopheles albimanus*) and stonefly (*Pteronarcys california*), respectively. The most sensitive freshwater invertebrate reported by

Mayer and Ellersieck (1986) was the water flea, *D. pulex*, with a 48-hr EC_{50} of 0.36 µg/L, based on immobilization.

In water, DDT is absorbed by fish directly through the skin, and is also accumulated by invertebrates, which are prey for many fish species. A range of LC_{50} values from 2 to 21 µg/L are given for freshwater fish in Connell and Miller (1984). LC_{50} values for freshwater fish species are also presented in Mayer and Ellersieck (1986). The most sensitive species reported was largemouth bass (*Micropterus salmoides*), with a 96-hr LC_{50} of 1.5 µg/L. Other LC_{50}s reported by Mayer and Ellersieck (1986) were 4.9, 5.0 and 15 µg/L for bluegill sunfish (*L. macrochirus*), black bullhead (*Ictalurus melas*), and channel catfish (*Ictalurus punctatus*), respectively. Chronic effects have been observed at 0.74 µg/L in chronic life-cycle tests with fathead minnows (*P. promelas*) (USEPA, 1980).

Sediment ERLs for DDT, DDD, DDE and total DDT are 1, 2, 2.2, and 1.58 µg/kg, respectively (Long and Morgan, 1990; Long *et al.,* 1995). Effects Range-Median (ERM) values for these same compounds are 7, 20, 27, and 46.1 µg/kg, respectively (Long and Morgan, 1990; Long *et al.,*1995).

Median lethal dietary concentrations in the range of 651 to 1,160 mg/kg have been reported for northern short-tailed shrews (*Blarina brevicauda*) exposed to DDT for up to 17 days via a corn oil diet (Blus, 1978). In studies reported in Klaassen *et al.* (1996), female rats given single DDT doses of 50 mg/kg showed estrogenic effects. Also reported, an LD_{50} of 113 mg/kg for male rats fed DDT, and an LD_{50} of 880 mg/kg for rats fed DDE. At sufficiently high doses, DDT can induce death in organisms by interfering with central nervous system transmission through the disruption of sodium ion passage (Connell and Miller, 1984).

Acute median lethal dosages for birds include LD_{50}s of >2,240 mg/kg for mallard ducks and 841 mg/kg for Japanese quail (Hudson *et al.,* 1984). Following chronic exposures to DDT dietary concentrations of 100 mg/kg, 50% of exposed adult mallards died in about one year. DDE has been found to cause eggshell thinning in birds consuming a diet containing DDT and its breakdown products. Weimeyer *et al.,* (1970) found 14 to 15% eggshell thinning in American

kestrels (*Falco sparverius*) given a daily DDE dietary concentration of 3 mg/kg for less than 7 months. Stendell *et al.* (1989) fed pine voles (*Microtus pinetorum*) from pesticide-contaminated apple orchards to three captive American kestrels. The pine voles contained 48 mg/kg DDE, 3.5 mg/kg DDD, and 14.1 mg/kg DDT. One of the kestrels, which died at 31 days, contained 147 mg/kg DDE in the carcass (wet weight).

Chlordane (*alpha* and *gamma*). Chlordane was formerly used as a pesticide in the United States. It is very persistent in the environment and bioaccumulates in aquatic and terrestrial organisms (USEPA, 1985). Aquatic LCVs for chlordane include 1.6, 16, and 1.09 µg/L for fish, daphnids, and non-daphnid invertebrates, respectively (Suter and Tsao, 1996). EqP-based sediment LCVs, based on 1% sediment organic carbon content, were calculated at 26,000, 260,000, and 18,000 µg/kg for fish, daphnids, and non-daphnid invertebrates, respectively (Jones *et al.*, 1997).

Polychlorinated Biphenyls. PCBs have been shown to cause reproductive failure, birth defects, skin lesions, tumors, liver disorders, and death in fish and wildlife (Eisler, 1986a). Due to their high lipid solubility, PCBs bioaccumulate and biomagnify within the food chain. At the study area, the maximum detected concentrations of two PCB Aroclors, Aroclor-1254 and Aroclor-1260, were greater than screening criteria.

Eisler (1986a) reports LC_{50} values for freshwater and marine organism exposed to various Aroclors from 0.1 to 10 µg/L, with crustaceans and younger developmental stages being the most sensitive. For Aroclor-1260, the LCV for fish is <1.3 µg/L (Suter and Tsao, 1996). Based on the EqP approach and 1% sediment organic carbon content, the LCV for fish exposed to Aroclor-1260 in sediment is <63,000 µg/L (Jones *et al.*, 1997).

Fish are a major source of PCBs to wildlife (O'Hara and Rice, 1996). Mink, which consume fish, have been found to be very sensitive to PCBs (Fuller and Hobson, 1986 *cited in* O'Hara and Rice, 1996). A LOAEL for reproductive effects of 3.425 mg/kg-day was observed in mink exposed to Aroclor-1016 in the diet for 18 months (Aulerich and Ringer, 1980 *cited in* Sample *et*

al., 1996). As in mammals, PCBs can severely affect the reproduction of avian piscivores (O'Hara and Rice, 1996).

Waterfowl may also be impacted by PCB contamination. In a study by Heath *et al.* (1972 *cited in* Eisler, 1986a), LD_{50}s for mallards fed Aroclor-1248 and Aroclor-1260 were associated with dietary concentrations of 2,798 mg/kg and 1,975 mg/kg, respectively.

Inorganics

Aluminum. The LCV for fish is 3,288 µg/L based on 28-day embryo-larval tests with the fathead minnow, *P. promelas* (USEPA, 1988 *cited in* Suter and Tsao, 1996). Lowest chronic value for daphnids was reported as 1,900 µg/L (McCauley *et al.*, 1986 *cited in* Suter and Tsao, 1996). An aluminum BCF of 268 has been reported for brook trout (*Salvelinus fontinalis*) and BCFs for water fleas (*D. magna*) exposed to aluminum chloride ranged from 320 to 1,020 (Cleveland *et al.*, 1991; Havas, 1985 *cited in* AQUIRE [USEPA, 1998b]).

For mammals and birds, evidence suggests that the direct toxic potential of aluminum is low compared to that of many other inorganics; mammals and birds can effectively limit the absorption of aluminum and effectively excrete any excess (Scheuhammer, 1987). Significant accumulation in tissues of mice required dietary doses in excess of 200 mg/kg-day (Scheuhammer, 1987). Oral LD_{50} values for several animal species range from 380 to 780 mg/kg (USEPA, 1985).

There is some evidence of potential toxicity of aluminum in soil to plants, particularly tree seedlings and crops, at low pH (< 5.0) (Kelly *et al.*, 1990). High concentrations of calcium and magnesium and a high organic carbon content in soils have been documented to decrease aluminum toxicity through buffering and complexation, respectively (Kelly *et al.*, 1990; Andersson, 1988).

Antimony. Antimony (Sb) is a naturally occurring metal that is used in various manufacturing processes. LCVs for antimony exposure to fathead minnow, *P. promelas,* and daphnid, *D. magna*, of 1,600 and 5,400 μg/L, respectively, were reported by Kimball (no date *cited in* Suter

and Tsao, 1996). For freshwater algae (*Selenastrum capricornutum*), inhibition of the synthesis of chlorophyll a was observed during antimony exposure of 610 μg/L (96-hour EC_{50}) (USEPA, 1978 *cited in* Suter and Tsao, 1996). Accumulation of antimony has been demonstrated in marine invertebrates (Amiard, 1973 *cited in* AQUIRE [USEPA, 1998b]).

Antimony can be toxic to mammals. Testing by Schroeder *et al.* (1968 *cited in* Sample *et al.*, 1996) showed a chronic oral dose of 5 mg/L in drinking water caused a reduction in the median life span of female mice.

Arsenic. The toxicity of arsenic depends on its form: trivalent arsenic [As (III)] leads to enzyme inhibition, while pentavalent arsenic [As (V)] probably acts by interfering with formation of ATP (uncoupling of oxidative phosphorylation) (Eisler, 1988a). Arsenic has been found to be carcinogenic, teratogenic, embryotoxic, and fetotoxic in laboratory species (NAS, 1980).

Reported LC_{50}s for freshwater invertebrates vary widely. Several of the values in this range include: a 96-hour As (V) LC_{50} for *D. magna* of 7,400 µg/L (USEPA, 1980 *cited in* Eisler,1988a); a 96-hour As (III) LC_{50} for *D. pulex* of 1,300 µg/L (USEPA, 1980 *cited in* Eisler, 1988a); a 96-hour As (III) LC_{50} for *Pteronarcys californica* of 38,000 µg/L (Johnson and Finley, 1980 *cited in* Eisler, 1988a); and a 96-hour As (III) LC_{50} for *Simocephalus serrulatus* of 810 µg/L (USEPA, 1985 *cited in* Eisler, 1988a).

Eisler (1988a) reports that BCFs for arsenic in aquatic invertebrates and fish are relatively low. BCF values for As (III) in most aquatic invertebrates and fish were not greater than 17. For As (V), the BCFs were not greater than 6, and the maximum BCF for organoarsenicals was 9 (USEPA, 1980; USEPA, 1985 *cited in* Eisler, 1988a).

Sediment ERL and ERM values for arsenic are 8.2 and 70 mg/kg, respectively (Long *et al.*, 1995). The OMEE LEL and Severe Effect Level (SEL) for arsenic are similar, at 6 and 33 mg/kg, respectively (Persaud *et al.*, 1993).

Toxicity to terrestrial receptors may vary greatly depending on the form of arsenic. A single oral dose of 1 to 4 grams of sodium arsenite was lethal to cattle (*Bos* spp.) (NRCC, 1978 *cited in* Eisler, 1988a). A single oral dose of 2.5 to 7.5 mg/kg of arsenic acid was also acutely toxic to domestic goats, *Capra* spp. (NRCC, 1978 *cited in* Eisler, 1988a). A 50 to 150 mg dose of sodium arsenite was lethal to a domestic dog, *Canis familiaris* (NRCC, 1978 *cited in* Eisler, 1988a), and single oral doses of 39.4 and 15.1 mg/kg of arsenic trioxide were associated with 96-hour LD_{50}s in mice, *Mus* sp. and rats, *Rattus* sp., respectively (NAS, 1977 *cited in* Eisler, 1988a).

Toxicity benchmarks for avian species, based on exposure to sodium arsenite, include: an acute oral LD_{50} of 47.6 mg/kg for California quail, *Callipepla californica* (Hudson *et al.,* 1984); an acute oral LD_{50} of 323 mg/kg for mallard, *Anas platyrhynchos* (Hudson *et al.,* 1984); and an acute oral LD_{50} of 389 mg/kg for ring-necked pheasant, *Phasianus colchicus*, (Hudson *et al.*, 1984). A NOAEL of 1.25 mg/kg-day was estimated in chickens after 56 days of exposure (Hermayer *et al.,* 1977 *cited in* NAS, 1980).

Barium. Barium readily forms insoluble carbonate and sulfate salts which have low toxicity, but soluble barium salts may be toxic (USEPA, 1985). The Tier II SCV calculated by Suter and Tsao (1996) is 4.0 µg/L. In seawater, barium concentrations ranging from 0.1 to 0.9 mg/L have been shown to be toxic to mussel embryos (*Mytilus californianus*) (Spangenberg and Cherr, 1996).

BCFs for barium in marine animals, plankton and brown algae are 100, 120 and 260, respectively (ATSDR, 1992b). Although there is some evidence that barium may bioconcentrate in certain terrestrial plants and aquatic freshwater organisms, the extent of plant uptake and the subsequent uptake by aquatic or terrestrial animals is not known (ATSDR, 1992b). Estimated soil-to-plant bioaccumulation factors (BAFs) are 0.015 to 0.15 (Bysshe, 1988).

Guidelines for the pollution classification of Great Lakes harbor sediments classify sediment barium concentrations of <20, 20-60, and >60 mg/kg as non-polluted, moderately polluted, and heavily polluted, respectively (USEPA, 1977 *cited in* Beyer, 1990).

Oral LD_{50}s for barium (as barium carbonate) are reported as 418 and 200 mg/kg for rats and mice, respectively (Sax and Lewis, 1989). Exposure of barium chloride to rats via water consumption over a 16-month period resulted in a NOAEL of 5.1 mg/kg-day for effects on growth and hypertension (Perry *et al.*, 1983 *cited in* Sample *et al.*, 1996).

Beryllium. LCVs for freshwater daphnids and plants are 5.3 and 100,000 μg/L, respectively (Suter and Tsao, 1996). Bluegill sunfish have been shown to bioconcentrate beryllium (Barrows *et al.*, 1980 *cited in* AQUIRE [USEPA, 1998b]). A NOAEL for longevity and weight loss in rats of 0.66 mg/kg-d was observed by Schroeder and Mitchner (1975 *cited in* Sample *et al.*, 1996) in a study where rats were exposed to beryllium sulfate in drinking water over their lifetime.

Cadmium. The literature review of cadmium effects by Eisler (1985) concluded that freshwater organisms were the most sensitive biota. Concentrations of 0.8 to 9.9 µg/L in water were lethal to several species of aquatic insects, crustaceans, and teleosts. Eisler (1985) also reported that cadmium concentrations ranging from 0.7 to 5.0 µg/L were associated with sublethal effects (decreased growth, inhibited reproduction, and population alterations) in these same groups. Cadmium has also been shown to be highly toxic to South African clawed frog (*Xenopus laevis*) embryos (Herkovits *et al.*, 1997). At the most sensitive embryonic stage, a concentration of 1 mg Cd (II)/L arrested development in 100% of exposed individuals.

Mammals and birds are less sensitive to the biocidal properties of cadmium than freshwater biota (Eisler, 2000). Cadmium in mammals can bioaccumulate and interfere with zinc-containing enzymes, resulting in impairment of kidney function, reproduction, and growth (Scheuhammer, 1987).

Chromium. Chromium has not been observed to biomagnify, and concentrations are usually highest at lower trophic levels (Eisler, 1986b). The toxicity of chromium varies widely between organisms and is dependent on form. Adverse effects of chromium to sensitive freshwater species have been documented at 10 µg/L of Cr (VI) and 30 µg/L of Cr (III) (Eisler, 1986b). For wildlife, adverse effects have been reported at 5.1 mg and 10.0 mg of Cr (VI) and Cr (III),

respectively, per kilogram of diet (Eisler, 1986b). These data support the generalization drawn by Eisler that Cr (VI) is more toxic to freshwater species and mammals than Cr (III).

Exposure to Cr (VI) has been demonstrated to reduce growth rates in both freshwater algae and duckweed, and to affect the survival and fecundity of cladocerans (Eisler, 1986b). Some salts of chromium are carcinogenic in rats and Cr (VI) is a teratogen in hamsters (USEPA, 1985).

Cobalt. Cobalt is an essential element that can be accumulated by plants and animals (USEPA, 1985). Mobility in aquatic systems is limited because cobalt adsorbs to clay minerals and hydrous oxides of iron, manganese, and aluminum in the clay fractions of sediments and soils (USEPA, 1985). The LCV for daphnids is 5.1 µg/L (Suter and Tsao, 1996). Estimated soil-to-plant BAFs range from 0.007 to 0.02 (Bysshe, 1988).

Copper. Mean acute toxicity values for freshwater species range from 7.2 µg/L for the daphnid, *D. pulicaria,* to 10,200 µg/L for bluegill sunfish, *L. macrochirus* (USEPA, 1985). Chronic toxicity values for freshwater species range from 3.9 µg/L for brook trout to 60.4 µg/L for northern pike (USEPA, 1985).

Earthworms bioconcentrate copper and can be negatively affected via a decrease in growth, reproduction, or survival (Beyer, 1990). For the soil-dwelling collembolan, *Folsomia fimetaria,* Scotts-Fordsmand *et al.* (1997) reported a soil EC_{10} for reproduction of 38 mg/kg, and a soil EC_{10} between 509 and 845 mg/kg for growth (depending on sex and developmental stage). Bysshe (1988) suggested that concentrations of copper in soils will generally kill plants before they can accumulate tissue concentrations that are toxic to grazing animals. However, experimentation has shown that chronic exposure to dietary copper can impact both sheep and swine (USEPA, 1985). Aulerich *et al.* (1982 *cited in* Sample *et al.,* 1996) determined a NOAEL for reproductive effects in mink of 11.7 mg/kg-day.

Cyanide. Cyanide most commonly occurs as hydrogen cyanide and its salts--sodium and potassium cyanide. Cyanides are both man-made and naturally occurring substances. They are found in several plant species as cyanogenic glycosides and are produced by certain bacteria,

fungi, and algae. In very small amounts, cyanide is a necessary requirement in the human diet. Cyanides are released to the environment from industrial sources and are not known to biomagnify in organisms (Eisler, 1991).

Fish were the most sensitive aquatic organisms to cyanide as adverse effects on swimming and reproduction were reported between 5 and 7.2 ug/L with lethal effects noted between 20 and 76 ug/L (Eisler, 1991). The acute and chronic ambient water quality criteria are 22 and 5.2 ug/L, respectively (USEPA, 2002a).

Cyanides are readily absorbed orally. The central nervous system (CNS) is the primary target organ for cyanide toxicity. Neurotoxicity has been observed in animals following ingestion and inhalation of cyanides. Cardiac and respiratory effects, possibly CNS-mediated, have also been reported. Short-term exposure to high concentrations produces almost immediate collapse, respiratory arrest, and death (Hartung, 1982; EPA, 1985). In animal studies, cyanides have produced fetotoxicity and teratogenic effects.

No adverse effects were observed on reproductive performance or lactation of rats fed 500 mg cyanide/kg diet throughout gestation and lactation. Litter size, weight of pups at birth, and food consumption and growth rate of pups were not significantly different from controls (Tewe and Maner, 1981).

Iron. The NAWQC for iron is 1,000 µg/L. The LCV for fish is 1,300 µg/L (Amelung, 1981 *cited in* Suter and Tsao, 1996). This concentration caused 100% morality in an embryo-larval test with rainbow trout exposed to dissolved iron salts. The LCV for daphnids (158 µg/L) is a threshold for reproductive effects from a 21-day test of iron chloride with *D. magna* (Dave, 1984 *cited in* Suter and Tsao, 1996). Pentreath (1973 *cited in* AQUIRE [USEPA, 1998b]) measured an iron BCF of 9.53 for the mussel, *Mytilus edulis*.

Lead. Lead is toxic to all phyla of aquatic biota (Wong *et al.*, 1978 *cited in* Eisler, 1988b). Based on a review of toxicity testing literature, Eisler (1988b) reported adverse effects to aquatic biota associated with lead concentrations ranging from 1 to 5.1 µg/L.

For domestic and laboratory animals, Eisler (1988b) reported that survival was reduced at acute oral doses of 5 mg/kg (rat), at chronic oral doses of 5 mg/kg-day (dog), and at dietary doses of 1.7 mg/kg-day (horse). Lead affects the kidneys, bone and central nervous system in mammals and can have adverse effects on histopathology, neuropsychology, fetotoxicity, growth and reproduction (Eisler, 2000). In addition, lead may interfere with enzymes involved in cellular oxidative processes, and possibly affect the release of impulses at certain nerve endings (Locke and Thomas, 1996). The primary source of lead poisoning in wild waterfowl, and in large raptors that prey on waterfowl, has been the ingestion of shotgun pellets (Locke and Thomas, 1996).

Adverse effects associated with lead in soil have been documented for terrestrial plants (Bysshe, 1988; Eisler, 1988b). Earthworms may bioaccumulate lead (Beyer, 1990; Roberts and Dorough, 1985), and high concentrations of lead may be toxic to earthworms, affecting both survival and rate of reproduction. Eisler (1988b) generalized that organolead compounds are more toxic than inorganic lead compounds, and that younger organisms are more susceptible than older organisms.

Mercury. Mercury is a mutagen, teratogen, and carcinogen, and causes embryocidal, cytochemical, and histopathological effects. Methylmercury can be bioconcentrated in organisms and biomagnified through food chains (Wolfe *et al.*, 1998; Eisler, 1987b).

Chronic values for inorganic (or total) mercury are <0.23 µg/L for fish (*P. promelas* through the embryo-larval stage) and 0.96 µg/L for daphnids (*D. magna* in flow-through life-cycle tests) (Call *et al.*, 1983; Biesinger *et al.*, 1982, respectively, *cited in* Suter and Tsao, 1996). The transformation of inorganic mercury by anaerobic sediment microorganisms produces methylmercury (Wolfe *et al.*, 1998). Chronic values for methylmercury are reported as 0.52 µg/L for fish (brook trout in three-generation life-cycle test) and <0.04 µg/L for daphnids (McKim *et al.*, 1976; Biesinger *et al.*, 1982, respectively, *cited in* Suter and Tsao, 1996).

As summarized in Sample *et al.* (1996), reproductive NOAELs for animals exposed to mercury in their diet include 1 mg/kg-day for mink exposed to mercuric chloride for 6 months (Aulerich *et al.,* 1974 cited in Sample *et al.*, 1996), 0.45 mg/kg-day for Japanese quail exposed to mercuric chloride for 1 year (Hill and Schaffner, 1976 cited in Sample *et al.*, 1996), 13.2 mg/kg-day for mice exposed to mercuric sulfide for 20 months (Revis *et al.,* 1989 cited in Sample *et al.*, 1996), and 0.032 mg/kg-day for rats exposed to methyl mercury chloride over 3 generations (Verschuuren *et al.,* 1976 cited in Sample *et al.*, 1996).

Nickel. LCVs for daphnids, non-daphnid invertebrates, and aquatic plants are <5, 128.4, and 5 µg/L, respectively (Suter and Tsao, 1996). Nickel is not significantly accumulated by aquatic organisms (USEPA, 1985). Bysshe (1988) estimated a soil-to-plant BAF of 0.06 for nickel.

Rats fed 40 mg/kg-day of nickel sulfate hexahydrate in their food over 3 generations showed no effects on reproduction (Ambrose *et al.,* 1976 *cited in* Sample *et al.,* 1996). The NOAEL for mallards orally exposed to nickel sulfate for 90 days was 77.4 mg/kg-day (Cain and Pafford, 1981 *cited in* Sample *et al.,* 1996).

Selenium. In flow-through toxicity studies, selenium, as selenate, was found to reduce larval fathead minnow biomass at 108.1 μg/L (LOEC) and to impair algal and rotifer population growth rates at similar concentrations (Dobbs *et al.*, 1996). As reported in Suter and Tsao (1996), LCVs for fish, daphnids, and aquatic plants are 88.32, 91.65 and 100 μg/L, respectively.

Regardless of the original source, adverse environmental effects appear to result largely from transfer of selenium from lower to higher trophic levels (Riedel and Sanders, 1996). High bioconcentration and accumulation of selenium from water by numerous species of algae, fish, and invertebrates is well documented at levels of 0.015 to 3.3 μg/kg (Eisler, 1987c). Game fish populations have suffered reproductive failure after bioaccumulation of selenium from concentrations of about 10 μg/L dissolved selenium (Cumbie and Van Horne, 1978 *cited in* Riedel and Sanders, 1996). Mortality, gross malformations, and internal abnormalities of the young of several wetland bird species have been observed where high selenate concentrations exist (up to 350 μg/L) (Ohlendorf *et al.*, 1986; Ohlendorf *et al.,* 1990 *cited in* Riedel and

Sanders, 1996). In mammals, selenium is a essential trace element that shows evidence of toxicity at higher doses (Domingo, 1994).

Based on biological effects data compiled from the literature, sediment selenium concentrations of 2.5 mg/kg would be a threshold based on predicted effects, and concentrations of 4.0 mg/kg would be the observed threshold for fish and wildlife toxicity (Van Derveer and Canton, 1997).

Thallium. Information on the toxicity and biological fate of thallium is limited. LCVs for fish, daphnids, and plants are 57, 130, and 100 μg/L, respectively (Suter and Tsao, 1996). The reproductive subchronic LOAEL for male rats orally exposed to thallium sulfate in drinking water for 60 days was 0.74 mg/kg-day (Formigli *et al.,* 1986 *cited in* Sample *et al.,* 1996). Thallium has been demonstrated to bioconcentrate in duckweed (*Lemna minor*) (Kwan and Smith, 1991; Kwan and Smith, 1988 *cited in* AQUIRE [USEPA, 1998b]).

Vanadium. Information on the toxicity and biological fate of vanadium is limited. Suter and Tsao (1996) report LCVs of 80 µg/L for fish and 1,900 µg/L for daphnids. In a study conducted with mallard ducks, individuals were exposed to vanadyl sulfate in their diet for 12 weeks. The NOAEL for mortality, body weight, and blood chemistry was 11.38 mg/kg-day (White and Dieter, 1978 *cited in* Sample *et al.,* 1996).

Zinc. Adverse effects of zinc exposure have been documented on the growth, reproduction, and survival of freshwater species of aquatic plants, invertebrates, and vertebrates at concentrations between 10 and 25 µg/L (Eisler, 1993). 96-Hour LC_{50} values for freshwater invertebrates range from 32 to 40,930 µg/L and from 66 to 40,900 µg/L for freshwater teleosts (Eisler, 1993). LCVs for fish, daphnids, non-daphnid invertebrates, and aquatic plants are 36.41, 46.73, >5,243, and 30 µg/L, respectively (Suter and Tsao, 1996). BCF values ranged from 107 to 1,130 for insects and from 51 to 432 for freshwater fish (USEPA, 1980 *cited in* Eisler, 1993).

Varying concentrations of zinc may also affect sediment invertebrates. At a mine tailings site, populations of freshwater oligochaetes and leeches were reduced in numbers of individuals and numbers of taxa in areas where the concentration of zinc in sediment was >20 g/kg (Willis, 1985

cited in Eisler, 1993). In contrast, the NOAA ERL value for sediment, which reflects a level at which impacts are possible, is 150 mg/kg (Long *et al.*, 1995).

Reduced survival has been reported for terrestrial plants (sensitive species) and soil invertebrates at soil concentrations of >100 mg/kg and from 470 to 6,400 mg/kg, respectively (Eisler, 1993). Increased dietary zinc has also been shown to have adverse effects on poultry, avian wildlife, livestock and laboratory animals (Eisler, 1993).

4.2.3 Site Conceptual Model

As discussed above in Section 4.2.1, a variety of ecological receptors may be present within the Murphy Wetland present at the Site. Insects and other invertebrates, amphibians, reptiles, birds and mammals representing a diverse assemblage of feeding guilds are important components of the ecological community present within the Murphy Wetland. These species may potentially be exposed to surface water, and sediment present at the site and forms the basis to the development of a site conceptual model.

4.2.3.1 Exposure Pathways

The former activities at the site may have resulted in contamination of the adjacent Murphy Wetland sediments (and surface water as contaminants are released to the overlying water from the sediments). These contaminants may directly affect aquatic organisms including invertebrates and amphibian larvae and/or may be transferred to aquatic vegetation or macroinvertebrates. The plants and invertebrates may subsequently be consumed by ecological receptors inhabiting the wetland potentially resulting in adverse impacts to these populations or to higher trophic levels.

Figure 4-2 presents a site conceptual model for the Site that details potential exposure pathways for ecological receptors inhabiting the Murphy Wetland.

A complete exposure pathway exists if the ecological receptors have contact with the COPC in one or more medium and there is an exposure route (ingestion, dermal contact) to the receptor. Species groups most likely to receive potential exposures to site COPCs are those whose activities frequently bring them into direct contact with sediment and surface water, that directly consume aquatic plants and/or detritus (dead plant material), or that feed upon species possessing one or both of these characteristics. Species were selected as indicators for exposure evaluation to represent various components of the food chain present at the Murphy Wetland.

4.2.3.2 Assessment Endpoints and Measurement Endpoints

Assessment endpoints represent an expression of an ecological attribute that is to be protected (USEPA, 1996). The selection of the assessment endpoints considered the following:

- Existing habitats and species potentially present at the site:
- Contaminants present and their concentrations;
- Modes of toxicity to various receptors by contaminants;
- Ecologically relevant receptors that are potentially sensitive or likely to be highly exposed to life history attributes; and
- Potentially complete exposure pathways.

Table 4-7 presents the assessment endpoints that were selected for important components of the Murphy Wetland communities identified within the Site. The selected assessment endpoints represent both community level endpoints (e.g., benthic macroinvertebrate diversity and productivity) and population level endpoints (e.g., survival, growth and reproduction of particular guilds such as omnivorous birds).

Measurement endpoints are used to evaluate responses of each assessment endpoint exposed to a stressor (USEPA, 1997a). The measurement endpoints proposed for the ERA are also presented in Table 4-7. The selected parameters represent both community and population level measures.

A brief discussion of the proposed measurement endpoints for each assessment endpoint is presented below.

Community-based measurement endpoints were selected for community level assessment endpoints and evaluated via comparison of concentrations in site media to benchmark values (e.g., ambient water quality criteria, sediment quality benchmarks). For population level endpoints that assess receptor guilds present within the Murphy Wetland (as detailed in the site conceptual model), specific indicator species were selected as measurement endpoints.

The selection of indicator species is based on several factors including:

- Potential for contact with COCs;
- Sensitivity to COCs present at the site;
- Natural history information readily available to assess exposure and toxicity;
- Ecological relevance; and
- Social or economic importance.

Based on these considerations, a variety of indicator species were selected as receptor species for the two habitats identified within the Murphy Wetland. Specific indicator species selected include the muskrat *(Ondatra zibethicus),* mallard (*Anas platyrhynchos*) and short-tailed shrew (*Blarina brevicauda*). These three wildlife receptors were also included in the risk assessment conducted for the Aberjona River as Wells G&H OU-3 (M&E, 2003).

Water Column Macroinvertebrate Community Survival and Reproduction

Contaminants detected in surface water samples collected from the seasonally ponded portion within the Murphy Wetland were compared to chronic and acute ambient water quality criteria (USEPA, 2002a). If criteria are unavailable, adverse chronic and acute effect levels reported in the literature (Suter and Tsao, 1996) were used to evaluate the detected constituents. Acute AWQC and effect levels correspond to contaminant concentrations that would cause less than

50% mortality in 5% of exposed populations in a brief exposure. Chronic AWQC and effect levels are based on acute-chronic ratios between acute effects and chronic values that incorporate adverse effects on growth, reproductive success and survival over all or most of the lifecycle of the test organism.

Benthic Macroinvertebarate Community Diversity and Productivity

The evaluation of this assessment endpoint compared COPC concentrations within the sediment to applicable sediment quality criteria and guidelines associated with effects on benthic biota. Applicable criteria/guidelines for this evaluation included Sediment Quality Criteria (SQCs) and Sediment Quality Benchmarks (SQBs) (USEPA, 1996), National Oceanic and Atmospheric Administration (NOAA) Effects Range - Low (ER-Ls) and Effect Range - Median (ER-Ms) (Long et al, 1995 and Long and Morgan, 1990), Ontario Ministry of Environment and Energy (MOE) Lowest Effect Levels (LELs) and Severe Effect Levels (SELs) (Persaud et al., 1993), and Oak Ridge National Laboratory (ORNL) Sediment Secondary Chronic Values (SCVs) (Jones *et al.,* 1997).

Sediment contaminant concentrations below the lower thresholds (i.e., SQCs, SQBs, ER-Ls, and LELs) are unlikely to result in adverse impacts to the benthic community while concentrations above the upper thresholds (i.e., ER-Ms and SELs) are likely to limit the diversity and abundance of benthic biota.

Mammalian Aquatic Herbivore Survival, Reproduction, and Growth

Mammalian herbivores that use the seasonally ponded habitat were assessed by estimating exposure to the muskrat. The muskrat is a common aquatic species that is important to aquatic systems by influencing aquatic vegetation density and diversity. The muskrat has a relatively high ingestion rate. Estimated contaminant exposure doses were compared to chronic survival, reproductive, or growth effect levels associated with both a No Observable Adverse Effect Level (NOAEL) reported in the literature. An exposure dose that exceeds the chronic NOAEL indicates effects are possible.

Avian Aquatic Omnivore Survival, Reproduction, and Growth

Mallards were selected as an indicator species for omnivore waterfowl that may inhabit the aquatic cover types identified within the Study Area. The mallard is important ecologically as it disperses seeds of aquatic vegetation and is an important component in the diet of many predators. Mallards are exposed to contaminants as they forage on both plants and invertebrates within shallow areas of water and sediment. The mallard is also an important game species. Estimated contaminant exposure doses were compared to chronic NOAEL survival, reproductive, or growth effect levels reported in the literature. Exceeding the chronic NOAEL indicates effects are possible.

Mammalian Terrestrial Insectivore Survival, Reproduction, and Growth

The short-tailed shrew is common within a variety of terrestrial habitats. The shrew is generally a fossorial species with a small home range. The diet of the short-tailed shrew is comprised primarily of insects and other invertebrates with small vertebrates and plant matter also consumed. The short-tailed shrew represents a sensitive indicator for an insectivore species as it would be exposed to contaminants that accumulate in invertebrates, has a small home range, and has a high food intake rate relative to its body weight. Estimated contaminant exposure doses received by the shrew within the forested/scrub-shrub habitat and within the seasonally ponded area were compared to chronic NOAEL survival, reproductive, or growth effect levels reported in the literature. An exposure dose that exceeds the chronic NOAEL indicates effects are possible to individuals.

For each of the individual indicator species discussed above, the assessment endpoint references an impact on survival, growth or reproduction of a population. Adverse effects on populations can be inferred from measures associated with impaired survival, growth or reproduction. Some COPC exposures may be associated with sub-lethal effects that do not directly influence mortality or reproductive success. However, these sub-lethal effects may increase the probability of death or negatively influence behavior or reproduction by enhancing susceptibility to predation or parasitism, or weakening competitive ability. For this ERA, it is assumed that

toxicity reference values representing sub-lethal and non-reproductive endpoints may indirectly affect the survival or reproduction of the exposed population, potentially leading to a reduction in study area populations.

4.3 Analysis of Ecological Exposure and Effects

The analysis component of the ERA consists of assessing the exposure of the selected assessment endpoint receptors to the COPCs (Exposure Characterization) and assessing the toxicity of the COPCs to the receptors (Ecological Effects Characterization).

4.3.1 Exposure Characterization

Exposure represents the contact (including ingestion) of a measurement receptor with a COPC through the various exposure pathways identified in Section 4.2.3. Exposure to community measurement receptors (i.e., aquatic water invertebrates, benthic invertebrates) is simply represented by the concentrations of COPCs within the media of concern that the particular community inhabits. Surface water (dissolved and total) and sediment contaminant concentrations (mean and maximum) are provided in Appendix D.1. These concentrations are assumed to represent exposure point concentrations for these community receptors.

Exposure to contaminants via the food chain is evaluated by modeling exposure to the selected indicator species or measurement receptors (muskrat, mallard, and short-tailed shrew). The exposure scenarios developed in the Problem Formulation place receptor species within exposure pathways that are most likely to contribute to contaminant intake.

The muskrat may be exposed to sediment COPCs through direct ingestion and through consumption of vegetation and aquatic invertebrates that have accumulated contaminants through plant or invertebrate uptake. The short-tailed shrew may consume contaminants directly through sediment ingestion or indirectly via the consumption of invertebrates that are in direct contact with contaminated sediment. The mallard would be exposed to Murphy Wetland COPCs through the ingestion of both vegetation and invertebrates that are in direct contact with

contaminated sediment. The purpose of the exposure assessment is to formulate these exposure pathways into algorithms that can predict an estimate of total exposure.

The methods and calculations required for quantification of exposure doses are described within this section. Exposure to contaminants at the site by the selected indicator species is estimated by the following equation:

$$ED = [(S_{conc} \times S_{diet}) + (P_{conc} \times P_{diet}) + (I_{conc} \times I_{diet})] (FIR) (AUF) (TUF) + (W_{conc}) (WIR) (AUF) (TUF)$$

Where:

ED	=	Exposure Dose (mg/kg-body weight-day);
S_{conc}	=	Sediment COPC concentration (mg/kg);
S_{diet}	=	% of diet sediment comprises;
P_{conc}	=	Plant COPC concentration (mg/kg);
P_{diet}	=	% of diet plants comprise;
I_{conc}	=	Invertebrate COPC concentration (mg/kg);
I_{diet}	=	% of diet invertebrates comprise;
FIR	=	Food ingestion rate (kg/kg-body weight-day);
W_{conc}	=	Surface water (total) COPC concentration (mg/L);
WIR	=	Water ingestion rate (L/kg BW-day);
TUF	=	Temporal use factor (% of year at Site); and
AUF	=	Area use factor (% of home range comprised of habitat evaluated).

Dietary information for the muskrat, mallard and short-tailed shrew was obtained directly from the Aberjona River BERA (M&E, 2003). Specifically, food and water ingestion rates, dietary composition (relative percentage of vegetation and invertebrates in the diet as well as sediment ingestion rates) were obtained from the Aberjona River BERA. The model inputs for the muskrat, mallard and short-tailed shrew are presented in Tables 4-8 through 4-10, respectively.

4.3.1.1 COPC Concentrations in Plants

Concentrations of COPCs in vegetation were determined by multiplying the mean and maximum (or 95% UCL, whichever is less) sediment concentrations by the average plant uptake factors calculated within the Aberjona River BERA (M&E, 2003). For the few COPCs where a plant

uptake factor was not provided (i.e., VOCs and PCB congeners), a plant uptake factor for organic COPCs was derived from Travis and Arms (1988). Plant uptake bioaccumulation factors and calculated mean and maximum plant tissue concentrations are presented in Table 4-11.

4.3.1.2 COPC Concentrations in Invertebrates

Site-specific sediment data from the seasonally ponded area and the forested/scrub-shrub cover type were used to estimate COPC body burdens within invertebrate prey. The concentration of COPCs in invertebrates were estimated using different methods for inorganic and organic COPCs. For organic COPCs, an equilibrium partitioning model was used to estimate earthworm body burdens. The basic assumption underlying this equilibrium partitioning model, presented in Sample *et al.* (1997), is that invertebrates are in equilibrium with the aqueous phase of soil.

For inorganic COPCs, regression equations relating contaminant concentrations in soil and earthworm tissue (Sample *et al.*, 1998) were used to estimate burdens of arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, and zinc in earthworms at the study area. Concentration factors for aluminum (0.34), barium (0.36), and iron (0.38) (dry weight to dry weight), based on coupled analyses of soil and biota, were taken from Beyer and Stafford (1993). Uptake factors were not available for antimony, beryllium, cobalt, thallium, and vanadium. An uptake factor of 0.5 (dry weight to dry weight) was assumed to estimate the concentration of these inorganics in worm tissue.

Calculated invertebrate COPC concentrations for both the seasonally ponded and forest/scrub-shrub habitats, based on average or maximum sediment COPC concentrations are presented in Tables 4-12 through 4-15.

4.3.1.3 COPC Exposure Estimation for Avian/Mammalian Receptors

For each of the avian/mammalian receptors, two exposure models were calculated, an average case scenario and a maximum case scenario. The average case scenario was a dietary exposure model based on mean concentrations of each COPC calculated for sediment, surface water, and

plant/invertebrate tissue as appropriate for the receptor. An arithmetic mean of all of the sediment samples collected within the seasonally ponded area and the forested/scrub-shrub cover types was calculated. The arithmetic mean of surface water samples collected from the seasonally ponded area was used to represent mean values for both habitats as surface water sampling data from the forested/scrub-shrub habitat are unavailable. The calculated mean sediment concentrations were used to calculate mean plant and invertebrate tissue concentrations that were subsequently used to determine the total dose from dietary exposure to the muskrat, mallard and shrew.

The maximum, or acute exposure case scenario, was modeled by calculating the 95% upper confidence limit (95% UCL) for all of the sediment samples collected within the seasonally ponded area and the forested/scrub-shrub cover types. The 95% UCL of the average concentration is the value that, when calculated for an infinitely large randomly selected set of subsamples, will equal or exceed the true average 95% of the time. The 95% UCL is frequently used in risk assessment to represent the reasonable maximum exposure (RME) to occur at a site. USEPA requires the use of the 95% UCL on the arithmetic mean concentration for the estimation of the RME risk in human health risk assessment (USEPA 1989; 1992b; and 1994). Therefore, whenever possible, the 95% UCL has been calculated and used for the maximum exposure cases. The 95% UCLs were calculated using EPA=s program ProUCL Statistical Software Version 2.1 (EPA, 2002b). The 95% UCL values could be calculated by this program if four or more samples were available for summarization from a station or sample grouping. When less than four samples were available, the program was unable to calculate a 95% UCL value, and the maximum sample concentration for the COPC was used. Only three surface water samples were collected from the Murphy Wetland, therefore, the maximum surface water COPC concentrations were used for both habitats. Also, if the 95% UCL value was greater than the maximum detected concentration due to skewed distribution of the data, the maximum detected concentration was used. For the forested/scrub-shrub habitat, the 95% UCL value was always greater than the maximum detected concentration due to skewed distribution of the data.

Sediment ingestion rates were calculated by multiplying estimates of sediment ingestion found in the literature (expressed as a percentage of total food intake) by the food consumption rate. In

the case of the muskrat where a species-specific sediment ingestion value was not available in the literature, a value from a species with similar foraging habits was used (i.e., mallard).

It is important to note that an oral bioavailability factor of 1 was assumed for each chemical evaluated in the ingestion pathway. The use of a factor of 1 assumes that 100% of the chemical ingested in the diet is bioavailable, and that bioavailability is similar to that of the bioassay from which the toxicity reference value (TRV) is derived. Use of a factor of 1 also assumes that there is no difference in uptake of a chemical between that of the receptor species and the species from which the TRV was derived. The only exception to this assumption was for the bioavailability of arsenic from incidental sediment ingestion to the mammals (muskrat and shrew).

As seen from the swine study conducted in conjunction with the Aberjona River BERA (M&E, 2003), only approximately 50% of the arsenic in sediment fed to young swine was bioavailable. In the study, data were collected to calculate the relative bioavailability (RBA) of arsenic from site sediments. RBA is an estimate of the oral bioavailability to humans of arsenic from study area sediments compared to that of a reference arsenic compound administered in drinking water. "Best Estimate" RBA values determined in this study ranged from 37% to 51%, indicating that arsenic from sediments is absorbed less extensively than arsenic from drinking water. The most conservative RBA value determined for study area sediments (51%) was selected as the most appropriate to evaluate the oral toxicity of arsenic in sediments at all stations within the study area for mammals (muskrat and shrew). The site-specific RBA value of 51% was used to adjust the incidental sediment ingestion dose for each of the mammal indicator species (i.e., muskrat and short-tailed shrew). The dose from plant material was not adjusted by this RBA, since no RBA for plants was derived.

Muskrat

The home range for a muskrat is relatively small, and consequently, the seasonally ponded area was assumed to provide all of a muskrat's foraging area. The average and maximum case scenarios were calculated for all COPCs for the muskrat. Average and maximum (or 95% UCL) COPC concentrations in sediment were used to estimate incidental sediment ingestion (3.3% of

diet) and to estimate plant and invertebrate tissue concentrations (Tables 4-11 to 4-13). The estimation of invertebrate tissue concentrations of inorganic COPCs are based on reported soil-biota uptake rates associated with earthworms. Dietary exposure for the muskrat assumes a diet comprised of 90% plant tissue and 10% invertebrates (see Table 4-8). Exposure from surface water ingestion was based on the average and maximum COPC concentrations in surface water for the seasonally ponded habitat.

Mallard

The home range of mallards is large, and can range from 40 to 1,440 ha (96 to 3,556 acres) (USEPA, 1993d). The 0.8-acre seasonally ponded area was conservatively assumed to provide 5% of a mallard's foraging area. For the mallard, the average and maximum case scenarios were calculated for all COPCs. Average and maximum (or 95% UCL) COPC concentrations in the seasonally ponded habitat sediment were used to estimate incidental sediment ingestion (3.3% of diet) and to estimate plant and invertebrate tissue concentrations (Tables 4-11 to 4-13).). The estimation of invertebrate tissue concentrations of inorganic COPCs are based on reported soil-biota uptake rates associated with earthworms. Exposure from surface water ingestion was based on the average and maximum COPC concentrations in surface water for the seasonally ponded habitat. Dietary exposure for mallard was based on 33% plant tissue and 67% invertebrates (see Table 4-9).

Short-tailed Shrew

The home range of a short-tailed shrew is small, on the order of less than one acre (EPA, 1993d). The risk evaluation for shrew populations assumed that the forested/scrub-shrub and the seasonally ponded cover types may provide all of a shrew's foraging area. It is assumed that the seasonally ponded area would be accessible to small mammals for foraging during periods of drier weather (temporal use factor estimated at 0.67) while the forested/scrub-shrub habitat is accessible year-round.

Average and maximum (or 95% UCL) COPC concentrations in sediment were used to estimate incidental sediment ingestion and to estimate invertebrate tissue concentrations (Tables 4-12

through 4-15). Dietary exposure for the shrew assumes a diet comprised of 31% invertebrates with sediment ingestion representing 13% of the diet (M&E, 2003). Exposure from surface water ingestion was based on the average and maximum COPC concentrations in surface water for the seasonally ponded habitat.

4.3.2 Ecological Effects Characterization

Potential risk from exposure to COPCs was assessed by the comparison of calculated exposures to appropriate toxicity reference values (TRVs) for each of the receptors. Community-level TRVs are media specific (i.e., concentration in surface water or sediment) while TRVs for receptor species are provided in terms of dose ingested. The selected TRVs for each receptor are identified and discussed below.

4.3.2.1 Water Invertebrate TRVs

TRVs for aquatic invertebrates present within the seasonally ponded habitat of the Murphy Wetland were obtained from the following sources: available acute and chronic ambient water quality criteria (USEPA, 2002a) and secondary values from Great Lakes Water Quality Initiative as reported in Suter and Tsao, 1996. The selected chronic and acute surface water TRVs are presented in Table 4-16 for each COPC.

Water hardness is important in determining ambient water quality criteria (AWQC) for some metals. The lowest water hardness value (46 mg/L) for the seasonally ponded area samples was used in determining the appropriate TRVs for these metals.

4.3.2.2 Benthic Invertebrate TRVs

Criteria, guidelines and benchmarks were obtained from various regulatory agencies for COPCs detected in sediments within the seasonally ponded area of the Murphy Wetland sediment as well as through the equilibrium partitioning (EqP) approach for organic contaminants (Jones *et al.*, 1997). Applicable criteria/guidelines for this evaluation include the screening benchmarks

identified earlier (see Section 4.2.2.3) as well as additional benchmarks associated with greater impacts.

Sediment contaminant concentrations below the lower thresholds (i.e., SQCs, SQBs, ERLs, and LELs) are unlikely to result in adverse impacts to the benthic community while concentrations above the upper thresholds (i.e., ER-Ms and SELs) are likely to severely limit the diversity and abundance of benthic biota. The sediment TRVs selected for the benthic invertebrate community are presented in Table 4-17.

NOAA sediment guidelines (Long et al., 1995) presented in USEPA (1996) are primarily based on marine and estuarine sediment data. These guidelines were developed from a data set of studies that correlated sediment contaminant concentrations with effects to biota (or absence of adverse effects to biota). The ER-L and ER-M represent the 10^{th} percentile concentration and the median concentration, respectively, of the toxic effects data set.

MOE sediment guidelines (Persaud et al., 1993) were developed from a review of available freshwater data regarding contaminant concentrations (observed or predicted) and biological effects on benthic biota. These data were sorted and the Lowest Effect Level (LEL) and Severe Effect Level (SEL) were identified. The LEL represents a concentration that has no effect on the majority of benthic species and is similar to the TEL established by NOAA. The SEL represents a concentration that may adversely affect most sediment-dwelling organisms. The SELs guidelines for organic contaminants are normalized to the sediment organic carbon content (EqP approach) as discussed below.

The EqP approach was also used to calculate sediment quality benchmarks (SQCs, SQBs, SELs and SCVs) for non-ionic organic contaminants (USEPA, 1996; Persaud *et al.,* 1993; and Jones *et al.*, 1997). Calculating a benchmark using the EqP approach requires that the organic carbon content of the sediment be known and that an organic-carbon-water partitioning coefficient and a surface water criteria or effects level for each contaminant be identified. The EqP approach is based on a correlation between contaminant concentrations in sediment, on an organic carbon basis, to their corresponding concentrations in the interstitial pore water of the sediment. The

EqP approach assumes that the partitioning of the contaminant between the sediment and interstitial water are in equilibrium. A total organic carbon content of 0.0439 (4.39%) was used to derive the benchmarks presented in Table 4-17 as this value represents the lowest total organic carbon detected in the sediments of the seasonally ponded area of the Murphy Wetland.

4.3.2.3 Wildlife TRVs

Wildlife toxicity reference values (TRVs) were selected to evaluate potential effects of the estimated exposure doses received by the selected avian and mammalian measurement receptor species (i.e., muskrat, shrew and mallard). For this ERA, the mammalian and avian toxicity values presented in the Aberjona River BERA (M&E, 2003) were generally utilized in this study.

Because toxicity data for the selected receptor species are unavailable, it is necessary to extrapolate toxicity data from other species, usually laboratory test animals. However, the test endpoints for the laboratory species must be significant to the measurement receptor species under field conditions. Endpoints that were considered significant for this risk assessment included adverse effects on growth, reproduction, and survival that are most likely to result in adverse effects to wildlife populations. Other endpoints (e.g., liver damage) were selected if more significant endpoints were unavailable. These other endpoints were primarily used for VOCs and PAHs. TRVs selected for each COPCs for mammals and birds are presented in Tables 4-18 and 4-19, respectively.

The lowest chronic No Observable Adverse Effect Level (NOAEL), if available for avian and mammalian species was selected for assessing the effects of exposure by the measurement receptor species. If a chronic NOAEL was unavailable, then the chronic Lowest Observable Adverse Effect Level (LOAEL) or acute lethal value (e.g., LD50) reported in the scientific literature were adjusted by uncertainty factors of 0.1 and 0.01, respectively, to derive a TRV equivalent to a chronic NOAEL.

Toxicity Equivalency Factors (TEFs) were used to equate toxicity of PCB congeners with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) that represents the most toxic and

extensively studied isomer. TEFs for birds and mammals used for each of the PCB congeners are presented in Table 4-20 (Van den Berg et al., 1998).

4.4 Risk Characterization

Potential risks to the selected measurement receptors from COPCs detected in the media of concern at the Site were evaluated by the hazard quotient method which compares estimated exposure doses with applicable toxicity reference values (TRVs). This comparison (expressed as a hazard quotient) is calculated for each COPC as follows:

HQ = ED/TRV

Where:

HQ = Hazard Quotient;
ED = Exposure Dose (from Section 4.3.1); and,
TRV = Toxicity Reference Value (from Section 4.3.2).

If the calculated hazard quotient is less than one, then it is unlikely that that contaminant will result in an adverse effect on that measurement receptor. Conversely, a hazard quotient greater than one indicates that that particular measurement receptor may be at risk of an adverse effect from that contaminant. A Hazard Index is also calculated based on the sum of the COPC-specific HQs to determine the risk from multiple stressors within the same chemical class (e.g., VOCs, SVOCs, pesticides/PCBs and inorganics). It is important to note that HQs provide only a general characterization of potential impacts to the local biota. An HQ less than one is indicative of non-risk, however, an HQ greater than unity does not in itself represent an unacceptable risk. Other site-specific factors (e.g., bioavailability) present at the Site may affect the initial screening calculation.

4.4.1 Water Column Invertebrates Measurement Receptor

Risk to the water column macroinvertebrate community from the detected COPCs within the surface waters of the seasonally ponded area within the Murphy Wetland were assessed by comparing concentrations of the COPCs in surface water with criteria or benchmarks protective

of aquatic life. In addition, surface water concentrations of these COPCs detected in the reference wetlands (M&E, 2003) were also compared to the levels detected within the Murphy Wetland. The results of this comparison are presented in Table 4-21.

Total recoverable mean concentrations of aluminum, barium, cyanide, iron and manganese exceed their respective chronic benchmarks at surface water samples from the Murphy Wetland. None of the five COPCs exceeds its respective acute benchmark.

Aluminum was detected in one of three samples at a concentration (244 ug/L) above its chronic ambient water quality criterion (AWQC) of 87 ug/L but below the acute AWQC of 750 ug/L. Toxicity of aluminum is related to pH and hardness with toxicity generally decreasing with increasing pH and hardness. The mean aluminum concentration (567 ug/L) detected in the wetland reference area surface water samples exceeds the maximum concentration detected in the Murphy Wetland suggesting that aluminum may not be a COPC that is entirely associated with the Site but is representative of regional conditions. However, many high quality waters have elevated aluminum levels above the chronic AWQC (USEPA, 2002a).

Barium exceeds its chronic benchmark at all three Murphy Wetland surface water samples. The detected concentrations of barium, however, did not exceed its acute benchmark at any sampling location. Detected barium concentrations with the Murphy Wetland surface water sampler also exceed the mean barium concentration (32 ug/L) detected in the wetland reference area surface water sampler. The chronic benchmark (calculated as 3.9 ug/L) represents a total recoverable concentration and was derived as a secondary chronic TRV using the Tier II methodology (Suter and Tsao, 1996). This secondary value may represent a very conservative benchmark as dissolved barium concentrations resulting in toxic effects to aquatic biota are generally above 50,000 µg/L as barium is typically precipitated into an insoluble, non-toxic compound by sulfate and/or carbonate present within the surface water (USEPA, 1986). Dissolved concentrations of barium do not exceed this 50,000 µg/L threshold in any of the filtered Murphy Wetland surface water samples. Therefore, barium may not present a potential chronic risk to aquatic invertebrates present within the seasonally ponded area of the Murphy Wetland.

Cyanide also exceeds its chronic AWQC at two of three surface water samples but was not elevated above its acute AWQC. Cyanide was not detected in the surface water samples collected from the reference wetlands. The most sensitive receptors to cyanide identified in deriving its AWQC are fish which are not present at the Murphy Wetland. Invertebrates were affected at concentrations above levels detected in Murphy Wetland surface water samples (USEPA, 1986, Suter and Tsao, 1996).Therefore, cyanide levels detected within the seasonally ponded area of the Murphy Wetland also present a low risk to aquatic invertebrates present within this area.

Iron and manganese were both elevated above their chronic AWQC (1000 ug/L) or chronic Tier II benchmark (80 ug/L), respectively, at two of three surface water samples collected from the seasonally ponded area within the Murphy Wetland. Manganese was not detected above its acute Tier II benchmark while an acute AWQC for iron is not available. The mean iron concentration (3940 ug/L) and manganese concentration (650 ug/L) detected in the wetland reference area surface water samples exceed the mean and maximum iron and manganese concentrations detected in the seasonally ponded area of the Murphy Wetland suggesting that iron and manganese may not be COPCs that are entirely associated with the Site but are representative of regional conditions.

4.4.2 Benthic Invertebrate Measurement Receptor

Risk to the benthic macroinvertebrate community from the detected COPCs within the sediments of the seasonally ponded area within the Murphy Wetland were assessed by comparing concentrations of the COPCs in sediment with benchmarks protective of benthic biota. In addition, sediment concentrations of these COPCs detected in the reference wetlands (M&E, 2003) were also compared to the levels detected within the Murphy Wetland. The results of this comparison are presented in Table 4-22. It should be noted that benchmarks are unavailable for a considerable number of COPCs. Therefore, risk attributable to these COPCs cannot be quantified.

Acetone and carbon disulfide exceed their respective benchmark at the one sample where these COPCs were detected. Although not detected at several other sampling locations within the seasonally ponded area of the Murphy Wetland, the reporting limits were elevated at these locations (i.e., greater than two times their respective benchmarks) and it is unclear if these COPCs may potentially be present at levels of concern at these sampling locations.

At most sampling locations within the seasonally ponded area of the Murphy Wetland, PAHs were generally elevated above their lower benchmarks (e.g., ER-Ls) where adverse effects to benthic invertebrates are first observed but were not above their higher benchmarks (e.g., SELs) that are typically associated with severe adverse impacts to the benthic macroinvertebrate community. In addition, detected concentrations of PAHs were usually higher in the reference wetland samples than noted within the Murphy Wetland suggesting that PAHs may be attributable to urban conditions in the vicinity of the Site. Several additional SVOCs including 2-methylphenol and phenol were also detected above their respective benchmarks and background levels indicating adverse effects from these COPCs to the benthic community are also possible.

Although several pesticides (e.g., DDT and chlordane) were detected within sediments of the seasonally ponded area of the Murphy Wetland above their lower benchmarks (i.e., ER-Ls), the concentrations of these COPCs were below both reference levels and higher benchmarks (e.g., SELs) associated with severe effects to the benthic community.

PCB Aroclors 1254 and 1260 were both frequently detected above their lower and higher benchmarks (as well as reference wetland levels) indicating that these COPCs may potentially impact the benthic macroinvertebrate community. Aroclor 1254 was not detected in reference wetland sediment while mean and 95% UCL reference concentrations of Aroclor 1260 were over three orders of magnitude lower than noted within the Murphy Wetland sediment. Aroclor 1254 was detected above its SEL benchmark at 76% of the sediment samples within the seasonally ponded area of the Murphy Wetland while Aroclor 1260 exceeded its SEL benchmark at over one-half the sediment samples (53%). The elevated PCB Aroclor levels (mean concentrations of Aroclors 1254 and 1260 result in HQs of 14 and 27, respectively, for the SEL benchmark)

suggest severe impairment to the benthic macroinvertebrate community from these COPCs is possible.

Several inorganics including arsenic, cadmium, copper, iron and mercury were generally elevated above their lower benchmarks (i.e., ER-Ls) and reference concentrations but were detected below levels associated with severe adverse effects (i.e., ER-Ms). However, the concentrations of chromium and lead within the sediments of the seasonally ponded area of the Murphy Wetland were typically elevated above their ER-M guidelines (at approximately 75% of the sediment samples). In addition, the mean concentrations of chromium and lead were elevated over one order of magnitude above the ER-M guideline (i.e., HQs of 16 and 13, respectively) suggesting adverse effects to the benthic macroinvertebrate community are likely. Zinc was also elevated above its ER-M guideline at four of five samples where this COPC was analyzed. However, unlike chromium and lead, the mean and maximum concentrations of zinc were less than two times the ER-M guideline. The maximum detected concentration of antimony (117 mg/kg) was also elevated 5 times above its respective ER-M benchmark.

Overall, the detected concentrations of several COPCs including PCB Aroclor 1254, Aroclor 1260, chromium and lead within the sediments of the seasonally ponded area of the Murphy Wetland are substantially elevated above benchmarks associated with severe impairment of the macrobenthic invertebrate community. These COPCs are likely to adversely affect macroinvertebrates within this area by decreasing community diversity and/or abundance.

4.4.3 Mammalian Herbivore Measurement Receptor

Risks to the herbivorous muskrat from detected COPC concentrations in the seasonally ponded area of the Murphy Wetland sediments and surface water (as well as modeled concentrations in aquatic vegetation and invertebrates) are presented in Table 4-23. The mean hazard index (sum of hazard quotients for each COPC class) is less than 1 for VOCs but exceeds 1 for SVOCs (hazard index is 3), pesticides/PCBs (hazard index is 140) and inorganics (hazard index is 420). Although the mean hazard index for SVOCs exceeds unity no individual COPC within the SVOC group has a mean HQ above 1 indicating little risk to the muskrat. The maximum dose of

indeno(1,2,3-cd)pyrene ingested by the muskrat results in a HQ of 2. However, the mean exposure dose represents a more realistic exposure scenario for the muskrat within the small area of habitat provided by the seasonally ponded area of the Murphy Wetland.

The elevated mean hazard index for pesticides/PCBs is attributable to risk from PCB Aroclors 1254 and 1260 (HQs of 100 and 22, respectively that total 87% of the hazard index) and PCB congeners (HQ of 16 that provides 11% of the hazard index). PCBs present within the seasonally ponded area of the Murphy Wetland are of concern to foraging mammals within this area as mean exposure doses are anticipated to exceed NOAEL TRVs by a considerable margin. Muskrat exposure to PCBs (both Aroclors and congeners) is primarily through ingestion of aquatic invertebrates rather than plant, water or incidental sediment ingestion.

The mean hazard index for inorganics is 420 and is primarily associated with elevated HQs for iron (HQ is 370), lead (HQ is 21) and chromium (HQ is 9). These three COPCs provide approximately 95% of the mean hazard index and are of concern to foraging herbivores within the Murphy Wetland as muskrat exposure to iron, lead and chromium is primarily from plant ingestion. However, the mean concentration of iron detected in the sediments of the seasonally ponded area of the Murphy Wetland is similar to the iron levels detected in the reference wetlands (i.e., mean Murphy Wetland sediment concentration is less than 95% UCL iron level within reference wetlands). Therefore, risk attributable to iron is not expected to be significantly greater than regional risks from this COPC. In addition, iron is an essential nutrient that may only be toxic to some organisms at very high concentrations. Conversely, mean chromium and lead concentrations in the sediments of the seasonally ponded area significantly exceed their respective levels in the reference wetlands.

Other inorganic COPCs providing risk include antimony (HQ is 3) and barium (HQ is 4). Barium exposure is primarily through plant ingestion while antimony exposure is via aquatic invertebrate and sediment ingestion. Although the arsenic and vanadium HQs are also above 1 (5 and 6, respectively), the mean concentrations of these COPCs are greater within the reference wetland samples indicating a regional risk rather than a risk specific to the Site.

4.4.4 Avian Omnivore Measurement Receptor

Risks to the omnivorous mallard duck from detected COPC concentrations in the seasonally ponded area of the Murphy Wetland sediments and surface water (as well as modeled concentrations in aquatic vegetation and invertebrates) are presented in Table 4-24. The mean hazard index (sum of hazard quotients for each COPC class) is less than 1 for VOCs and SVOCs. Although the mean hazard index for pesticides/PCBs exceeds unity no individual pesticide/PCB COPC has a mean HQ above 1 indicating little risk potential to the mallard. The maximum dose of Aroclor 1260 ingested by the mallard results in a HQ of 2. However, the mean exposure dose represents a more realistic exposure scenario for the mallard within the small area of habitat provided by the seasonally ponded area of the Murphy Wetland.

The mean hazard index also exceeds 1 for inorganics (hazard index is 2). The only COPC that has a mean HQ at or above 1 is lead (HQ is 1). Mallard exposure to lead is through both plant and aquatic invertebrate ingestion with incidental sediment ingestion also contributing to the total exposure dose (see Appendix D.2).

4.4.5 Mammalian Insectivore Measurement Receptor

Risks to the insectivorous short-tailed shrew from detected COPC concentrations in the seasonally ponded area and the forested scrub-shrub areas of the Murphy Wetland sediments and surface water (as well as modeled concentrations within invertebrates) are presented in Tables 4-25 and 4-26, respectively.

4.4.5.1 Seasonally Ponded Area

The mean hazard index (sum of hazard quotients for each COPC class) is less than 1 for VOCs but exceeds 1 for SVOCs (hazard index is 2), pesticides/PCBs (hazard index is 140) and inorganics (hazard index is 37). Although the mean hazard index for SVOCs exceeds unity no individual COPC within the SVOC group has a mean HQ above 1 indicating little risk to the shrew from SVOCs.

The elevated mean hazard index for pesticides/PCBs is attributable to risk from PCB Aroclors 1254 and 1260 (HQs of 110 and 18, respectively that total approximately 90% of the hazard index) and PCB congeners (HQ of 16 that provides 11% of the hazard index). PCBs present within the seasonally ponded area of the Murphy Wetland are of concern to foraging mammalian insectivores within this area as mean exposure doses are anticipated to exceed NOAEL TRVs by a considerable margin. Shrew exposure to PCBs (both Aroclors and congeners) is primarily through ingestion of invertebrates with incidental sediment ingestion also contributing to the total exposure dose.

The mean hazard index to the shrew attributable to inorganics is 37 and is primarily associated with elevated HQs for iron (HQ is 26), chromium (HQ is 2), antimony (HQ is 3), and lead (HQ is 2). These four COPCs provide approximately 90% of the mean hazard index for inorganics and are of concern to foraging mammalian insectivores within the seasonally ponded area. Shrew exposure to iron, chromium, and lead is primarily from sediment ingestion with antimony exposure from both invertebrate and sediment ingestion. However, as discussed above, the mean concentration of iron detected in the sediments of the seasonally ponded area of the Murphy Wetland is similar to the iron levels detected in the reference wetlands (i.e., mean Murphy Wetland sediment concentration is less than 95% UCL iron level noted within reference wetlands). Therefore, risk attributable to iron is not expected to be significantly greater than regional risks from this COPC. Another inorganic COPC that provides risk is vanadium (HQ is 2) with exposure of this COPC occurring through invertebrate and sediment ingestion. Although the vanadium HQ exceeds unity, the mean concentration of vanadium is greater within the reference wetland samples indicating a potential regional risk from vanadium rather than a risk specific to the Site.

Overall, the concentrations of PCB Aroclors and congeners and several inorganic COPCs (chromium, antimony, lead) within the sediments of the seasonally ponded area of the Murphy Wetland are expected to result in exposure doses to the shrew that exceed NOAEL TRVs indicating adverse effects are possible to insectivorous mammals.

4.4.5.2 Forest/Scrub-Shrub Area

The mean hazard index exceeds 1 for PCBs (hazard index is 54) and inorganics (hazard index is 33). PCB Aroclors 1254 and 1260 present within the forested/scrub-shrub area of the Murphy Wetland are of concern to foraging mammalian insectivores within this area as mean exposure doses are anticipated to exceed NOAEL TRVs (HQs of 51 and 3, respectively). Shrew exposure to PCB Aroclors is primarily through ingestion of invertebrates.

The potential risk to the shrew attributable to inorganics is primarily associated with elevated HQs for iron (HQ is 27) and chromium (HQ is 3). These COPCs provide over 90% of the mean hazard index for inorganics and are of concern to foraging mammalian insectivores within the forested/scrub-shrub portion of the Murphy Wetland. Shrew exposure to iron and chromium is primarily from soil ingestion. The mean soil concentration of iron within the reference wetlands exceeds the mean concentration detected in the forested/scrub-shrub area of the Murphy Wetland. Therefore, risk to the shrew from iron exposure is representative of regional risk attributable to this COPC and unlikely to be associated specifically with the Site.

Overall, the concentrations of PCB Aroclors and chromium within the soils of the forested/scrub-shrub area of the Murphy Wetland are expected to result in exposure doses to the shrew that exceed NOAEL TRVs indicating adverse effects are possible to insectivorous mammals within this habitat.

4.4.6 Refinement of COPCs for Mammalian and Avian Receptors

Based on the results of the risk characterization for the muskrat, mallard and short-tailed shrew, a number of the contaminants found at concentrations above screening-level concentrations and selected as COPCs, can be eliminated from further consideration for these herbivorous, omnivorous and insectivorous trophic level receptors. There were no indications of significant ecological risk from VOCs or SVOCs to any of these ecological receptors. Among the pesticide/PCBs, only Aroclors 1254 and 1260 and PCB congeners have elevated HQs for all

three receptor species within the Murphy Wetland. Due to the negligible ecological risk to receptor species, ecological risk from VOCs, SVOCs and pesticides will not be evaluated further.

Among the inorganics identified as COPCs in surface water, sediment and/or surface soil in the Murphy Wetland, beryllium, cadmium, chromium VI, cobalt, copper, cyanide, mercury, nickel, selenium, thallium and zinc did not have HQs greater than 1 for any mammalian or avian receptor species. No significant ecological effects appear to be associated with these COPCs to birds and/or mammals in the study area and these COPCs will not be considered further for contribution to ecological risk.

Several inorganics, including arsenic, barium, iron and vanadium, had low HQs (HQs < 4) and/or mean concentrations similar to levels detected at the reference wetland locations for all of the mammalian and avian receptor species. Due to the limited risk of these metals compared to reference toxicity values and similar exposures to receptors at reference locations, these COPCs will also not be considered further for contribution to ecological risk for these receptors.

The dietary exposure models for shrew and muskrat resulted in HQs greater than 1 for PCB Aroclors and congeners, antimony, chromium and lead at either the seasonally ponded area and/or the forested/scrub-shrub area of the Murphy Wetland for most of these receptors. These remaining COPC will be further evaluated for potential risk to one or more of the mammalian/ avian receptor species by using less conservative LOAEL-based TRVs and average-case exposure scenarios for the three receptor species. A summary of toxicity studies and associated LOAEL TRVs for the muskrat, shrew and mallard are presented in Tables 4-27 and 4-28. The LOAEL TRV represents an upper bound threshold effects level at which ecological impacts are predicted to occur. Where the average case scenario for exposure within the habitat area exceeds the LOAEL-based TRV, it is assumed that the COPC represents a significant risk to receptor populations. In order to maintain consistency, LOAEL TRVs selected in the Wells G&H OU-2 (M&E, 2003) were also used in this BERA.

4.4.6.1 LOAEL Comparison of COPCs for Mammalian Herbivore Receptor

LOAEL risks to the herbivorous muskrat from detected COPC concentrations in the seasonally ponded area of the Murphy Wetland sediments and surface water (as well as modeled concentrations in aquatic vegetation and invertebrates) are presented in Table 4-29. The mean hazard index is 16 for pesticides/PCBs and 4 for inorganics. The elevated mean hazard index for pesticides/PCBs is primarily attributable to risk from PCB Aroclor 1254 (HQs is 13) with Aroclor 1260 and PCB congeners having an HQ of 2 and 1, respectively. The LOAEL endpoints for Aroclor 1254 and the PCB congeners are associated with adverse effects on reproduction. The Aroclor 1254 LOAEL is based on dietary ingestion to oldfield mice (*Peromyscus poliontus*) that caused a reduction in the number of litters, offspring weight and offspring survival (Sample et al., 1996). The LOAEL for PCB congeners is based on dietary ingestion that caused reproductive impairment to rats by reducing fertility and survival of offspring. The LOAEL endpoint for Aroclor 1260 is associated with cancer and may not be entirely relevant for wild populations that have typically have a short lifespan such as muskrats. Overall, PCBs present within the seasonally ponded area of the Murphy Wetland are of concern to foraging mammalian herbivores within this area as mean exposure doses are anticipated to exceed LOAEL TRVs associated with reproductive impairment.

The mean hazard index for inorganics based on the LOAEL TRVs is 4 and is primarily associated with chromium (HQ is 2) and lead (HQ is 2). The LOAEL TRVs for these two COPCs are associated with reproductive impairment in rats receiving chromium (in the form of chromium chloride) or lead (in the form of lead acetate) in water or their diet. Therefore, decreased reproductive rates attributable to chromium and lead may also present a risk to muskrats inhabiting the seasonally ponded area of the Murphy Wetland.

4.4.6.2 LOAEL Comparison of COPCs for Avian Omnivore Receptor

The exposure dose of lead was the only COPC predicted to exceed its NOAEL TRV for the mallard. Risks (based on a LOAEL TRV) to the omnivorous mallard from detected lead concentrations in the seasonally ponded area of the Murphy Wetland sediments and surface

water (as well as modeled concentrations in aquatic vegetation and invertebrates) are presented in Table 4-30. The mean HQ for lead based on the LOAEL TRV is less than 1 indicating risks are unlikely to omnivorous birds that forage within this area.

4.4.6.3 LOAEL Comparison of COPCs for Mammalian Insectivore Receptor

Risks based on LOAEL TRVs to the insectivorous shrew from detected (and modeled) COPC concentrations in the seasonally ponded and forested/scrub-shrub areas of the Murphy Wetland are presented in Table 4-31. The mean hazard index is 16 for pesticides/PCBs and 1 for inorganics for the seasonally ponded habitat. The elevated mean hazard index for pesticides/PCBs is primarily attributable to risk from PCB Aroclor 1254 (HQs is 13) with Aroclor 1260 and PCB congeners having an HQ of 2 and 1, respectively. As discussed above, the LOAEL endpoints for Aroclor 1254 and the PCB congeners are associated with adverse effects on reproduction while the LOAEL TRV for Aroclor 1260 is associated with cancer and may not be entirely relevant. Overall, PCBs present within the seasonally ponded area of the Murphy Wetland are of concern to foraging mammalian insectivores within this area as mean exposure doses are anticipated to exceed LOAEL TRVs associated with reproductive impairment. Although the mean hazard index for inorganics for the seasonally ponded area based on the LOAEL TRVs is 1, no individual COPC has an HQ that exceeds unity. Therefore, adverse effects attributable to antimony, chromium and lead would appear unlikely based on an average exposure scenario.

For the forested/scrub-shrub area of the Murphy Wetland, the estimated exposure dose of Aroclor 1254 (HQ is 6) was predicted to exceed its respective LOAEL TRV associated with decreased reproduction in rats/mice. Therefore, a decrease in reproduction attributable to PCB Aroclor 1254 may present a risk to shrews inhabiting the forested/scrub-shrub area of the Murphy Wetland.

4.4.7 Uncertainty

There are considerable uncertainties associated with estimates of risk in any ERA, as the risk estimates are based on a number of assumptions regarding exposure and toxicity. There is uncertainty associated with the site conceptual model, with natural variation and parameter error, and with model error (USEPA, 1997). A thorough understanding of the uncertainties associated with risk estimates is critical to understanding predicted risks and placing them in proper perspective.

Uncertainty associated with the conceptual model (Figure 4-1) includes assumptions about the sources of contaminants and the fate and transport of the contaminants at the Site. The prediction of risk in this ERA does not distinguish the sources of contaminants that are identified as COPCs. For example, the Murphy Wetland receives runoff from areas located outside the Site limits such as the culvert present under the railroad right-of-way.

There is some uncertainty in the selection of the receptors as representative of communities utilizing the habitats in the Murphy Wetland. Habitat quality for some of the receptor species appears marginal within portions of the Site and will influence actual presence or exposure of species or communities within the different portions of the Murphy Wetland. For example, the muskrat was selected as a herbivorous mammal that is likely to inhabit the seasonally ponded area of the Murphy Wetland. The assumption that the muskrat (or other aquatic mammalian species) uses this ponded area throughout the year likely overestimated the exposure to sediment COPCs to herbivorous mammals. Therefore the calculated risk to muskrat populations is associated with some uncertainty.

4.4.7.1 Exposure Estimation

Exposure estimates for indicator species are a source of uncertainty in the ERA. Values for exposure parameters (*e.g.*, body weight, food intake rate, sediment ingestion rate) were based on literature values, not site-specific data. For instance, it was assumed, based on other studies, that approximately 30% of the shrew diet is comprised of earthworms. It was also assumed that

contaminant body burdens in earthworms are far greater than would be found in any of the other prey items shrews typically consume. The accuracy of each of these assumptions may be debated. However, the approach maintained in the ERA was to utilize conservative exposure parameters while maintaining a realistic evaluation of the potential for risk.

There is also uncertainty in using data collected in the Aberjona River BERA (M&E, 2003) to represent concentrations to which an indicator species may be exposed to at this Site. Plant tissue collected from one portion of the Aberjona River BERA study area were used to calculate uptake factors applied to this Site. However, using uptake factors derived from an adjacent site for each specific COPC decreased the uncertainty over using literature values.

The bioaccumulative potential of plants varies among species, and even within different parts of the plant. Therefore, there are additional uncertainties in assuming the tissue concentrations from whole plants are representative of the exposure of a consumer, particularly for a species that might selectively graze on a specific species or part of a plant.

Both the muskrat and mallard ingest aquatic invertebrates as a portion of their diet (10 percent and 67 percent, respectively). The estimation of organic COPC concentrations within aquatic invertebrate tissue was based on soil biota uptake factors reported in the literature for earthworms. These uptake factors introduce uncertainty in the exposure estimation (particularly for the mallard) as they may overestimate or underestimate concentrations within aquatic invertebrates.

It is commonly assumed that the data used to characterize exposure (sediment, surface water or surface soil concentrations) are normally distributed. Ecological data, however, often do not fit a normal distribution, since they tend to have many low values and fewer high values. Since the mean is actually used in exposure estimated to represent a time-average, the arithmetic mean in some cases may over estimate exposure. Statistical analysis of the data used in the ERA revealed that some of the COPC concentrations are not normally distributed, however, arithmetic means were still used to evaluate exposure. This was a conservative assumption and a source of uncertainty, since the arithmetic means are usually higher than geometric means, which are

appropriate for log-normally distributed data. However, the relative magnitude of this uncertainty is likely small and would not significantly change the risk conclusions.

In general, there is high confidence that data collected for the ERA represent the types and distributions of sediment and surface soil contaminants within the seasonally ponded area of the Murphy Wetland at the Site. However, exposure estimates are always uncertain in that they are driven by available data and by the methods used to collect those data. For example, exposure uncertainty is associated with the removal, prior to sampling, of coarse organic material (leaf litter or detritus) overlaying sediment or soil. Analytical data reflect the concentration of COPCs in sediment, and finer organic matter underlying the coarse organic matter at the surface. Therefore, analytical data may under- or overestimate exposures for invertebrates that inhabit or contact only coarse particulate organic matter at the substrate surface. Surface soil data within the forested/scrub-shrub portion of the Murphy Wetland are limited to PCB Aroclors and inorganics as VOC and SVOC data are unavailable for this area. In addition, the data for all inorganic COPCs except chromium and lead is limited to a single sediment sample. Therefore, the estimated exposure concentrations of wildlife receptors to these COPCs contains a large amount of uncertainty. However, as little risk to receptors from these COPCs was predicted within the seasonally ponded area of the Murphy Wetland, these COPCs are likely to provide minimal risk compared to the primary COPCs at the Site that drive risk; PCBs, chromium and lead.

In general, conservative assumptions were also made about exposure duration and site use factors. Assumptions were made that exposure remains constant over the seasonal exposure duration of an individual animal. In fact, the home range of many species varies from one life stage to another. Migration of individuals in and out of the study area would also affect exposure duration. It is plausible that for receptors such as the mallard, foraging within the seasonally ponded area of the Murphy Wetland may increase over the 5 percent site use factor estimated. If foraging is restricted, for example, during hen incubation, to only the seasonally ponded area, the exposure does estimate would increase by approximately a factor of 20. However, maximum exposure scenarios are very conservative, as they assume the highest sample concentrations for a contaminant was spread evenly over the entire range of an organism's residence or foraging

range. With the exception of some benthic invertebrates, this assumption is very conservative, because none of the vertebrate species would likely be confined to an area representative of a single sample within the Murphy Wetland for a period of time approximating the exposure duration. Consequently, maximum exposure estimates for most of the models are worst-case scenarios that tend to grossly overestimate exposure.

4.4.7.2 Toxicological Data

Toxicity values for indicator species and communities were based on literature values. As is the case for literature-based exposure parameter values, this is a major source of uncertainty in the ERA. The sensitivity of receptors in the Murphy Wetland may be different than the sensitivity of species used in tests reported in the literature.

A considerable number of sediment COPCs do not have toxicological benchmarks available for receptors such as benthic macroinvertebrates. Therefore, potential effects to benthic biota from these COPCs are uncertain and cannot be evaluated quantitatively. The risk at the site to benthic organisms from these COPCs, particularly those that exceed concentrations detected in the reference wetland sediment, is likely to increase overall.

Assumptions about the equality of contaminant form between laboratory tests and site field conditions must also be made in the absence of speciation analyses. This is a source of uncertainty, since toxicity may vary with the form of the toxicant in the environment. Thus, the actual toxicities of COPCs evaluated in this ERA could be higher or lower than indicated by the TRVs used in the development of HQs. HQs were subsequently summed to provide a HI for each general class of COPCs (e.g., VOCs, SVOCs, pesticides/PCBs, inorganics) in order to clarify ecological risk. However, there are several uncertainties associated with this approach as it is assumed that target organs and modes of toxic action are similar and the toxicity is additive for each COPC within its general class. These assumptions may not necessarily be true.

Another source of uncertainty is the extrapolation of LOAELs to NOAELs using an uncertainty factor of ten. This approach is likely conservative. Dourson and Stara (1983 *cited in* USEPA,

1997) determined that 96% of the chemicals included in a data review had LOAEL/NOAEL ratios of five or less. The use of an uncertainty factor of 10, although potentially conservative, also serves to counter some of the uncertainty associated with interspecies extrapolations, for which a specific uncertainty factor was not used.

Based on the review of available studies for which possible LOAEL TRV values were given, a large source of uncertainty is the selection of a TRV for estimation of HQs. The results of different studies often varied several orders of magnitude, based on using various forms of the COPC, different species, and different endpoints. One of the largest sources of uncertainty in all of these TRV values is the form of the chemical used to determine the laboratory exposure. The HQ approach uses the assumption that the absorption of the chemical from the diet will be the same as the absorption of the chemical in the form used in the laboratory. Often this assumption is very conservative, because absorption of metals ingested with sediment or plant material, is greatly reduced from forms given in laboratory studies.

One of the main uncertainties of the assessment is associated with the toxicity values for the indicator species. A considerable number of the COPCs for avian indicator species do not have an associated toxicity value. Therefore, an evaluation of these COPCs to provide risk to the mallard indicator species could not be provided. For avian species this would result in an underestimation of the total risk. For example, no avian toxicity value was found in the literature for high molecular weight PAHs. Therefore, it is unclear whether detected concentrations of these contaminants within site sediments and surface soils may present a risk to avian species (as represented by the mallard) inhabiting the Site. However, PAH levels were generally higher within sediment samples collected from reference wetlands than within the Murphy Wetland.

4.5 Summary

Overall, the ERA predicted risk to ecological receptors that may inhabit the Murphy Wetland. The primary risk drivers are PCBs, chromium and lead while the receptors identified as being at risk are aquatic invertebrates, herbivorous mammals and insecfivorous mammals. Highest risk to benthic invertebrates are attributable to levels of PCBs, lead, and chromium within the

sediment of the seasonally ponded area of the Murphy Wetland. There was also evidence of high potential risk on the reproduction of muskrats (herbivorous mammal) due to exposure to PCBs, lead, and chromium within the seasonally ponded area of Murphy Wetland. There was low risk potential to mallards (avian omnivore) that forage on the Site from lead. The risk potential to shrews (insectivorous mammal) inhabiting the Murphy Wetland was high and attributable to PCBs. A summary of the risks are discussed below and presented in the following table.

Summary of Ecological Receptor Risks for Murphy Wetland

Receptor	Receptor Indicator Species	Habitat	Major Contributors to Risk*
Macrobenthic Community	Not Applicable	Seasonally Ponded Area	PCB Aroclors 1254/1260** chromium lead zinc
Mammalian Herbivore	Muskrat	Seasonally Ponded Area	PCB congeners** PCB Aroclors 1254/1260** chromium lead
Mammalian Insectivore	Short-tailed Shrew	Seasonally Ponded Area	PCB congeners** Aroclors 1254/1260**
		Forested/Scrub-Shrub Area	Aroclor 1254**

Notes:
* - HQ > 1 for LOAEL or ER-M/SEL
** - Greatest risk driver for that receptor
NA – Not applicable
HQ – Hazard Quotient
LOAEL – Lowest Observable Adverse Effect Level
ER-M/SEL – Effects Range-Median and Severe Effect Level (Sediment Benchmarks)
PCB – polychlorinated biphenyls

The effects-based screening resulted in the selection of 5 COPCs in surface water (all inorganics) and 60 COPCs in sediment/surface soil (VOCs, SVOCs, pesticides/PCBs, and inorganics) for evaluation in the ERA. Five indicator species or indicator communities were selected to evaluate risks associated with exposure to the COPCs in the surface water and sediment/surface soil of the Site. Endpoints in the ERA were selected to represent ecological attributes that are to be protected (assessment endpoints) and a measurable characteristic of those attributes (measurement endpoints) that can be used to gauge the degree of impact that has or may occur.

Each endpoint has associated with it a magnitude of risk and a degree of uncertainty. The magnitude of risk incorporates both the degree to which the endpoint was exceeded and also the proportion of the habitat affected. If the NOAEL TRV (lower effects threshold) was exceeded at the site, the contaminant was concluded to pose a low risk to populations. The highest risk was associated with contaminants that exceeded upper threshold effects levels based on LOAEL TRVs. If high HQs were present only for the maximum (or 95% UCL) COPC concentration, the magnitude of the overall risk to the population from exposure to the COPC was considered low.

The invertebrate endpoints suggest that there may be impacts from organic and inorganic contaminants on invertebrate communities inhabiting the seasonally ponded area of the Murphy Wetland. The strength of the evidence was based entirely on exceedances of sediment-effects benchmarks. The benchmark analysis indicated a high risk potential to benthic invertebrate communities from PCB Aroclors 1254 and 1260 and from inorganics, especially chromium, lead, and zinc with the highest HQs attributable to PCBs, chromium and lead. Since the benchmarks used for each of these COPCs was the SEL (severe effect level) they represent contaminant levels that potentially eliminate many of the benthic organisms within the community (Persaud, *et al.*, 1993). Biological effects evaluations, in the form of sediment toxicity testing or benthic community structure were not undertaken for this ERA.

Analysis of the mean exposure assessment for muskrat indicated HQs greater than 1 based on NOAEL TRVs, for PCB Aroclors 1254 and 1260, PCB congeners, antimony, arsenic, barium, chromium, iron, lead and vanadium. Arsenic, barium, iron and vanadium had low HQs (HQs < 4 based on NOAEL TRVs) and/or mean concentrations similar to levels detected at the reference wetland locations indicating a low risk potential. The mean estimated exposure to antimony does not exceed the upper effect level based on the LOAEL TRV. However, mean exposure doses of PCB Aroclors 1254 and 1260, PCB congeners, chromium and lead estimated to be ingested by the muskrat result in HQs above 1 based on LOAEL TRVs. Due to the elevated HQs (particularly for PCB Aroclor 1254), the magnitude of the risk for muskrat exposure to these COPCs is high. These results indicate a potential impact on reproduction of mammal

populations such as muskrat exposed to PCBs in the diet while foraging in the seasonally ponded area of the Murphy Wetland.

The mallard was used to represent waterfowl having relatively high exposure to sediments. Based on NOAEL TRVs, lead represented the only COPC to have a HQ greater than 1 for the Site based on the average exposure case. The concentrations of lead indicated low risk for reduction in reproduction or sublethal effects to populations, but there was no evidence for high risk to populations since the lead LOAEL HQ was less than 1. The assessment of the waterfowl endpoint indicates a low risk to the sub-population of mallards at the seasonally ponded area of the Murphy Wetland from exposure to lead. The magnitude of the risk to mallard populations from lead was low since it is based on the NOAEL TRV value, which represents the threshold for effects for potential impacts to populations.

Short-tailed shrew exposure models were used to evaluate potential risk to small mammal populations living in and near the Murphy Wetland. Analysis of the mean exposure assessment for shrew indicated HQs greater than 1, based on NOAEL TRVs, for PCB Aroclors 1254 and 1260, PCB congeners, antimony, chromium, iron, lead and vanadium at the seasonally ponded area of the Murphy Wetland while PCB Aroclors 1254 and 1260, chromium and iron have HQs greater than 1 (also based on NOAEL TRVs) at the forested/scrub-shrub area of the Murphy Wetland. Iron and vanadium had mean concentrations similar to levels detected at the reference wetland locations indicating a low risk potential due to Site exposure. The mean estimated exposures to antimony, chromium and lead do not exceed the upper effect level based on their respective LOAEL TRV at either habitat within the Murphy Wetland. However, mean exposure doses of PCB Aroclor 1254 estimated to be received by the shrew at the seasonally ponded and the forested/scrub-shrub areas result in an HQ above 1 based on its LOAEL TRV. In addition, the mean exposure doses of PCB Aroclor 1260 and PCB congeners at the seasonally ponded area of the Murphy Wetland are also above 1. Due to the elevated HQs (particularly for PCB Aroclor 1254), the magnitude of the risk for shrew exposure to PCB Aroclor 1254 is high. These results indicate a potential impact on reproduction of mammal insectivore populations such as shrews exposed to PCBs in the diet while foraging in the seasonally ponded and forested/ scrub-shrub areas of the Murphy Wetland.

The uncertainty associated with the estimation of risk, summarized in section 4.4.7, was qualitatively assessed, and based on many factors. A major source of uncertainty for mammalian and avian indicators was the relevance of the available TRVs. High uncertainty was also associated with COPCs that had corresponding high concentrations at reference locations. In cases where the magnitude of risk was low, and was associated with high degree of uncertainty, the overall risk for that endpoint was considered negligible.

5.0 SUMMARY AND CONCLUSIONS

This section summarizes the findings and conclusions of the field investigation activities and baseline human health and ecological risk assessments conducted for the Southwest Properties in Woburn, Massachusetts. The Southwest Properties are part of the 2nd operable unit (OU-2) of the Wells G&H Superfund Site. The purpose of this report was to assess contamination at the Southwest Properties and evaluate human health and ecological risks related to the contamination. The environmental setting, geology, surface hydrology, hydrogeology, human health risk and ecological risk are summarized in the following text. Information on the nature and extent of contamination and the fate and transport of contaminants is provided in the Supplemental RI (RETEC, 2003).

The Southwest Properties Site is part of the Well G&H Superfund Site, which is a triangular shaped parcel of land comprising approximately 330 acres bounded by Route 128/Interstate 95 to the north, the Boston and Main (B&M) Railroad to the west, Interstate 93 to the east and Salem and Cedar Streets to the south. The Southwest Properties are comprised of three parcels of land known as Aberjona Auto Parts (Aberjona property), Whitney Barrel (Whitney property), and Murphy Waste Oil (Murphy property), which are also listed as three separate MADEP BWSC "Chapter 21-E" sites.

OU-2, also referred to as the Central Area, was identified by EPA in the September 14, 1989 Wells G&H ROD as an area requiring further evaluation. A RI/FS of the Central Area was undertaken by several PRPs pursuant to a September 8, 1991 Consent Decree, which specified the obligations for each PRP, and specifically identified the three Southwest Properties (Aberjona, Whitney, and Murphy) as part of the Central Area. One of the objectives of the work required was to gather the data necessary for EPA to prepare a baseline risk assessment for the Southwest Properties and assess the need for remedial action.

This report presents the findings of the field investigations and the HHRA/ERA conducted at the Southwest Properties.

5.1.1 Site Description

The land use at and in vicinity of the Southwest Properties is highly developed with light commercial and light industrial parks bordering the wetlands area associated with the Aberjona River floodplain. Currently, the Aberjona property is a fenced, idle auto salvage yard with an active auto repair establishment and landscaping company as tenants. The Whitney property is occupied by a variety of small businesses (e.g., landscaping). The Murphy property is leased by Clean Harbors Environmental Services and registered as a TSDF under RCRA. The Murphy Property is currently used for treatment and storage of waste oil.

5.1.2 Geology/Hydrogeology

The area in the vicinity of the Southwest Properties is underlain by unconsolidated glacial deposits that unconformably overlie crystalline bedrock. The unconsolidated deposits at the edges of the Aberjona River Valley are primarily ground moraine deposits. Within the Eastern Uplands, two varieties of till have been identified, a lodgment till and an ablation till. The lodgment till lies directly on the bedrock surface and is up to 30 feet thick and very densely packed. Overlying the lodgment till is a thin layer of ablation till, which is more sandy and less densely packed than the lodgment till.

The low lying western portion of the Central Area Aquifer is comprised of stratified outwash deposits that generally overlie bedrock directly. In some areas, there is a thin layer of lodgment till between the outwash deposits and bedrock surface.

Swamp deposits consisting of decayed vegetal matter, silt, sand, and possibly clay generally lie at the surface, except where covered by artificial fill, and are found within the wetlands that border the Aberjona River and its tributaries. The swamp deposit thickness varies considerably and is generally less than 5 feet; although, areas as thick as 25 feet have been identified.

The stratified drift deposits fill the Aberjona River Valley, make up the Central Area Aquifer, and are up to 130 feet thick. The stratified drift deposits are well sorted and possess much higher hydraulic conductivity than the till. City of Woburn public water supply wells G&H and the J. J. Riley supply wells were constructed in the stratified drift. The hydraulic conductivity of the

stratified drift deposits ranges from 0.1 feet per day in the finer grained deposits to 350 feet per day in the gravelly layers.

The bedrock underlying the Site has been mapped as Salem Granodiorite, Dedham Granite, and undifferential metavolcanics. The bedrock is generally competent, and is not extensively fractured. The hydraulic conductivity of the bedrock is generally low and, in general, potential well yields would be low.

The Aberjona River, which has its headwaters in the Town of Reading and empties into the Mystic Lakes in the Town of Winchester, flows north to south to the east of the Southwest Properties. Relatively small amounts of groundwater enter the Aberjona River Valley from upgradient areas north of Interstate 95 (Route 128), and exit the narrow southern end of the valley south of Salem Street. A 38 acre wetland area exists along both sides of the Aberjona River within the 100-year floodplain.

Groundwater in the stratified drift is unconfined, and water levels fluctuate continuously in response to recharge and discharge. The water table is generally at or near the ground surface in most of the low-lying areas. The direction of groundwater flow is typically inward toward the central axis of the river. Under non-pumping conditions, groundwater discharges to the river and adjacent wetlands. With respect to the Southwest Properties, groundwater flow is generally to the east, towards the Aberjona River in both unconsolidated soils and shallow bedrock.

Depth to groundwater at the Southwest Properties varies seasonally, and with proximity to the river and wetland, but generally ranges from 5 to 9 feet from the ground surface in upland portions of the site.

5.1.3 Field Investigation

Environmental data used in the preparation of this human health and ecological risk assessments were collected during several sampling events conducted by, or on behalf of, property owners (i.e., Clean Harbors), PRPs (Beatrice) and split samples collected on behalf of USEPA. The data, scope and location of investigative activity vary by property.

The Aberjona Property was investigated twice by the PRP, once in 1993 and subsequently in 2002 with EPA oversight and split sample collection. These investigations resulted in the collection of 10 surface soil, 15 subsurface soil samples from 1993 and 2003, and 13 groundwater samples from 2002. Only groundwater data from the 2002 sampling effort were utilized in the human health risk assessment since earlier rounds of groundwater sampling (1993 and prior) were not considered representative of current conditions. EPA accepted split samples during the 2002 investigation effort, included 1 surface soil, 2 subsurface soil, and 3 groundwater samples. The split-samples were treated as unique samples rather than duplicate samples, and thus were considered separate values in the determination of the frequency of detection.

The Whitney Property was also investigated by the PRP in 1993 and 2002 (with EPA oversight). Collectively, these investigations resulted in the collection of 17 surface soil, 10 subsurface soil samples from 1993 and 2003, and 12 groundwater samples from 2002. As described above for the Aberjona Property, only groundwater data from the 2002 sampling effort were utilized in the human health risk assessment. Split samples accepted by EPA during the 2002 investigation effort, included 3 surface soil, 3 subsurface soil and 3 groundwater samples, were also treated as unique samples rather than duplicates.

The Murphy Property was investigated twice by the PRP, but has also been extensively investigated by the property leasee (Clean Harbors) in the 1980s and 1990s. EPA also conducted oversight during the PRP's 2003 investigation. Collectively, these investigations resulted in the collection of 25 surface soil and 90 subsurface soil samples. As with Aberjona and Whitney, only recently collected groundwater data collected from this property were utilized in the human health risk assessment. However, these data includes sampling conducted on behalf of Clean Harbors in 2001 and by the PRP in 2002, as well as splits collected on behalf of EPA in 2002. Split samples accepted by EPA during the PRP's 2002 investigation of the Murphy Property included 1 surface soil, 1 subsurface soil, and 1 groundwater sample, which were treated as unique samples rather than duplicates.

The Murphy wetland was investigated twice by the PRP in 1993 and 2002, and several times by Clean Harbors in 1997 and 1998. EPA also conducted oversight during the PRP's 2003

investigation of the wetland. Collectively, these investigations resulted in the collection of 68 sediment samples. Only three surface water samples collected during the 2002 investigation were utilized in the human health risk assessment because prior surface water sampling conducted in 1993 was not representative of current conditions. Split samples accepted by USEPA during the PRP's 2002 investigation of the Murphy wetland include 4 sediment samples. Surface water samples were not split.

Analytes for the 1993 sampling conducted by the PRP included VOCs, SVOCs, pesticides, PCBs, metals, and cyanide. Sampling conducted in 2002 by the PRP included the same analytes, plus VPH/EPH, hexavalent chromium, and PCB congeners. A summary of data utilized and the general analytical suite is provided in Table 5-1.

5.1.4 Baseline Human Health Risk Assessment

The baseline human health risk assessment was performed to evaluate the potential for adverse health effects to human populations who may come into contact with contaminants present in environmental media at the Southwest Properties. Exposures were evaluated for the following media: surface and subsurface soil, groundwater, air, surface water, and sediment. Chemicals of Potential Concern (COPCs) for the environmental media were identified for the properties and wetland area that compose the Southwest Properties (Aberjona, Whitney, and Murphy Properties and the Murphy wetland), which were quantitatively evaluated under current and/or future land-use conditions.

The arsenic bioavailability study that was performed as part of the Aberjona River Study Operable Unit 3 Risk Assessment was also used in this risk assessment. The arsenic bioavailability study was completed to assist in the quantification of sediment risks. This site-specific bioassay determined that arsenic is absorbed less efficiently from sediment than from a water medium. The most conservative relative bioavailability estimate from the study was used in this risk assessment to quantify sediment ingestion risks at the Murphy wetland.

Table 5-1
Summary of Data Utilized – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2
Woburn, Massachusetts

Property	Investigation Dates	Sample Data Utilized (1)	General Analytical Suite	Source Documents
Aberjona	1993	18 soil	VOC, SVOC, pesticide, PCB, metals, cyanide	RETEC 1994
	2002	18 soil 13 groundwater	VOC, SVOC, pesticide, PCB, PCB congeners, metals, cyanide	RETEC 2003 TRC 2004
Whitney	1993	8 soil	VOC, SVOC, pesticide, PCB, metals, cyanide	RETEC 1994
	2001	3 groundwater	VOC, SVOC, VPH, EPH, metals, hex chrome, cyanide, pesticide, PCB, PCB congeners	RETEC 2003
	2002	23 soil 9 groundwater	VOC, SVOC, pesticide, PCB, PCB congeners, metals, cyanide	RETEC 2003 TRC 2004
Murphy	1987-1998	57 soil	VOC, SVOC, pesticide, PCB, metals, cyanide	Clean Harbors 1996, 1998
	1997-1998	52 sediment	PCBs, chromium, lead, petroleum	Clean Harbors 1996, 1998
	1993	7 soil 3 wetland soil	VOC, SVOC, pesticide, PCB, metals, cyanide	RETEC 1994
	2001	27 groundwater		RETEC 2003
	2002	8 soil 12 sediment 6 groundwater 3 surface water	VOC, SVOC, pesticide, PCB, PCB congeners, metals, cyanide	RETEC 2003 TRC 2004

Notes:
(1) – Only groundwater or surface water samples from 2001/2002 investigations were utilized in HHRA.
VOC – volatile organic compounds
VPH – volatile petroleum hydrocarbons
EPH – extractable petroleum hydrocarbons
SVOC – semivolatile organic compounds
PCB – polychlorinated biphenyls

Site-specific hexavalent chromium data were collected and used in the risk assessment to more accurately characterize soil, groundwater, and sediment risks at the Southwest Properties. Only hexavalent chromium data obtained using the ion chromatography method for soil/sediment and Method 7196A for groundwater were quantitatively evaluated in the human health risk assessment.

Possible human exposure to the selected COPCs was characterized through exposure pathways for current and future land use. Current land use is commercial/industrial at all three sites. However, a residence exists on the southeast portion of the Aberjona property. The Southwest Properties are zoned industrial (City of Woburn, 1997). Many of the on-site areas of known contamination are currently fenced. However, access is not limited for a portion of the Aberjona property (Aberjona Triangle) and all of the Whitney property. In addition, commercial workers may access the secured areas. Based on this information, current receptors include residential at the Aberjona property, commercial at all three properties and trespasser at the Aberjona Triangle, Whitney property and Murphy wetland. Future receptors for all three properties include commercial, trespasser, recreational and construction worker. The future residential scenario is evaluated for the Aberjona residence only. In addition, a future off-site resident is evaluated for exposure to groundwater.

Whenever possible, 95% Upper Confidence Limits (UCLs), calculated using EPA's software ProUCL Version 2.1 (EPA, 2002a), were used as exposure point concentrations. Two sets of quantitative exposure estimates were prepared, corresponding to sets of exposure assumptions designated as central tendency (CT) and reasonable maximum exposure (RME) scenarios.

The potential for adverse health effects was evaluated by comparing the estimated incremental lifetime cancer risks (ILCRs) to the target risk range of 10^{-6} to 10^{-4} and the calculated hazard indices (HIs) for noncarcinogenic health effects to the target risk level of 1. Table 5-2 presents a risk summary for the Southwest Properties, with HIs and ILCRs summarized by property for surface soil, subsurface soil, groundwater, surface water, sediment and air, as applicable, for each of the receptors evaluated. When risks were estimated for a child and adult receptor, the child HIs are presented on Table 5-2 as the most conservative, while ILCRs presented on Table 5-2 are the sum of the child and adult risks (i.e., a total receptor cancer risk). The medium-specific risks presented by property have been summed together, as appropriate, when a receptor would be exposed to more than one medium. The Murphy wetland area was evaluated as a separate exposure

point because of its location (i.e., located mostly on the Whitney and Murphy properties). In cases where the total pathway HI exceeded 1, COPCs having similar systemic effects were summed for each pathway and medium. Table 5-1 also summarizes the primary risk contributors for those receptors with estimated ILCRs greater than the target range of 10^{-6} to 10^{-4} and target organ-specific HIs greater than 1.

5.1.4.1 Reasonable Maximum Exposure Based Risk

The media for which RME exposures for one or more pathways were within or below USEPA's target risk range for carcinogens (ILCR of 10^{-6} to 10^{-4}) and risk criterion for noncarcinogens (HI of 1) are summarized below by exposure point.

Aberjona

- All RME ILCRs and HIs are below criteria

Whitney

- Groundwater (Future Construction Worker)
- Surface Soil (Current/Future Older Child Trespasser)

Murphy

- All RME ILCRs and HIs are below criteria

Murphy Wetlands

- Surface water (Current/Future Trespasser and Future Adult/Child Recreational User)
- Sediment (Current Older Trespasser)

The media for which RME exposures for one or more pathways exceeded the target risk range for carcinogens and/or noncarcinogens are summarized below:

Table 5-2
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2
Woburn, Massachusetts

Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Contributors to Risk (> 1E-06, HI > 1)
Aberjona	Current	Commercial Worker	Adult	RME	9E-06	3E-02	None	None
				CT	5E-07	1E-02	None	None
		Trespasser*	Older Child	RME	1E-07	7E-03	None	None
				CT	2E-08	5E-03	None	None
		Resident**	Young Child/Adult	RME	3E-05	2E-02	None	None
				CT	7E-06	1E-02	None	None
	Future	Commercial Worker	Adult	RME	3E-06	5E-01	None	None
				CT	4E-07	3E-01	None	None
		Trespasser	Older Child	RME	4E-07	2E-02	None	None
				CT	4E-08	5E-03	None	None
		Resident**	Young Child/Adult	RME	3E-05	2E-02	None	None
				CT	7E-06	1E-02	None	None
		Recreational User** (Surface Soil)	Young Child/Adult	RME	4E-06	2E-01	None	None
				CT	2E-07	3E-02	None	None
		Recreational User** (Subsurface soil)	Young Child/Adult	RME	2E-05	4E-01	None	None
				CT	1E-06	6E-02	None	None
		Construction Worker (Surface Soil)	Adult	RME	3E-07	7E-02	None	None
				CT	8E-08	2E-02	None	None
		Construction Worker (Subsurface Soil)	Adult	RME	2E-06	4E-01	None	None
				CT	6E-07	1E-01	None	None

Table 5-2 (Continued)
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Contributors to Risk (> 1E-06, HI > 1)
Whitney	Current	Commercial Worker	Adult	RME	1E-04	2E+00	Surface Soil	PCB Aroclors
				CT	4E-06	1E-01	None	None
		Trespasser	Older Child	RME	8E-06	6E-01	None	None
				CT	5E-07	6E-02	None	None
	Future	Commercial Worker	Adult	RME	1E-04	1E+01	Surface Soil	PCB Aroclors
							Indoor Air	C5-C8 Aliphatics C9-C18 Aliphatics
				CT	1E-05	6E+00	Indoor Air	C5-C8 Aliphatics
		Trespasser	Older Child	RME	2E-05	1E+00	None	None
				CT	5E-07	6E-02	None	None
		Recreational User** (Surface Soil)	Young Child/Adult	RME	1E-04	8E+00	Surface Soil	PCB Aroclors
				CT	3E-06	4E-01	None	None
		Recreational User** (Subsurface Soil)	Young Child/Adult	RME	1E-03	2E+02	Subsurface Soil	benzo(a)pyrene arsenic alpha-chlordane gamma-chlordane 4,4'-DDE 4,4'-DDT PCB Aroclors PCB Congeners
				CT	4E-05	4E+01	Subsurface Soil	PCB Aroclors
		Construction Worker (Surface Soil)	Adult	RME	9E-06	4E+00	Surface Soil	PCB Aroclors
				CT	7E-07	2E-01	None	None
		Construction Worker (Subsurface Soil)	Adult	RME	9E-05	1E+02	Subsurface Soil	alpha-chlordane gamma-chlordane PCB Aroclors
				CT	1E-05	3E+01	Subsurface Soil	PCB Aroclors

Table 5-2 (Continued)
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Contributors to Risk (> 1E-06, HI > 1)
Murphy	Current	Commercial Worker	Adult	RME	8E-06	1E-01	None	None
				CT	1E-06	4E-02	None	None
	Future	Commercial Worker	Adult	RME	2E-05	2E+00	None***	None***
				CT	6E-06	1E+00	None	None
		Trespasser	Older Child	RME	1E-06	8E-02	None	None
				CT	1E-07	1E-02	None	None
		Recreational User** (Surface Soil)	Young Child/Adult	RME	1E-05	8E-01	None	None
				CT	7E-07	1E-01	None	None
		Recreational User** (Subsurface Soil)	Young Child/Adult	RME	9E-06	8E-01	None	None
				CT	7E-07	2E-01	None	None
		Construction Worker (Surface Soil)	Adult	RME	7E-07	2E-01	None	None
				CT	2E-07	4E-02	None	None
		Construction Worker (Subsurface Soil)	Adult	RME	1E-05	8E-01	None	None
				CT	4E-06	3E-01	None	None
Murphy Wetland	Current	Trespasser	Older Child	RME	1E-05	2E+00	None***	None***
				CT	1E-06	1E+00	None	None
	Future	Trespasser	Older Child	RME	2E-05	3E+00	Sediment	PCB Aroclors
				CT	1E-06	1E+00	None	None
		Recreational User**	Young Child/Adult	RME	3E-04	2E+01	Sediment	ethylenedibromide benzo(a)pyene dibenz(a,h)anthracene PCB congeners arsenic PCB Aroclors
				CT	6E-06	4E+00	Sediment	PCB Aroclors

Table 5-2 (Continued)
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Contributors to Risk (> 1E-06, HI > 1)
Off-Site Resident	Future	Resident**	Young Child/Adult	RME	2E-02	2E+02	Tap Water	1,3-dichlorobenzene benzene chlorodibromomethane cis-1,2-dichloroethene methyl tert-butyl ether methylene chloride tetrachloroethene trichloroethene vinyl chloride benzo(a)pyrene dibenz(a,h)anthracene C9-C18 Aliphatics C11-C22 Aromatics arsenic manganese PCB Congeners dieldrin 4,4'-DDD
							Inhalation of Volatiles from Groundwater	1,1,2-trichloroethane benzene trichloroethene tetrachloroethene vinyl chloride

Table 5-2 (Continued)
Summary of Receptor Risks – Human Heath Risk Assessment

Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

Property	Timeframe	Receptor	Receptor Age	RME or CT	Total Cancer Risks	Total Non-Cancer Risks	Media > 1E-04 or HI > 1	Contributors to Risk (> 1E-06, HI > 1)
Off-Site Resident (Cont.)	Future (Cont.)	Resident** (Cont.)	Young Child/Adult (Cont.)	CT	4E-04	8E+00	Tap Water	trichloroethene vinyl chloride benzo(a)pyrene dibenz(a,h)anthracene arsenic PCB Congeners
							Inhalation of Volatiles from Groundwater	1,1,2-trichloroethane trichloroethene vinyl chloride

Notes:
* - Trespasser exposure limited to the Aberjona Triangle at the Aberjona Property in the current scenario.
** - Cancer risks shown for adult and young child are summed. Non-cancer risks are shown for young child only.
*** - Cumulative HI value is above target HI of 1, but cumulative risk to individual target organs are below the target HI.
RME – Reasonable Maximum Exposure CT – Central Tendency HI – Hazard Index

Whitney

- Surface Soil (Current/Future Commercial Worker, Future Recreational User, Future Construction Worker)
- Subsurface soil (Future Recreational User, Future Construction Worker)
- Indoor air attributable to groundwater (Future Commercial Worker)

Murphy Wetland

- Sediment (Future Older Child Trespasser and Future Recreational User)

Off-Site Resident

- Tap Water/Shower Head (Young Child/Adult Resident)
- Indoor Air Exposure During Showering (Young Child/Adult Resident)

The contaminants responsible for driving risk for the RME case above the target risk ranges are summarized below by exposure point. Contaminants that are major contributors to risk (ILCRs $>10^{-4}$ or HIs >1) are shown in ***boldface italics***.

Whitney

- Surface Soil (***PCB Aroclors***)
- Subsurface soil (***PCB Aroclors***, ***PCB congeners***, ***chlordane,*** benzo(a)pyrene, arsenic, 4,4'-DDE, and 4,4'-DDT)
- Indoor Air (***C5-C8 Aliphatic Hydrocarbons, C9-C18 Aliphatics Hydrocarbons***)

Murphy Wetland

- Sediment (***chromium III, PCB Aroclors***, ethylene dibromide, benzo(a)pyrene, dibenz(a,h)anthracene, PCB congeners, and arsenic)

Off-Site Resident

- Tap Water/Shower Head (***1,3-dichlorobenzene, benzene, cis-1,2-dichloroethene***, ***trichloroethene***, ***vinyl chloride***, ***C9-C18 Aliphatic Hydrocarbons***, ***C11-C22 Aromatic Hydrocarbons***, ***arsenic***, ***manganese***, chlorodibromomethane, methyl tert-butyl ether, methylene chloride, tetrachloroethene, benzo(a)pyrene, dibenz(a,h)anthracene, PCB congeners, dieldrin, and 4,4'-DDD)

- Indoor Air During Showering (***1,1,2-trichloroethane, trichloroethene,*** vinyl chloride, benzene, and tetrachloroethene)

5.1.4.2 Central Tendency Based Risk

The media for which CT exposures for one or more pathways were above USEPA's target risk range for carcinogens and/or non-carcinogens are summarized below by exposure point:

Whitney

- Surface soil (Future Commercial Worker and Construction Worker)
- Subsurface soil (Future Recreational User and Future Construction Worker)
- Indoor Air attributable to groundwater (Future Commercial Worker)

Murphy Wetland

- Sediment (Future Recreational User)

Off-Site Resident

- Tap water (Future Off-Site Resident)
- Indoor Air (Future Off-Site Resident)

The contaminants responsible for driving risk above the target risk ranges in the CT case are summarized below by exposure point. Contaminants that are major contributors to risk (ILCRs $>10^{-4}$ or HIs >1) are shown in ***boldface italics***.

Whitney

- Subsurface Soil (***PCB Aroclors***)
- Indoor air attributable to groundwater (***C5-C8 Aliphatic Hydrocarbons***)

Murphy Wetlands

- Sediment (***PCB Aroclors***)

Off-Site Resident

- Ingestion and Dermal Contact with Groundwater (***trichloroethene***, ***vinyl chloride***, benzo(a)pyrene, dibenz(a,h)anthracene, arsenic, and PCB Congeners)
- Inhalation of Volatiles during showering (1,1,2-trichloroethane, trichloroethene, and vinyl chloride)

Lead in soil and sediment was evaluated through the use of EPA models for children and adults. The lead evaluation indicated that exposures to lead in current and future scenarios would not result in adult or childhood blood lead levels in excess of blood lead level goals. Therefore, lead in soil and sediment was determined not to be of concern for human receptors at the Southwest Properties. Since the average concentrations of lead in groundwater was below the Safe Drinking Water Act (SDWA) action level of 15 ug/L, the model default value was used. This results in a more conservative evaluation. Note however, the maximum concentration of lead detected in groundwater (148 ug/L) does exceed the SDWA action level and further evaluation may be required.

Evaluation of risks associated with background soils indicate that the total RME background cancer risks for arsenic is greater than the risk calculated for exposures to soil at any of the three

properties. Thus, the cancer risks in excess of the target risk range for the Future Recreational User at the Whitney property cannot be distinguished from the risk associated with arsenic with background conditions and therefore arsenic is not considered to be a major contributor of risk from exposure to soils for this property.

In addition, the risks calculated for sediment in the Murphy Wetland were compared to the risk calculated for wetland sediment background from the Wells G&H OU-3 River Study based on an equivalent recreational user scenario adjusted for 78 day per year exposures. Risks compared were for arsenic and benzo(a)pyrene contamination since these contaminants were identified as risk drivers in the Murphy Wetland and were also assessed in OU-3 background. This comparison is provided below:

Contaminant	Risk Basis	Murphy Wetland Recreational User	OU-2 Wetland 4-Day Recreational User*
Arsenic	ILCR	2E-06	8E-06
Benzo(a)pyrene	ILCR	8E-06	6E-06
* - Adjusted from 104 days per year to 78 days per year for equal comparison to the Murphy Wetland Recreational User.			

5.1.5 Ecological Risk Assessment

Overall, the ERA predicted risk to ecological receptors that may inhabit the Murphy Wetland. The primary risk drivers are PCBs, chromium and lead while the receptors identified as being at risk are aquatic invertebrates, herbivorous mammals and insectivorous mammals. Highest risk to benthic invertebrates are attributable to levels of PCBs, lead, and chromium within the sediment of the seasonally ponded area of the Murphy Wetland. There was also evidence of high potential risk on the reproduction of muskrats (herbivorous mammal) due to exposure to PCBs, lead, and chromium within the seasonally ponded area of Murphy Wetland. There was low risk potential to mallards (avian omnivore) that forage on the Site from lead. The risk potential to shrews (insectivorous mammal) inhabiting the Murphy Wetland was high and attributable to PCBs. A summary of the risks are discussed below and presented in Table 5-3.

The effects-based screening resulted in the selection of 5 COPCs in surface water (all inorganics) and 60 COPCs in sediment/surface soil (VOCs, SVOCs, pesticides/PCBs, and inorganics) for evaluation in the ERA. Five indicator species or indicator communities were selected to evaluate risks associated with exposure to the COPCs in the surface water and sediment/surface soil of the Site. Endpoints in the ERA were selected to represent ecological attributes that are to be protected (assessment endpoints) and a measurable characteristic of those attributes (measurement endpoints) that can be used to gauge the degree of impact that has or may occur.

Each endpoint has associated with it a magnitude of risk and a degree of uncertainty. The magnitude of risk incorporates both the degree to which the endpoint was exceeded and also the proportion of the habitat affected. If the NOAEL TRV (lower effects threshold) was exceeded at the site, the contaminant was concluded to pose a low risk to populations. The highest risk was associated with contaminants that exceeded upper threshold effects levels based on LOAEL TRVs. If high HQs were present only for the maximum (or 95% UCL) COPC concentration, the magnitude of the overall risk to the population from exposure to the COPC was considered low.

The invertebrate endpoints suggest that there may be impacts from organic and inorganic contaminants on invertebrate communities inhabiting the seasonally ponded area of the Murphy Wetland. The strength of the evidence was based entirely on exceedances of sediment-effects benchmarks. The benchmark analysis indicated a high risk potential to benthic invertebrate communities from PCB Aroclors 1254 and 1260 and from inorganics, especially chromium, lead, and zinc with the highest HQs attributable to PCBs, chromium and lead. Since the benchmarks used for each of these COPCs was the SEL (severe effect level) they represent contaminant levels that potentially eliminate many of the benthic organisms within the community (Persaud, *et al.*, 1993). Biological effects evaluations, in the form of sediment toxicity testing or benthic community structure were not undertaken for this ERA.

Table 5-3
Summary of Receptor Risks – Ecological Risk Assessment
Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts

Property	Receptor	Receptor Indicator Species	Habitat	Media	Major Contributors to Risk (HQ > 1 for LOAEL or ER-M/SEL)
Murphy Wetland	Macrobenthic Community	NA	Seasonally Ponded Area	Sediment	PCB Aroclors 1254/1260* chromium lead zinc
	Mammalian Herbivore	Muskrat	Seasonally Ponded Area	Sediment	PCB Congeners* PCB Aroclors 1254/1260* chromium lead
	Mammalian Insectivore	Short-tailed Shrew	Seasonally Ponded Area	Sediment	PCB Congeners* Aroclors 1254/1260*
			Forested/Scrub-Shrub Area	Sediment	Aroclor 1254*

Notes:
NA – Not applicable
HQ – Hazard Quotient
LOAEL – Lowest Observable Adverse Effect Level
ER-M/SEL – Effects Range-Median and Severe Effect Level (Sediment Benchmarks)
PCB – polychlorinated biphenyls
* - Greatest risk driver for that receptor

Analysis of the mean exposure assessment for muskrat indicated HQs greater than 1 based on NOAEL TRVs, for PCB Aroclors 1254 and 1260, PCB congeners, antimony, arsenic, barium, chromium, iron, lead and vanadium. Arsenic, barium, iron and vanadium had low HQs (HQs < 4 based on NOAEL TRVs) and/or mean concentrations similar to levels detected at the reference wetland locations indicating a low risk potential. The mean estimated exposure to antimony does not exceed the upper effect level based on the LOAEL TRV. However, mean exposure doses of PCB Aroclors 1254 and 1260, PCB congeners, chromium and lead estimated to be ingested by the muskrat result in HQs above 1 based on LOAEL TRVs. Due to the elevated HQs (particularly for PCB Aroclor 1254), the magnitude of the risk for muskrat exposure to these COPCs is high. These results indicate a potential impact on reproduction of mammal populations such as muskrat exposed to PCBs in the diet while foraging in the seasonally ponded area of the Murphy Wetland.

The mallard was used to represent waterfowl having relatively high exposure to sediments. Based on NOAEL TRVs, lead represented the only COPC to have a HQ greater than 1 for the Site based on the average exposure case. The concentrations of lead indicated low risk for reduction in reproduction or sublethal effects to populations, but there was no evidence for high risk to populations since the lead LOAEL HQ was less than 1. The assessment of the waterfowl endpoint indicates a low risk to the sub-population of mallards at the seasonally ponded area of the Murphy Wetland from exposure to lead. The magnitude of the risk to mallard populations from lead was low since it is based on the NOAEL TRV value, which represents the threshold for effects for potential impacts to populations.

Short-tailed shrew exposure models were used to evaluate potential risk to small mammal populations living in and near the Murphy Wetland. Analysis of the mean exposure assessment for shrew indicated HQs greater than 1, based on NOAEL TRVs, for PCB Aroclors 1254 and 1260, PCB congeners, antimony, chromium, iron, lead and vanadium at the seasonally ponded area of the Murphy Wetland while PCB Aroclors 1254 and 1260, chromium and iron have HQs greater than 1 (also based on NOAEL TRVs) at the forested/scrub-shrub area of the Murphy Wetland. Iron and vanadium had mean concentrations similar to levels detected at the reference wetland locations indicating a low risk potential due to Site exposure. The mean estimated

exposures to antimony, chromium and lead do not exceed the upper effect level based on their respective LOAEL TRV at either habitat within the Murphy Wetland. However, mean exposure doses of PCB Aroclor 1254 estimated to be received by the shrew at the seasonally ponded and the forested/scrub-shrub areas result in an HQ above 1 based on its LOAEL TRV. In addition, the mean exposure doses of PCB Aroclor 1260 and PCB congeners at the seasonally ponded area of the Murphy Wetland are also above 1. Due to the elevated HQs (particularly for PCB Aroclor 1254), the magnitude of the risk for shrew exposure to PCB Aroclor 1254 is high. These results indicate a potential impact on reproduction of mammal insectivore populations such as shrews exposed to PCBs in the diet while foraging in the seasonally ponded and forested/ scrub-shrub areas of the Murphy Wetland.

The uncertainty associated with the estimation of risk, summarized in section 4.4.7, was qualitatively assessed, and based on many factors. A major source of uncertainty for mammalian and avian indicators was the relevance of the available TRVs. High uncertainty was also associated with COPCs that had corresponding high concentrations at reference locations. In cases where the magnitude of risk was low, and was associated with high degree of uncertainty, the overall risk for that endpoint was considered negligible.

5.2 Conclusions

Conclusions for the human health risk assessment and the ecological risk assessment are presented below.

5.2.1 Human Health

Aberjona. The ILCRs and HIs are all below risk criteria for all scenarios and scenarios and pathways evaluated at the Aberjona property.

Whitney. The RME and/or CT ILCR and/or HI exceed the target risk range for the Current and Future Commercial Worker, Future Recreational User, and Future Construction Worker. Major risk drivers contributing to the exceedances for the Commercial Worker include direct contact with PCB Aroclors in surface soil as well as C5-C8 Aliphatic and C9-C18 Aliphatic

Hydrocarbons in indoor air attributable to subsurface soil. The major risk drivers contributing to the exceedance for the Recreational Worker are direct contact with PCB Aroclors in surface soil, and PCB Aroclors, PCB congeners, and chlordanes in subsurface soil. The major risk driver for Construction Worker exceedances is PCB Aroclors and chlordanes in subsurface soil.

Murphy. The ILCRs and HIs are all below risk management criteria for all scenarios and pathways evaluated.

Murphy Wetland. The RME ILCR exceeds the target risk range for the Future Young Child/Adult Recreational User. The RME and CT HIs were above the target HI of 1 for the Future Older Child Trespasser and the Future Young Child/Adult Recreational User. The major risk driver associated with the exceedance for the Future Trespasser is PCB Aroclors in sediment. The major risk drivers contributing to the exceedance for the Future Recreational receptor are chromium and PCB Aroclors in sediment for the RME case, and PCB Aroclors for the CT case.

Off-Site Resident. The RME and CT cancer and non-cancer risks exceed risk management criteria for the future off-site resident exposed to groundwater during household use. The major risk drivers associated with RME exceedances are direct contact with 1,3,-dichlorobenzene, benzene, cis-1,2-dichloroethene, trichloroethene, vinyl chloride, C9-C18 Aliphatic hydrocarbons, C11-C22 Aromatic Hydrocarbons, arsenic, and manganese. In the CT case, trichloroethene and vinyl chloride were the major risk drivers. The inhalation pathway also had RME exceedances of the cancer and non-cancer risk management criteria with 1,1,2-trichloroethane and trichloroethene as major risk drivers.

Six background surface and subsurface soil samples (AB-5, AB-10, AB- 17, WB-14, MR-19, and MR-18) were collected from locations that were outside of the areas of impact at the three properties. In addition, two background groundwater samples (MW-1 and MW-2) were collected from a location upgradient of the three properties. Soil samples were analyzed for metals only and groundwater samples were analyzed for VOCs, SVOCs, VPH, EPH, PCB congeners, metals (including hexavalent chromium), and cyanide. Background data were

compared to applicable screening criteria, and the screening resulted in the selection of arsenic as a COPC for background surface soil, and the selection of arsenic and manganese as subsurface soil COPCs. No COPCs were selected for groundwater background since all analytical results were below applicable screening criteria.

Cancer and non-cancer risk calculations for background conditions are provided in Appendix C.2. Risks associated with background soil were calculated using combined background data collected from Aberjona, Whitney and Murphy. Background COPCs were identified by comparing the maximum subsurface soil with preliminary remedial goals (PRGs) published by EPA Region 9 (EPA, 2002b). Arsenic was identified as a COPC in surface and subsurface soil and manganese was identified as a COPC in subsurface soil. However, calculated risk was determined to be less than the target cancer risk range and less than the target HI.

In addition, the comparison of Murphy Wetland risk drivers (arsenic and benzo(a) pyrene) with corresponding OU-3 background wetland risk calculation showed that OU-3 background risk was greater for arsenic, but less for benzo(a)pyrene. However, the ILCR risk for each contaminant in the Murphy Wetland and OU-3 background wetland was in the same order of magnitude.

The following two tables summarize RME and CT exposure scenarios and major risk contributors for current and future timeframes. Figure 5-1 provides a site plan summarizing human health risks.

Southwest Properties – Major RME Risk Contributor Summary				
Property	**Timeframe**	**Receptor**	**Media (>1E-04 or HI >1)**	**Major Contributors to Risk (>1E-04, HI >1)**
Whitney	Current/Future	Commercial Worker	Surface Soil	PCB Aroclors
	Future	Commercial Worker	Indoor Air	C5-C8 Aliphatic Hydrocarbons C9-C-18 Aliphatic Hydrocarbons
		Recreational User	Surface Soil	PCB Aroclors
			Subsurface Soil	PCB Aroclors PCB Congeners alpha-chlordane gamma-chlordane
		Construction Worker	Surface Soil	PCB Aroclors
			Subsurface Soil	PCB Aroclors alpha-chlordane gamma-chlordane
Murphy Wetland	Future	Trespasser	Sediment	PCB Aroclors
		Recreational User	Sediment	Chromium III PCB Aroclors
Off-Site Resident	Future	Resident	Tap Water	1,3-dichlorobenzene benzene cis-1,2-dichloroethene trichloroethene vinyl chloride C9-C18 Aliphatic Hydrocarbons C11-C22 Aromatic Hydrocarbons arsenic manganese
			Indoor Air (Showering)	1,1,2-trichloroethane trichloroethene

Southwest Properties – Major CT Risk Contributor Summary				
Property	**Timeframe**	**Receptor**	**Media (>1E-04 or HI >1)**	**Major Contributors to Risk (>1E-04, HI >1)**
Whitney	Future	Commercial Worker	Indoor Air	C5-C8 Aliphatics
		Recreational User	Subsurface Soil	PCB Aroclors
		Construction Worker	Subsurface Soil	PCB Aroclors
Murphy Wetland	Future	Recreational User	Sediment	PCB Aroclors

Southwest Properties – Major CT Risk Contributor Summary				
Property	**Timeframe**	**Receptor**	**Media (>1E-04 or HI >1)**	**Major Contributors to Risk (>1E-04, HI >1)**
Off-Site Resident	Future	Resident	Tap Water	1,1,2-trichloroethane trichloroethene vinyl chloride

5.2.2 Ecological Risk Assessment

The sediment benchmark analysis indicated potential effects on benthic communities within the seasonally ponded area of the Murphy Wetland from PCB Aroclors 1254 and 1260 and from inorganics, especially chromium, lead, and zinc. The highest risk to the benthic macroinvertebrate community is attributable to PCBs, chromium and lead. Since the benchmarks used for each of these COPCs was the SEL (severe effect level) they represent contaminant levels that potentially eliminate many of the benthic organisms within the community. Biological effects evaluations, in the form of sediment toxicity testing or benthic community structure were not undertaken for this ERA.

There was evidence of potential risk of impacts on the reproduction of muskrat due to the exposure to PCBs, chromium and lead within the seasonally ponded area of the Murphy Wetland. There was low risk to mallards foraging at the Murphy Wetland from exposure to lead. A potential reproductive risk to shrew populations is present at the Site from exposure to PCB Aroclors and Congeners in sediment and diet and this risk was highest for Aroclor 1254.

The following table summarizes the sediment risk drivers for the Murphy Wetland. A summary of the risk drivers for ecological receptors inhabiting the Murphy Wetland is also presented in Figure 5-1.

Summary of Ecological Receptor Risks for Murphy Wetland			
Receptor	**Receptor Indicator Species**	**Habitat**	**Major Contributors to Risk***
Macrobenthic Community	Not Applicable	Seasonally Ponded Area	PCB Aroclors 1254/1260** chromium lead zinc

Summary of Ecological Receptor Risks for Murphy Wetland			
Receptor	**Receptor Indicator Species**	**Habitat**	**Major Contributors to Risk***
Mammalian Herbivore	Muskrat	Seasonally Ponded Area	PCB congeners** PCB Aroclors 1254/1260** chromium lead
Mammalian Insectivore	Short-tailed Shrew	Seasonally Ponded Area	PCB congeners** Aroclors 1254/1260**
		Forested/Scrub-Shrub Area	Aroclor 1254**

Notes: * - HQ > 1 for LOAEL or ER-M/SEL ** - Greatest risk driver for that receptor. NA – Not applicable
HQ – Hazard Quotient LOAEL – Lowest Observable Adverse Effect Level
ER-M/SEL – Effects Range-Median and Severe Effect Level (Sediment Benchmarks)
PCB – polychlorinated biphenyls

6.0 REFERENCES

Executive Summary

City of Woburn, 1997. Zoning Map of the City of Woburn.

Clean Harbors 1996, *Corrective Action Investigation Report*, Volumes 1, 2, and 3. Murphy's Waste Oil Service, Inc., 252 Salem Street, Woburn, Massachusetts, April 15, 1996.

Clean Harbors, 1998, *Corrective Action Investigation Report (Part II)*, Volume I of I, Murphy's Waste Oil Sources, Inc., Woburn, Massachusetts, 1998.

RETEC, 1994, *Draft Remedial Investigation Southwest Properties, Wells G&H Site, Woburn, Massachusetts*, Prepared for Beatrice Company. Prepared by Remediation Technologies, Inc, Concord Massachusetts, February, 1994.

RETEC, 2003. *Supplemental Remedial Investigation Report, Southwest Properties, Volumes 1 through XXIII, Wells G&H Superfund Site, Woburn, Massachusetts*. Prepared for: Beatrice Company, Prepared by: The RETEC Group, Inc., Concord, Massachusetts, August 2003.

TRC, 2004. *EPA/TRC and RETEC Split Sample Comparison Report for the Wells G&H Southwest Properties Supplemental Remedial Investigation.* Prepared by TRC Environmental Corporation, Lowell, Massachusetts. February 2004.

U.S. Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Part A.* Interim Final. EPA/540/1-89/002. December 1989.

U.S. Environmental Protection Agency (EPA). 1992. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Office of Solid Waste and Emergency Response. Washington, D.C. Publication 9285.7-081. May 1992.

U.S. Environmental Protection Agency (EPA). 1994. *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children.* Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/R-93/081. February 1994.

U.S. Environmental Protection Agency (EPA). 2002a. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* OSWER 9285.6-10 Office of Emergency and Remedial Response, Washington, DC. December 2002.

U.S. Environmental Protection Agency (EPA). 2002b. *Preliminary remediation goals table. Region 9 technical support team.* Office of Superfund Programs. Region IX. October 1, 2002.

Section 1.0

Barosh, P.J., Fahey, R.J., and Pease, M.H., 1977. Preliminary Compilation of the Bedrock Geology of the Land Area of the Boston 2º Sheet, Massachusetts, Connecticut, Rhode Island, and New Hampshire. U.S. Geological Survey Open File Report 77-285.

Delaney, D.F. and Gay, F.B. Hydrology and Water Resources of the Coastal Drainage Basins of Northeastern Massachusetts, from Castell Neck River, Ipswich, to Mystic River, Boston: U.S. Geological Survey, Hydrologic Atlas 589. 1980.

Donaldson, R.M. and R.F. Barreras. 1996. Intestinal absorption of trace quantities of chromium. J. Lab. Clin. Med. 68:484-493.

Ebasco, 1988. Final Supplemental Remedial Investigation for Feasibility Study. Wells G&H Site, Woburn, Massachusetts. Prepared for the U.S. Environmental Protection Agency. Prepared by EBASCO Services Incorporated. December, 1988.

EPA 1989, U.S. Environmental Protection Agency, Record of Decision, Wells G&H Site, Woburn, Massachusetts, September 14, 1989.

GeoInsight 2000. *Summary of Technical and Remedial Information*, Olympia Nominee Trust Property, 60 Olympia Avenue, Woburn, Massachusetts. Prepared for Olympia Nominee Trust, Winchester, Massachusetts. Prepared by GeoInsight, Inc., Westford, Massachusetts, August 24, 2000.

GeoTrans 1987. Review of EPA Report titled, *"Wells G&H Site Remedial Investigation Report, Part I"*, Woburn, Massachusetts. Prepared by GeoTrans, Inc. July 1987.

GeoTrans 1994. *Wells G&H Site Central Area Remedial Investigation Phase IA Report, Volumes I, II and III*. Prepared for Beatrice Corporation, UniFirst Corporation, and W.R. Grace & Co. – CT. Prepared by GeoTrans, Inc. Groundwater Specialists, Harvard, Massachusetts January/February 1994.

GHR 1988. Site Assessment Report of the Former Whitney Barrel Company Site, 256 Salem Street, Woburn Massachusetts. Prepared for Ruth J. Whitney. Prepared by GHR Engineering Associates, Inc., Lexington, Massachusetts, 1988.

HMM 1990. New England Plastics, Wells G&H Site Hydrologic Site Investigation: Prepared by HMM Associates, Inc. February 1990.

Myette, C.F., Olimpio, J.C., and Johnso, D.G. Area of Influence and Zone of Contribution to Superfund-Site Wells G&H, Woburn, Massachusetts: U.S. Geological Survey WRI 87-4100. 1987.

NUS Corporation 1986. Wells G&H Site Remedial Investigation Report, Part 1, Woburn, Massachusetts, Volume I: Report prepared for Region I, U.S. EPA Waste Management Division. Prepared by NUS Corporation Superfund Division. October 17, 1986.

RETEC 1994, *Draft Remedial Investigation Southwest Properties, Wells G&H Site, Woburn, Massachusetts*, Prepared for Beatrice Company. Prepared by Remediation Technologies, Inc, Concord Massachusetts, February, 1994.

RETEC 2002. *Sampling and Analysis Plan, Supplemental Remedial Investigation, Volumes I & II. Southwest Properties, Wells G&H Superfund Site, Woburn, Massachusetts*. Prepared for Beatrice Company. Prepared by The RETEC Group, Concord, Massachusetts. November 2002.

RETEC 2003. Electronic mail correspondence from J. Greacen of The RETEC Group to D. Sullivan of TRC Environmental Corporation RE: The "transcription error" tables. March 24, 2003.

TRC 2002, Field Sampling Plan for RI/FS Oversight, Southwest Properties, Wells G&H Superfund Site, Operable Unit 2, Woburn, Massachusetts. Prepared by TRC Environmental Corporation, Lowell, Massachusetts, November 2002.

USGS, 1991. U.S. Geological Survey, Water Resources Data, Massachusetts and Rhode Island, Water year 1990: U.S. Geological Survey Water Data Report MA-RI-90-1. 1991.

Section 2.0

RETEC, 2003. *Supplemental Remedial Investigation Report, Southwest Properties, Volumes 1 through XXIII, Wells G&H Superfund Site, Woburn, Massachusetts*. Prepared for: Beatrice Company, Prepared by: The RETEC Group, Inc., Concord, Massachusetts, August 2003.

TRC, 2004. *EPA/TRC and RETEC Split Sample Comparison Report for the Wells G&H Southwest Properties Supplemental Remedial Investigation.* Prepared by TRC Environmental Corporation, Lowell, Massachusetts. February 2004.

U.S. Environmental Protection Agency (EPA). 1989a. *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference.* Environmental Research Laboratory. Corvallis, OR. EPA/600/3-89/013.

U.S. Environmental Protection Agency (EPA). 1989b. *Exposure Factors Handbook.* Office of Health and Environmental Assessment. Washington, DC. July 1989.

U.S. Environmental Protection Agency (EPA). 1991. *Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions.* Office of Solid Waste and Emergency Response. Washington, D.C. OSWER Directive 9355.0-30. Memo from Don R. Clay. April 22, 1991.

Section 3.0

Agency for Toxic Substances and Disease Registry (ATSDR). 1997a. *Toxicological Profile for antimony.* U.S. Department of Health and Human Services. Public Health Service. December 1997.

Agency for Toxic Substances and Disease Registry (ATSDR). 1997b. *Toxicological Profile for Barium.* U.S. Department of Health and Human Services. Public Health Service. December 1997.

Castell etal, 2002. Relative Bioavailability of Arsenic in Sediments from the Aberjona River, S.W. Castell, T.J. Evans, J. LeMay, W.J. Brattin, and A.M Wahlquist. Base line Human Health Risk Assessment Report, Wells G&H Superfund Site, Aberjona River Study, Operable Unit 3, Woburn, Massachusetts, March 2003.

Chen, C.J., C.W. Chen, M.M. Wu, and T.L. Kuo. 1992. Cancer Potential in Liver, Lung Bladder and Kidney Due to Ingested Inorganic Arsenic in Drinking Water. *Br. J. Cancer* 66:888-892.

City of Woburn 1997. Zoning Map of the City of Woburn.

Clean Harbors 1996, *Corrective Action Investigation Report*, Volumes 1, 2, and 3. Murphy's Waste Oil Service, Inc., 252 Salem Street, Woburn, Massachusetts, April 15, 1996.

Clean Harbors 1998, *Corrective Action Investigation Report (Part II),* Volume I of I, Murphy's Waste Oil Sources, Inc., Woburn, Massachusetts, 1998.

Conklin, A.W., S.C. Skinner, T.L. Felton, and C.L. Sanders. 1982. Clearance and Distribution of Intratracheally Instilled Vanadium Compounds in the Rat. *Toxicol. Lett.* 11:199-203.

Davidsson, L., A. Cederblad, B. Lonnerdal, and B. Sandstrom. 1989. Manganese Retention in Man: A Method for Estimating Manganese Absorption in Man. *Am. J. Clin. Nutr.* 49:170-179.

Foster and Chrostowski, 1986. Sara A. Foster and Paul C. Chrostowski, ICF Clement Assoc. *Integrated Exposure Model for Use of Tap Water Contaminated with Volatile Organic Chemicals.* 79th Annual Meeting of the Air Pollution Control Association, Minneapolis, Minnesota. June 1986.

Foster and Chrostowski, 1987. Sara A. Foster and Paul C. Chrostowski, ICF Clement Assoc., Washington, DC. *Inhalation Exposure to Volatile Organic Contaminants in the Shower.* 80th Annual Meeting of the Air Pollution Control Association New York, New York. June 21 – 26, 1987.

MADEP, 2002. Characterizing Risks Posed by Petroleum Contaminated Sites: *Implementation of the MADEP VPH/EPH Approach.* Final Policy #WSC-02-411. October 31, 2002.

McLellan, J.S., P.R. Flanagan, M.J. Chamberlain and L.S. Valberg. 1978. Measurement of Dietary Cadmium Absorption in Humans. *J. Toxicol. Environ. Health* 4:131-138.

Metcalf and Eddy, Inc. (M&E). 2000. Personal communication from J. Barry, Winchester Board of Health, to K. Scott, Metcalf & Eddy, Inc. regarding consumption of aquatic species from the Aberjona River. June 29, 2000.

Office of Environmental Health Hazard Assessment (OEHHA). 2002. *Technical Support Document for Describing Available Cancer Potency Factors.* California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section. December 2002.

RETEC 1994, *Draft Remedial Investigation Southwest Properties, Wells G&H Site, Woburn, Massachusetts,* Prepared for Beatrice Company. Prepared by Remediation Technologies, Inc, Concord Massachusetts, February, 1994.

RETEC 2002. Sampling and Analysis Plan, Supplemental Remedial Investigation, Volumes I and II. Southwest Properties, Wells G&H Superfund Site, Woburn, Massachusetts. Prepared for Beatrice Company. Prepared by: The RETEC Group, Concord, Massachusetts. July 19, 2002. November, 2002.

RETEC, 2003. *Supplemental Remedial Investigation Report, Southwest Properties, Volumes 1 through XXIII, Wells G&H Superfund Site, Woburn, Massachusetts.* Prepared for: Beatrice Company, Prepared by: The RETEC Group, Inc., Concord, Massachusetts, August 2003.

TRC 2004. *EPA/TRC and RETEC Split Sample Comparison Report for the Wells G&H Southwest Properties Supplemental Remedial Investigation.* Prepared by TRC Environmental Corporation, Lowell, Massachusetts. February 2004.

Tseng, W.P., H.M. Chu, S.W. How, J.M. Fong, C.S. Lin, and S. Yeh. 1968. *Prevalence of Skin Cancer in an Endemic Area of Chronic Arsenicism in Taiwan. J. Natl. Cancer Inst.* 40:453-462.

Tseng, W.P. 1977. *Effects and Dose-Response Relationships of Skin Cancer and Blackfoot Disease with Arsenic. Environ. Health Perspect.* 19:109-119.

U.S. Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Part A.* Interim Final. EPA/540/1-89/002. December 1989.

U.S. Environmental Protection Agency. 1991a. *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual* (PART B, Development of Risk-Based Preliminary Remediation Goals) Interim EPA/540/R-92/003, Publication 9285.701B, December 1991.

U.S. Environmental Protection Agency (EPA). 1991b. *Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions.* Office of Solid Waste and Emergency Response. Washington, D.C. OSWER Directive 9355.0-30. Memo from Don R. Clay. April 22, 1991.

U.S. Environmental Protection Agency (EPA). 1992. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Office of Solid Waste and Emergency Response. Washington, D.C. Publication 9285.7-081. May 1992.

U.S. Environmental Protection Agency (EPA). 1993a. *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons.* Office of Research and Development. Washington, DC. EPA/600/R-93/089. July 1993.

U.S. Environmental Protection Agency (EPA). 1993b. *Health Effects Assessment Summary Tables.* 1993.

U.S. Environmental Protection Agency (EPA). 1994a. *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities.* Office of Solid Waste and Emergency Response. Washington, D.C. OSWER Directive 9355.4-12. July 1994.

U.S. Environmental Protection Agency (EPA). 1994b. *Risk updates, no. 2.* EPA Region I. August 1994.

U.S. Environmental Protection Agency (EPA). 1994E. *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children.* Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/R-93/081. February 1994.

U.S. Environmental Protection Agency (EPA). 1995. *Risk Updates, No. 3.* EPA Region I. August 1995.

U.S. Environmental Protection Agency (EPA). 1996a. *Risk updates, no. 4.* EPA Region I. November 1996.

U.S. Environmental Protection Agency (EPA). 1997a. *Exposure factors handbook.* Office of Research and Development. Washington, D.C. August 1997.

U.S. Environmental Protection Agency (EPA). 1997b. *Health effects assessment summary tables, FY-1997 annual (HEAST).* Office of Health and Environmental Assessment. Environmental Assessment and Criteria Office and Office of Solid Waste and Emergency Response. Washington, D.C. July 1997.

U.S. Environmental Protection Agency (EPA). 1998a. Personal communication from M. McDonough, EPA, to D. Silverman, Metcalf & Eddy, Inc. regarding iron, cobalt and aluminum as COPCs for Wells G&H OU3. April 21, 1998.

U.S. Environmental Protection Agency (EPA). 2000. *Exposure and reassessment of 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (TCDD) and related compounds. National Center for Environmental Assessment.* March 2000.

U.S. Environmental Protection Agency (EPA). 2001a. *Risk assessment guidance for Superfund. Volume I: Human health evaluation manual. Part D, Standardized planning, reporting, and review of Superfund risk assessments. Interim.* Office of Solid Waste and Emergency Response. Washington, D.C. December 2001.

U.S. Environmental Protection Agency (EPA). 2001b. *Risk assessment guidance for Superfund Volume I: Human health evaluation manual (Part E, Supplemental guidance for dermal risk assessment), interim guidance.* Office of Emergency and Remedial Response. Washington, D.C. EPA/540/R-99/005. September 2001.

U.S. Environmental Protection Agency (EPA). 2001c. *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Interim.* Office of Solid Waste and Emergency Response. Washington, DC

U.S. Environmental Protection Agency (EPA). 2001d. *Integrated risk information system (IRIS).* Environmental Criterion and Assessment Office. February 2001.

U.S. Environmental Protection Agency. 2001e. *Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft).* Office of Research and Development, Washington, DC, EPA/600/P-01/002A. August 2001.

U.S. Environmental Protection Agency (EPA). 2002a. *User's guide for the integrated exposure uptake biokinetic model for lead in children.* Off ice of Emergency and Remedial Response. Washington, D.C. EPA 9285.7-42. May 2002.

U.S. Environmental Protection Agency (EPA). 2002b. *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance).* U.S. EPA Office of Solid Waste and Emergency Response (OSWER). November 29, 2002.

U.S. Environmental Protection Agency (EPA). 2002c. *Preliminary remediation goals table. Region 9 technical support team.* Office of Superfund Programs. Region IX. October 1, 2002.

U.S. Environmental Protection Agency (EPA). 2002d. *Drinking water standards.* Office of Water. October 2002.

U.S. Environmental Protection Agency (EPA). 2002e. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* OSWER 9285.6-10 Office of Emergency and Remedial Response, Washington, DC. December 2002.

U.S. Environmental Protection Agency (EPA). 2003a. *Baseline Human Health Risk Assessment Report, Wells G&H Superfund Site, Aberjona River Study, Operable Unit 3, Woburn, Massachusetts*. Prepared by Metcalf & Eddy, Inc., Wakefield, Massachusetts. March 2003.

U.S. Environmental Protection Agency (EPA). 2003b. *Integrated risk information system (IRIS).* Environmental Criterion and Assessment Office. February 2003.

U.S. Environmental Protection Agency (EPA). 2003c. *Recommendations of the Technical Review Workgroup for lead for an approach to assessing risk associated with adult exposures to lead in soil.* Technical Review Workgroup for Lead. United States Environmental Protection Agency. January 2003.

Van den Berg *et al*. (1998). *Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ. Health Perspect.* 106(12):775-797.

Section 4.0

Agency for Toxic Substances and Disease Registry (ATSDR). 1992a. *Toxicological profile for pentachlorophenol*. U.S. Department of Health and Human Services. Public Health Service. July 1992.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992b. *Toxicological profile for barium*. U.S. Department of Health and Human Services. Public Health Service. July 1992.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992c. *Toxicological profile for cobalt*. U.S. Department of Health and Human Services. Public Health Service. July 1992.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994a. *Toxicological profile for acetone*. U.S. Department of Health and Human Services. Public Health Service. May 1994.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994b. *Toxicological profile for 4,4'-DDT, 4,4'-DDE, and 4,4'- DDD*. U.S. Department of Health and Human Services. Public Health Service. May 1994.

Agency for Toxic Substances and Disease Registry (ATSDR). 1995a. *Toxicological profile for polycyclic aromatic hydrocarbons (PAHS)*. U.S. Dept. of Health and Human Services. Public Health Service. August 1995.

Agency for Toxic Substances and Disease Registry (ATSDR). 1996a. *Toxicological profile for carbon disulfide*. U.S. Dept. of Health and Human Services. Public Health Service. August 1996.

Agency for Toxic Substances and Disease Registry (ATSDR). 1996b. *Toxicological profile for methyl tert-butyl ether*. U.S. Dept. of Health and Human Services. Public Health Service. August 1996.

Agency for Toxic Substances and Disease Registry (ATSDR). 1998. *Toxicological profile for phenol*. U.S. Dept. of Health and Human Services. Public Health Service. August 1998.

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. *Toxicological profile for lead*. U.S. Dept. of Health and Human Services. Public Health Service. Updated July 1999.

Agency for Toxic Substances and Disease Registry (ATSDR). 2000a. *Toxicological profile for polychlorinated biphenyls*. U.S. Dept. of Health and Human Services. Public Health Service. Updated November 2000.

Agency for Toxic Substances and Disease Registry (ATSDR). 2000b. *Toxicological profile for chromium*. U.S. Dept. of Health and Human Services. Public Health Service. Updated September 2000.

Andersson, M. 1988. Toxicity and tolerance of aluminum in vascular plants. *Water, Air and Soil Pollution* 39:439-463.

Beyer, W.N. 1990. Evaluating soil contamination. *U.S. Fish and Wildlife Service Biological Report* 90:25.

Beyer, W.N. and C. Stafford. 1993. Survey and evaluation of contaminants in earthworms and in soils derived from dredged material at confined disposal facilities in the Great Lakes region. *Environ. Monitor. Assessment.* 24:151-165.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *J. Wildlife Management* 58:375-382.

Blus, L.J. 1978. Short-tailed shrews: toxicity and residue relationships of DDT, dieldrin, and endrin. *Arch. Environ. Contam. Toxicol*. 7:83-98.

Buchman, M. 1999. NOAA Screening Quick Reference Tables, NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pp.

Bysshe, S.E. 1988. Uptake by biota. In: Bodek, I., W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt (eds.). *Environmental Inorganic Chemistry*. Pergamon Press. New York.

Clean Harbors, 1998, *Corrective Action Investigation Report (Part II)*, Volume I of I, Murphy's Waste Oil Sources, Inc., Woburn, Massachusetts, 1998.

Connell, D.W. and G.J. Miller. 1984. *Chemistry and ecotoxicology of pollution*. John Wiley and Sons. New York, New York. pp. 162-227.

Dobbs, M.G., D.S. Cherry, and J. Cairns, Jr. 1996. Toxicity and bioaccumulation of selenium to a three-trophic level food chain. *Environ. Toxicol. Chem*. 15:340-347.

Domingo, J.L. 1994. Metal-induced developmental toxicity in mammals: a review. *J. Toxicol.& Environ. Health.* 42:123-141.

Dutson, S.M., G.M. Booth, G.B. Schaalje, R.N. Castle, and R.E. Seegmiller. 1997. Comparative developmental dermal toxicity and mutagenicity of carbazole and benzo[*a*]carbazole. *Environ. Toxicol. Chem*. 16:2113-2117.

Duxbury, C.L., D.G. Dixon, and B.M. Greenburg. 1997. Effects of simulated solar radiation on the bioaccumulation of polycyclic aromatic hydrocarbons by the duckweed *Lemna gibba*. *Environ. Toxicol. Chem*. 16:1739-1748.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:46.

Eisler, R. 1986a. Polychlorinated biphenyl hazards to fish, wildlife and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:72.

Eisler, R. 1986b. Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:60.

Eisler, R. 1987a. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85: 81.

Eisler, R. 1987b. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:90.

Eisler, R. 1987c. Selenium hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:57.

Eisler, R. 1988a. Arsenic hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:92.

Eisler, R. 1988b. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:134.

Eisler, R. 1991. Cyanide hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85:1.23.

Eisler, R. 1993. Zinc hazards to fish, wildlife, and invertebrates: a synoptic review. *U.S. Fish and Wildlife Service Biological Report* 26:106.

Eisler, R. 2000. *Handbook of chemical risk assessment: health hazards to humans, plants and animals*, Volume I: Metals. Lewis Publishers, Boca Raton, FL.

Hartung, R. 1982. Cyanides and nitriles. In Clayton, F. D. and E. Clayton, Eds. *Patty's Industrial Hygiene and Toxicology*. Vol. 2C: 4845-4900. John Wiley & Sons, NY, NY.

Herkovits, J., P. Cardellini, C. Pavanati, and C.S. Perex-Coll. 1997. Susceptibility of early life stages of *Xenopus laevis* to cadmium. *Environ. Toxicol. Chem.* 16:312-316.

Hill, E.F., and M.B. Camardese. 1986. Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix. U.S. Fish and Wildlife Service Tech. Rep. 2.

Hudson, R.H., Tucker, R.K., and M.A. Haegle. 1984. *Handbook of toxicity of pesticides to wildlife*. U.S. Department of the Interior. Fish and Wildlife Service. Washington, D.C. Resource Publication 153.

Ireland, D.S., G.A. Burton, and G.G. Hess. 1996. In situ toxicity evaluations of turbidity and photoinduction of polycyclic aromatic hydrocarbons. *Environ. Toxicol. Chem.* 15:574-581.

Jones, D.S., G.W. Suter II, and R.N. Hull. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision. Lockheed Martin Energy Systems, Inc. ES/ER/TM-95/R4.

Jurens, P.G., and J.C. Schepens. 1993. Human Pentachlorophenol Poisoning. *Human and Exp. Toxicol.* 12:479-495.

Kelly, J.M., M. Schaedle, F.C. Thornton, and J.D. Joslin. 1990. Sensitivity of tree seedlings to aluminum: II. red oak, sugar maple, and European beech. *J. Environ. Quality* 19:172-180.

Klaassen, C.D. 1996. *Casarett and Doull's toxicology: The basic science of poisons, fifth edition*. McGraw-Hill, New York.

Locke, L.N. and N.J. Thomas. 1996. Lead poisoning of waterfowl and raptors. In: A. Fairbrother, L.N. Locke, and G.L. Hoff (eds.). *Noninfectious Diseases of Wildlife, Second Edition*. Iowa State University Press. Ames, Iowa.

Long, E.R., D.D. McDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management* 19:81-97.

Long, E.R. and L.G. Morgan. 1990. *The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program*. NOAA Technical Memorandum NOS OMA 52, Seattle, WA.

Lotufo, G. R. and J. W. Fleeger. 1996. Toxicity of sediment-associated pyrene and phenanthrene to *Limnodrilus hoffmeisteri* (Oligochaeta: Tubificidae). *Environ. Toxicol. Chem*. 15:1508-1516.

Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. *American wildlife and plants, a guide to wildlife food habitats*. Dover Publications, Inc. New York.

Massachusetts Natural Heritage and Endangered Species Program (MANHESP). 1999. Natural Heritage Atlas 2000-2001 Edition. MA Div. Fisheries and Wildlife. Oct.

Mayer, F.L. and M.R. Ellersieck. 1986. *Manual of acute toxicity: Interpretation and data base for 410 chemicals and 66 species of freshwater animals*. U.S. Department of the Interior. Fish and Wildlife Service. Washington, D.C. Resource Publication 160.

Metcalf & Eddy, Inc. (M&E). 2003. Baseline Ecological Risk Assessment – Aberjona River

National Academy of Science (NAS). 1980. *Mineral tolerance of domestic animals.* Subcommittee on mineral toxicity in animals. National Research Council. Washington, D.C.

Neff, J.M. 1985. Polycyclic Aromatic Hydrocarbons. In: Rand, G.M. and S.R. Petrocelli (eds). *Fundamentals of Aquatic Toxicology, Methods, and Applications*. Hemisphere Publishing Corporation. Washington, D.C.

Oberg, T. 2001. Prediction of physical properties for PCB congeners from molecular descriptions. Internet J. of Chem. Vol. 4, Article 11.

O=Hara, T.M. and C.D. Rice. 1996. Polychlorinated Biphenyls. In: A. Fairbrother, L.N. Locke, and G.L. Hoff (eds.). *Noninfectious Diseases of Wildlife, Second Edition*. Iowa State University Press. Ames, Iowa.

Patton, J.F., and M.P. Dieter. 1980. Effects of Petroleum Hydrocarbons on Hepatic Function in the Duck. Comp. Biochem. Physio. Vol. 65: 33-36.

Pelletier, M.C., R.M. Burgess, K.T. Ho, A. Kuhn, R.A. McKinney, and S.A. Ryba. 1997. Phototoxicity of individual polycyclic aromatic hydrocarbons and petroleum to marine invertebrate larvae and juveniles. *Environ. Toxicol. Chem*. 16:2190-2199.

Persaud, D., R. Jaaguagi, and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of the Environment. March.

RETEC Group, Inc. (RETEC). 2003. Supplemental Remedial Investigation Report – Southwest Properties, Wells G & H Superfund Site, Woburn, MA. August.

Riedel, G.F. and J.G. Sanders. 1996. The influence of pH and media composition on the uptake of inorganic selenium by *Chlamydomonas reinhardtii*. *Environ. Toxicol. Chem.* 15:1577-1583.

Roberts, B.L. and H.W. Dorough. 1985. Hazards of chemicals to earthworms. *Environ. Toxicol. Chem*. 4:307-323.

Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. Oak Ridge Nat. Lab. Publ. ES/ER/TM-86/R3.

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter II, and C.J.E. Welsh. 1997. Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants. Oak Ridge Nat. Lab. Publ. ORNL/TM-13391.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter II, and T.L. Ashwood. 1998. Development and Validation of Bioaccumulation Models for Earthworms. Oak Ridge Nat. Lab. Publ. ES/ER/TM-220.

Sample, B.E. and G.W. Suter, II. 1994. *Estimating Exposure of Terrestrial Wildlife to Contaminants*. Environmental Sciences Division. Oak Ridge National Laboratory. ES/ER/TM-125. September.

Sax, N.I. and L.J. Lewis, Sr. 1989. *Dangerous Properties of Industrial Materials, Seventh Edition. Vol. 1.* New York, NY.

Scheuhammer, A.M. 1987. The chronic toxicity of aluminum, cadmium, mercury, and lead in birds: a review. *Environ. Pollut.* 46:263-295.

Schwetz, B.A., J.F. Quest, P.A. Keeler, et al. 1978. Results of two-year toxicity and reproduction studies on pentachlorophenol. In: Rao, K.R., Ed. Pentachlorophenol: Chemistry, Pharmacology and Environmental Toxicology. New York, NY. Plenum Press.

Scotts-Fordsmand, J.J., P.H. Krogh, and J.M. Weeks. 1997. Sublethal toxicity of copper to a soil-dwelling springtail (*Folsomia fimetaria*) (Collembola: Isotomidae). *Environ. Toxicol. Chem*. 16:2538-2542.

Spangenberg, J.V. and G.N. Cherr. 1996. Developmental effects of barium exposure in a marine bivalve (*Mytilus californianus*). *Environ. Toxicol. Chem*. 15:1769-1774.

Stendell, R.C., Beyer, W.N., and R.A. Stehn. 1989. Accumulation of lead and organochlorine residues in captive American kestrels fed pine voles from apple orchards. *J. Wildlife Disease* 25:388-391.

Swartz, R.C., S.P. Ferraro, J.O. Lamberson, F.C. Cole, R.J. Ozretich, B.L. Boese, D.W. Schults, M. Behrenfeld, and G. Ankley. 1997. Photoactivation and toxicity of mixtures of polycyclic aromatic hydrocarbon compounds in marine sediment. *Environ. Toxicol. Chem*. 16:2151-2157.

Suter, G.W., II, and C.L. Tsao. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge Nat. Lab. Publ. ES/ER/TM-96/R2.

Tewe, O.O., and J. H. Maner. 1981. Long-term and carry-over effect of dietary inorganic cyanide in the life cycle performance and metabolism of rats. Toxicol-Apple Pharmacol. 58:1-7.

Travis, C.C., and A.D. Arms. 1988. Bioconcentration of Organics in Beef, Milk and Vegetation. Environmental Science and Technology. Vol. 22: 271-274.

TRC 2004. EPA/TRC and RETEC Split Sample Comparison Report for the Wells G&H Southwest Properties Supplemental Remedial Investigation. Prepared by TRC Environmental Corporation, Lowell, Massachusetts. February 2004.

U.S. Air Force. 1989. The Installation Restoration Toxicology Guide. Pentachorophenol Vol. 3. Harry G. Armstrong Aerospace Medical Research Laboratory, Air Force Systems command, Wright-Patterson AFB, OH. Pp. 39-49.

U.S. Environmental Protection Agency (USEPA). 1980. *Ambient water quality criteria for DDT.* Office of Water Regulations and Standards. Washington, D.C. EPA/440/5-80/038.

U.S. Environmental Protection Agency (USEPA). 1984. *Health effects assessment for iron (and compounds).* Environmental Criteria and Assessment Office and Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/1-86/054. September.

U.S. Environmental Protection Agency (USEPA). 1985. *Chemical, physical, and biological properties of compounds present at hazardous waste sites - final report*. Prepared by Clement Associates, Inc. for the U.S. Environmental Protection Agency. September.

U.S. Environmental Protection Agency (USEPA). 1986. *Quality criteria for water*. Office of Water Regulations and Standards. Washington, D.C. EPA 440/5-86-001. May.

U.S. Environmental Protection Agency (USEPA). 1989. *Risk assessment guidance for Superfund. Volume I: Human health evaluation manual. Part A.* Interim Final. EPA/540/1-89/002. December.

U.S. Environmental Protection Agency (USEPA). 1992. *Supplemental guidance to RAGS: calculating the concentration term.* Office of Solid Waste and Emergency Response. Washington, D.C. Publication 9285.7-081. May.

U.S. Environmental Protection Agency (USEPA). 1993a. Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water. PB93-154656. February.

U.S. Environmental Protection Agency (USEPA). 1993b. *Wildlife exposure factors handbook, Volume I of II*. Office of Research and Development. EPA/600/R-93/187a. December.

U.S. Environmental Protection Agency (USEPA). 1994. *Guidance manual for the integrated exposure uptake biokinetic model for lead in children.* Office of Solid Waster and Emergency Response. Washington, D.C. EPA/540/R-93/081. February.

U.S. Environmental Protection Agency (USEPA). 1996. Ecotox Thresholds. Eco Update. Office of Solid Waste and Emergency Response. EPA 540/F-95/038. January.

U.S. Environmental Protection Agency (USEPA). 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. EPA/540/R-97-006. June.

U.S. Environmental Protection Agency (USEPA). 1998a. Guidelines for Ecological Risk Assessment. Risk Assessment Forum. Washington, D.C. EPA/630/R-95/002Fa. May.

U.S. Environmental Protection Agency (USEPA). 1998b. *AQUIRE - Aquatic toxicity information retrieval database*. Office of Research and Development. National Health and Environmental Effects Laboratory. Mid-Continent Ecology Division. Duluth, MN. Last updated on 4/29/98.

U.S. Environmental Protection Agency (USEPA). 2002a. National Recommended Water Quality Criteria:2002. Office of Water/Office of Science and Technology. EPA 822-R-02-047. November.

U.S. Environmental Protection Agency (EPA). 2002b. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* OSWER 9285.6-10 Office of Emergency and Remedial Response, Washington, DC. December 2002.

Van den Berg, M., L. Bimbaum, A.T.C. Bosveld, B. Brunstrom, P. Cook, M. Feely, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Laresen, F.X.R. van Leeuwen, A.K.D. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Tounes, F. Waern, and T. Zacharewski. 1998. Toxicity Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife. Environmental Health Perspectives. Vol. 106: 775-792.

Van Derveer, W.D. and S.P. Canton. 1997. Selenium sediment toxicity thresholds and derivation of water quality criteria for freshwater biota of western streams. *Environ. Toxicol. Chem.* 16:1260-1268.

Wiemeyer, Stanley N., and Richard D. Porter. 1970. DDE thins eggshells of captive American kestrels. Nature. 227:737-738.

Williams, P.L. 1982. Pentachlorophenol, an assessment of the occupational hazard. J. Am. Ind. Hyg. Assoc. 43:799-810.

Wolfe, M.F., S. Schwarzbach, and R.A. Sulaiman. !998. Effects of mercury on wildlife a comprehensive review. *Environ. Toxicol. Chem.* 17:146-160.

Wren, C.D., D.B. Hunter, J.F. Leatherland, and P.M. Stokes. 1987. The effects of polychlorinated biphenyls and methylmercury, singly, and in combination on mink. II: reproduction and kit development. Arch. Environ. Contam. Toxicol. 16: 449-454.

Section 5.0

City of Woburn, 1997. Zoning Map of the City of Woburn.

RETEC, 2003.Supplemental Remedial Investigation Report, Southwest Properties, Volumes 1 through XXIII, Wells G&H Superfund Site, Woburn, Massachusetts, Prepared for: Beatrice Company, Prepared by: The RETEC Group, Inc., Concord, Massachusetts, August 2003.

U.S. Environmental Protection Agency (EPA). 2002a. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* OSWER 9285.6-10 Office of Emergency and Remedial Response, Washington, DC. December 2002.

U.S. Environmental Protection Agency (EPA). 2002a. *Preliminary remediation goals table. Region 9 technical support team.* Office of Superfund Programs. Region IX. October 1, 2002.

APPENDIX B

ANALYTICAL RESULTS

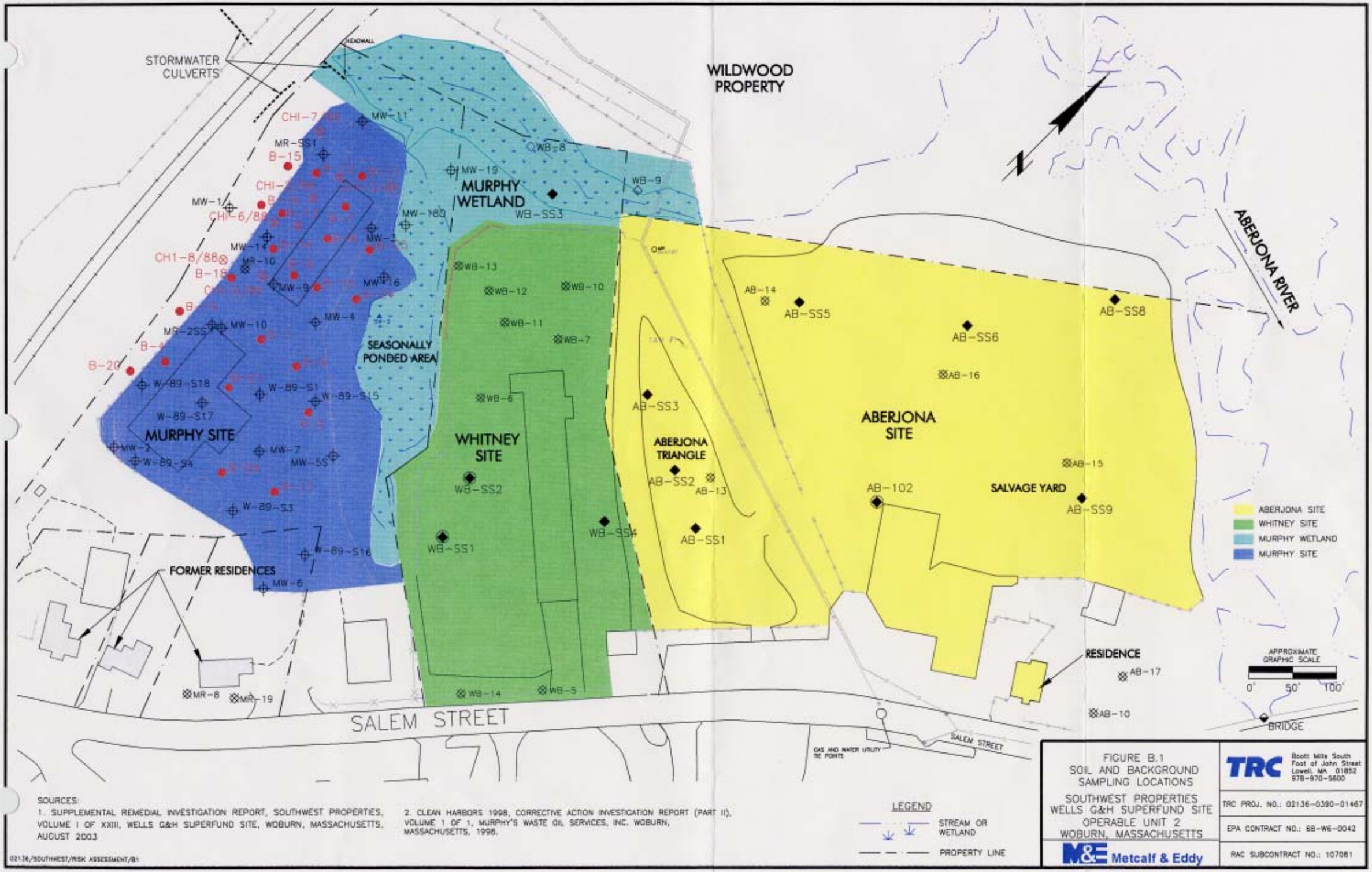
Soil, Groundwater, Surface Water, Sediment

Appendix B

Contents

Appendix B.1

Soil Data Summary Tables



SOURCES:

1. SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT, SOUTHWEST PROPERTIES, VOLUME I OF XXIII, WELLS G&H SUPERFUND SITE, WOBURN, MASSACHUSETTS, AUGUST 2003

2. CLEAN HARBORS 1998, CORRECTIVE ACTION INVESTIGATION REPORT (PART II), VOLUME 1 OF 1, MURPHY'S WASTE OIL SERVICES, INC. WOBURN, MASSACHUSETTS, 1998.

LEGEND

STREAM OR WETLAND

PROPERTY LINE

FIGURE B.1
SOIL AND BACKGROUND SAMPLING LOCATIONS
SOUTHWEST PROPERTIES
WELLS G&H SUPERFUND SITE
OPERABLE UNIT 2
WOBURN, MASSACHUSETTS

TRC
Boott Mills South
Foot of John Street
Lowell, MA 01852
978-970-5600

TRC PROJ. NO.: 02136-0390-01467

EPA CONTRACT NO.: 68-W6-0042

RAC SUBCONTRACT NO.: 107061

M&E Metcalf & Eddy

02136/SOUTHWEST/RISK ASSESSMENT/B1

B.1.1 Soil Data Summary Table ~ Aberjona Property
Wells G&H Superfund Site, Operable Unit 2
Woburn, Massachusetts

Property	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona
Location	AB-15	AB-16	AB-16	AB-SS1	AB-SS2	AB-SS3	AB-SS4	AB-SS5	AB-SS6	AB-SS7	AB-SS8	AB-SS9	AB-14	AB-14
Sample ID	AB-15/0-2	AB-16/0-2	AB16SS(0-2.0)	AB-SS1	AB-SS2	AB-SS3	AB-SS4	AB-SS5	AB-SS6	AB-SS7	AB-SS8	AB-SS9	AB-14/0-2	AB14SS(0-2.0)
Date	11/26/2002	11/26/2002	11/26/2002	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	11/26/2002	11/26/2002
Soil (S)	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Top (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom (ft)	2	2	2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	2
Volatile Organic Compounds														
1,1,1,2-Tetrachloroethane														
1,2,3-Trichlorobenzene														
1,2,3-Trichloropropane														
1,2,4-Trimethylbenzene														
1,2-Dichloroethene (total)				2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
1,3,5-Trimethylbenzene														
1,3-Dichloropropane														
1,4-Dichlorobutane														
2,2-Dichloropropane														
2-Chloroethyl vinyl ether														
Acrolein														
Acrylonitrile														
Bromobenzene														
Bromochloromethane														
Dibromomethane														
Ethyl ether														
Ethyl methacrylate														
Hexachlorobutadiene	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Iodomethane														
m- & p- Xylenes			68 U											
n-Butylbenzene														
n-Propylbenzene														
Naphthalene	3.1 UJ	4 UJ	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
o-Chlorotoluene														
o-Xylene			34 UJ											
p-Chlorotoluene														
p-Isopropyltoluene														
sec-Butylbenzene														
tert-Butylbenzene														
trans-1,4-Dichloro-2-butene														
Vinyl Acetate														
Dichlorodifluoromethane	1.7 U	1.8 U	34 U											
Chloromethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 UJ	2.5 UJ	2.6 U	2.6 UJ	2.6 UJ		
Vinyl chloride	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Bromomethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.4 J		
Chloroethane	1.7 U	1.8 U	34 UJ	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Fluorotrichloromethane	1.7 U	1.8 U	34 U											
1,1-Dichloroethene	1.7 U	1.8 U	34 U	1.2	1.1 J	2.8 U	1.1 J	4.8 J	1.7 J	2.6 U	0.9 J	1.8 J		
Freon 113	1.7 U	1.8 U	34 U											
Acetone	3.7 JEB	4.6 UJ	170 U	8.9 UJ	5.1 UJ	8.3 UJ	9.1 UJ	112 UJ	9 UJ	14.4 UJ	33 UJ	11 UJ		
Carbon disulfide	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Methyl acetate	1.7 U	1.8 U	34 U											
Methylene chloride	7.8 UJ	9.4 UJ	280 U	13.9 UJ	5.6 UJ	15.6 UJ	15.5 UJ	74 UJ	16 UJ	14.2 UJ	30 UJ	21 UJ		
trans-1,2-Dichloroethene	1.7 U	1.8 U	34 U											
Methyl tert-butyl ether	1.7 U	1.8 U	34 U											
1,1-Dichloroethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
cis-1,2-Dichloroethene	1.7 U	1.8 U	34 U											
2-Butanone (MEK)	4.3 U	4.6 U	100 U	10.8 UJ	4.7 UJ	5.3 UJ	5.7 UJ	31.9 UJ	6.1 UJ	4.6 UJ	5.8 UJ	5.2 U		
Chloroform	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
1,1,1-Trichloroethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Cyclohexane	1.7 U	1.8 U	34 UJ											
Carbon tetrachloride	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Benzene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
1,2-Dichloroethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		

B.1.1 Soil Data Summary Table ~ Aberjona Property
Wells G&H Superfund Site, Operable Unit 2
Woburn, Massachusetts

Property	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona	Aberjona
Location	AB-15	AB-16	AB-16	AB-SS1	AB-SS2	AB-SS3	AB-SS4	AB-SS5	AB-SS6	AB-SS7	AB-SS8	AB-SS9	AB-14	AB-14
Sample ID	AB-15/0-2	AB-16/0-2	AB16SS(0-2.0)	AB-SS1	AB-SS2	AB-SS3	AB-SS4	AB-SS5	AB-SS6	AB-SS7	AB-SS8	AB-SS9	AB-14/0-2	AB14SS(0-2.0)
Date	11/26/2002	11/26/2002	11/26/2002	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	9/1/1993	11/26/2002	11/26/2002
Soil (S)	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Top (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom (ft)	2	2	2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	2
Volatile Organic Compounds (cont.)														
Trichloroethene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Methyl cyclohexane	1.7 U	1.8 U	34 U											
1,2-Dichloropropane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Bromodichloromethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
cis-1,3-Dichloropropene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
4-Methyl-2-pentanone	4.3 UJ	4.6 UJ	170 U	2.7 U	2.7 U	2.8 U	3 U	13.3 UJ	2.5 UJ	2.6 U	2.6 UJ	2.6 UJ		
Toluene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	22.3	2.5 U	2.6 U	1.4 J	2.6 U		
trans-1,3-Dichloropropene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
1,1,2-Trichloroethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Tetrachloroethene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
2-Hexanone	4.3 U	4.6 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 UJ	2.5 UJ	2.6 U	2.6 UJ	2.6 UJ		
Chlorodibromomethane	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Ethylenedibromide	1.7 U	1.8 U	0.01 UJ											
Chlorobenzene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Ethylbenzene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	16	2.5 U	2.6 U	1.5 J	2.6 U		
Xylenes (total)	1.7 U	1.8 U	68 U	2.7 U	2.7 U	2.8 U	3 U	162.2	2.5 U	2.6 U	8	2.6 U		
Styrene	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	2.7 J	2.5 U	2.6 U	2.6 U	2.6 U		
Bromoform	1.7 U	1.8 U	34 U	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
Isopropylbenzene	1.7 U	1.8 U	34 U											
1,1,2,2-Tetrachloroethane	1.7 U	1.8 U	34 UJ	2.7 U	2.7 U	2.8 U	3 U	13.3 U	2.5 U	2.6 U	2.6 U	2.6 U		
1,3-Dichlorobenzene	1.7 U	1.8 U	34 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
1,4-Dichlorobenzene	1.7 U	1.8 U	34 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
1,2-Dichlorobenzene	1.7 U	1.8 U	34 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
1,2-Dibromo-3-chloropropane	1.7 U	1.8 U	34 U											
1,2,4-Trichlorobenzene	1.7 U	1.8 U	34 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Semivolatile Organic Compounds														
Benzaldehyde	270 UJ	270 UJ	130 UJ											
Phenol	4.2 UJ	5.2 UJ	130 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2-Chlorophenol	270 U	270 U	130 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Bis(2-chloroethyl) ether	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2-Methylphenol	2.8 UJ	2.7 UJ	130 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2,2'-Oxybis(1-Chloropropane)	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Bis(2-chloroisopropyl) ether			52 U											
Acetophenone	270 U	270 U	52 U											
4-Methylphenol	270 U	270 U	130 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
N-Nitrosodi-n-propylamine	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Hexachloroethane	270 UJ	270 UJ	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Nitrobenzene	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Isophorone	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2-Nitrophenol	270 UJ	270 UJ	130 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2,4-Dimethylphenol	270 UJ	270 UJ	130 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Bis(2-chloroethoxy) methane	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2,4-Dichlorophenol	270 U	270 U	130 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
4-Chloroaniline	270 UJ	270 UJ	52 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
Caprolactam	270 U	270 U	52 UJ											
4-Chloro-3-Methylphenol	270 U	270 U	130 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2-Methylnaphthalene	270 U	270 U	52 U	370 U	358 U	383 U	412 U	1418	35 J	358 U	347 U	347 U		
Hexachlorocyclopentadiene	270 UJ	270 UJ	52 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2,4,6-Trichlorophenol	270 UJ	270 UJ	130 UJ	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2,4,5-Trichlorophenol	270 UJ	270 UJ	130 UJ	926 U	896 U	958 U	1029 U	1773 U	877 U	896 U	868 U	868 U		
1,1'-Biphenyl	270 U	270 U	52 UJ											
2-Chloronaphthalene	270 U	270 U	52 U	370 U	358 U	383 U	412 U	709 U	351 U	358 U	347 U	347 U		
2-Nitroaniline	270 UJ	270 UJ	52 U	926 U	896 U	958 U	1029 U	1773 U	877 U	896 U	868 U	868 U		
Dimethyl phthalate	270 U	270 U	52 U	370 U	358 U	383 U	41 J	709 U	351 U	358 U	347 U	347 U		