FINAL REPORT

Raytheon Company

Phase II Comprehensive Site Assessment

Former Raytheon Facility
430 Boston Post Road
Wayland, Massachusetts
(Volume I)

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LIST OF ACRONYMS

α	Attenuation Factor
Alpha	Alpha Analytical Laboratories
ARAH	area of readily apparent harm
ASL	above mean sea level
AUL	Activity and Use Limitation
AVS/SEM	acid volatile sulfide and simultaneously extracted metals
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
BWSC	Bureau of Waste Site Cleanup
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
CF	Conversion Factor
Cfs	cubic feet per second
CHI	Clean Harbors, Inc.
Cis-1,2-DCE	cis-1,2-dichloroethene
cm^2	square centimeters
COCs	compounds of concern
COPECs	chemicals of potential ecological concern
CSF	Cancer Slope Factor
D	Dilution Factor
1,1-DCE	1,1-dichloroethene
DEM	Department of Environmental Management
DNAPL	dense non-aqueous phase liquid
ED	Exposure Dose
ELCR	Excess Lifetime Cancer Risk
Entrix	Entrix, Inc.
EPC	exposure point concentration
EPH	extractable petroleum hydrocarbons
ERM	Environmental Resources Management
ft^2	square feet
Geosearch	Geosearch, Inc.
GIS	Geographical Information System
GMNWR	Great Meadows National Wildlife Refuge
gpd	gallons per day
gpm	gallons per minute
GPR	Ground Penetrating Radar
H	Henry's Law Constant
H&A	Haley & Aldrich, Inc.
HI	Hazard Index
ICP	inductively coupled plasma
IH	Imminent Hazard
IRA	Immediate Response Action
IWWTP	Industrial Waste Water Treatment Plant
K_{oc}	Organic Carbon Partition Coefficient

K_{ow}	Octanol Water Coefficient
Laidlaw	Laidlaw, Inc.
LRA	Limited Removal Action
LSP	Licensed Site Professional
LTBI	Locations to Be Investigated
m^2	square meters
MA DEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
Middlesex Registry of Deeds	Middlesex County South Registry of Deeds, Registry District of the Land Court
mg/kg	milligrams per kilogram (approximately equal to ppm)
mg/L	milligrams per liter (approximately equal to ppm)
NERO	Northeast Regional Office
NHESP	National Heritage Endangered Species Program
NOR	Notice of Responsibility
NPDES	National Pollutant Discharge Elimination System
NRS	Numerical Ranking Score
OHM	oil and/or hazardous materials
ORP	oxidation-reduction potential
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PID	photo-ionization detector
PIP	Public Involvement Plan
PM_{10}	Respirable Particulates
Ppb	parts per billion
Ppm	parts per million
QA/QC	Quality Assurance/Quality Control
RAF	Relative Absorption Factor
RAM	Release Abatement Measure
RAO	Response Action Outcome
Raytheon	Raytheon Company
RC	Reportable Concentration
RESD	Raytheon Electronic Systems Division
RfD	Reference Dose
RQD	Rock Quality Designation
RTN	release tracking number
SIP	Site Inspection Prioritization
SOW	Scope of Work
SVOCs	semi-volatile organic compounds
TCE	trichloroethene
TPH	total petroleum hydrocarbons
UCL	Upper Concentration Limit
µg/L	micrograms per liter (approximately equal to ppb)

EXECUTIVE SUMMARY

On behalf of Raytheon Company (Raytheon), Environmental Resources Management (ERM) has prepared this Phase II – Comprehensive Site Assessment (Phase II) Report for an approximately 83-acre property located at 430 Boston Post Road in Wayland, Massachusetts (defined as the "Site", Figure 1). The Site, surrounding properties and physical features are shown in Figure 2. This report was prepared to satisfy requirements of the Massachusetts Contingency Plan (MCP), specifically 310 CMR 40.0830. The Phase II is the second part of a five-phase process required under the MCP for assessment and remediation of a release(s) of oil and/or hazardous materials (OHM) to the environment. The Phase II is used to determine if remedial actions are necessary.

The Phase II included a series of field investigations through November 2000 to further assess the source(s), nature and extent of impact from releases of OHM. Multiple short-term remedial response actions have been completed to abate identified sources of release including drywells, sumps, drains, catch basins, storage tanks and one localized fill area.

Phase II field sampling included soil, groundwater and wetland sediment, surface water and biota. The results were utilized to conduct a Method 3 Risk Characterization and develop the following conclusions:

1. Where feasible, past identified sources of OHM releases have been abated (through completion of Limited Removal Actions (LRAs) or Release Abatement Measures (RAMs).

2. The extent of Site OHM impact appears limited to soil, groundwater and wetland sediment.

3. Site groundwater and wetland sediment pose a condition of "significant risk," likely requiring abatement measures.

4. The site does not pose a "significant risk" of harm to human safety or public welfare, as defined in the MCP.

A Phase III-Remedial Alternative Evaluation is necessary.

1.0 INTRODUCTION

1.1 BACKGROUND

On behalf of Raytheon Company (Raytheon), Environmental Resources Management (ERM) has prepared this Phase II – Comprehensive Site Assessment (Phase II) Report for an approximately 83-acre property located at 430 Boston Post Road in Wayland, Massachusetts (defined as the "Site," Figure 1). The Site, surrounding properties and physical features are displayed in Figure 2.

This report is submitted to satisfy requirements of the Massachusetts Contingency Plan (MCP), specifically 310 CMR 40.0830, for a Phase II. The Phase II is the second part of a five-phase process required under the MCP for assessment and remediation of a release(s) of oil and/or hazardous materials (OHM) to the environment. Raytheon has conducted the Phase II under a Tier IB Permit (No. 133939) issued by the Massachusetts Department of Environmental Protection (MA DEP), Bureau of Waste Site Cleanup (BWSC), Northeast Regional Office (NERO) located in Wilmington, Massachusetts.

Raytheon utilized the Site from 1955 to 1995 for electronic testing and chemical process research to support in-house prototype manufacturing. In 1995, Raytheon ceased operations and decommissioned the facility. The purpose of the assessment was to evaluate the potential for past release(s) of OHM to soil and/or ground water associated with historic facility operations. Identification of impacts to Site soil and ground water prompted notification of a release of OHM to the MA DEP in January 1996. Subsequent assessment and remedial actions proceeded in order to satisfy requirements of the MCP (310 CMR 40.0000). A chronology of the Site regulatory history, investigations and remedial activities is presented in Table 1.

On behalf of Raytheon, ERM initiated a series of field investigations between 1995 and 2000 to further assess the source(s), nature and extent of impact from releases of OHM. Where feasible, short-term remedial response actions were conducted to abate identified sources of release including drywells, sumps, drains, catch basins, storage tanks and one localized fill area. Remedial actions included cleaning, removal and decommissioning of remaining structures, removal of surrounding impacts to soil and management of remediation wastes. These short-term remedial actions, Limited Response Actions (LRAs) and Release Abatement Measures (RAMs) successfully abated each identified source, resulting in residual impacts limited largely to ground water and wetland sediments.

In accordance with MCP requirements, a Phase I – Initial Site Investigation (Phase I) Report was filed with the MA DEP on 20 May 1996 (updated 30 January 1997). The Site was subsequently Tier Classified in May 1997 as a Tier IB "Disposal Site" and issued a permit (No. 133939) from the MA DEP to conduct additional assessment and remedial response actions under Phase II. A Phase II Scope of Work (SOW) dated 27 February 1998, was submitted to DEP describing the scope and nature of investigative and sampling programs to be undertaken to meet MCP performance standards for the Phase II (Appendix A). An addendum to the Phase II SOW was filed 20 September 1999, outlining the scope of the wetland investigation (Appendix A).

This report describes assessment and remedial response actions completed since submittal of the Phase I, updates the use, ownership and regulatory history of the Site; describes the nature and extent of residual OHM impact in affected media and characterizes the potential risk posed by the Site to human health, safety, public welfare, and the environment. The results of the Phase II are used to determine the need for remedial actions at the Site. Evaluation of remedial alternatives will be conducted under Phase III to identify the most appropriate remedy for the Site. Design, construction/implementation of remedial actions will be conducted under Phase IV Remedy Implementation Plan (RIP).

1.2 *PURPOSE & SCOPE*

The purpose of the Phase II is to identify:

- The source(s), nature and extent of release(s) of OHM in potentially affected media (air, soil, ground water, sediment, and surface water);
- The potential risk of harm posed by remaining residual impacts of the release condition to human health, safety, public welfare, and the environment; and
- The need to conduct remedial actions for affected media.

The Phase II was conducted as a series of sequential investigations, building upon prior data collected. Field investigations focused largely on defining the extent of OHM impact in ground water, wetland sediment and surface water.

Phase II field activities were initiated in May 1998, beginning with the expansion of the test pit program, advancement of soil borings and the installation of monitoring wells. An addendum to the Phase II SOW was filed on 20 September 1999 to address additional data gaps discovered upon verification of impact to wetland sediments. A summary of the Phase II SOW and addendum is presented in Methods (Section 4.0). Copies of the SOW and addendum are included in Appendix A.

The remainder of this report is formatted consistent with 310 CMR 40.0835, MCP requirements for a Phase II Report, including:

Section 2.0- Summary of Phase I - Initial Site Investigation, providing a brief summary of the Phase I, including a description of the purpose and scope of the investigation, results and conclusions as pertinent to development of the Phase II SOW.

Section 3.0- Update to the Phase I-Initial Site Investigation, updates the Site status since filing of the Phase I in May 1996 including the regulatory status (e.g., additional release conditions, remedial response actions, permit modifications, etc.), property ownership, activities and uses and deeded restrictions.

Section 4.0- Methods, presents the methodology to the field investigation as described in the Phase II SOW and addendum. A chronology of field activities conducted as part of the Phase II is also provided.

Section 5.0- Results, presents the results of the Phase II field investigations including: regional and Site geology and hydrogeology; source, nature and extent of impact to affected media and likely mechanisms for the fate and transport of residual OHM within and between affected media.

Section 6.0- Risk Characterization, presents the Method 3 Risk Characterization including a quantitative assessment of the potential risk posed by residual OHM to categories of hypothetical human receptors, safety, public welfare, and the environment. Characterization of the potential risk to the environment includes a Stage I Environmental Screening (Stage I) and a summary of the Stage II Environmental Risk Characterization (Stage II). The complete Environmental Risk Characterization report is included in Appendix E.

Section 7.0- Conclusions, presents the regulatory outcome of the Phase II. Evaluation of Remedial Response Action Alternatives and selection of the Preferred Remedial Action Alternative(s) will be conducted under Phase III. Remedy Design and Implementation will be conducted under Phase IV.

2.0 SUMMARY OF THE PHASE I-INITIAL SITE INVESTIGATION

2.1 PURPOSE & SCOPE

In 1995, Raytheon ceased operations and commenced decommissioning of the facility. An environmental site assessment, to evaluate the potential for past release(s) of OHM to soil and/or ground water associated with historic facility operations, was conducted.

To achieve these goals, a Phase I investigation was completed, including:

- A review of available facility, local, state and federal environmental files, historic facility operations plans, Sanborn insurance maps and historic aerial photographs;
- An interior visual inspection of the buildings in March 1996 following decommissioning;
- Deployment of Ground Penetrating Radar (GPR) surveys in an effort to identify the location of suspected subsurface features including utilities, drywells, underground storage tanks (USTs) and associated structures;
- An extensive field sampling program including evaluation of potential sources of release(s), surrounding soil and ground water quality and Site geology/hydrogeology; and
- Abatement of impacts to soil associated with releases of OHM to three drywells and the boiler room pit and sump as each as separate LRAs.

2.2 RESULTS & CONCLUSIONS

- Raytheon had utilized the Site for research and development including photographic and printed circuit board development, electronic testing, machining, welding, painting and hydraulic testing (Figure 3);
- Categories of OHM used included volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), metals, heating and lubricating oils; and
- Potential areas of concern relative to OHM release included nine petroleum USTs, seven drywells, one boiler room pit and sump, two abandoned leaching fields, combined storm/wastewater conveyance/discharge and areas of historic filling (Figure 3).

Based on the field investigation:

- Oil-impacted soils and 0.1 foot of separate phase petroleum product (No. 6 fuel oil) were discovered near a former 20,000-gallon UST (WAY-02) which was closed in place in 1983 (Figure 3). No other issues were identified regarding the other eight former USTs;
- Three of the seven drywells, and the boiler room pit and sump, required abatement due to releases of PCBs, metals (chromium, cadmium and lead) and total petroleum hydrocarbons (TPH) to soil at levels in excess of applicable MCP Reportable Concentrations (RCs), RC S-1. LRAs were conducted in five areas to remove impacted soils (Figure 3). Remaining residual levels of OHM following the LRAs were below applicable RCs (i.e., RCS-1);
- Based on a review of aerial photos, a reportable release condition associated with "unknown" petroleum hydrocarbons in soil was detected at one (TP-3) of seven test pit locations (Figure 3). This condition resulted in notification, further assessment and abatement as a RAM;
- Potential impacts to wetland sediments at outfall OF-1 required further investigation during Phase II (Figure 3);
- Impacts to ground water were limited to 1,1-dichloroethene (1,1-DCE) at levels of up to 5 micrograms per liter (µg/L) in two isolated wells (RAY-01 and MW-7), requiring further assessment during Phase II (Figure 3); and
- Site conditions maintained a low potential to adversely impact potential receptors. No time critical remedial response actions were warranted.

Additional assessment and abatement activities were conducted as Preliminary Response Actions following submittal of the Phase I Report are described in Update to the Phase I (Section 3.0). For additional details regarding the Phase I refer to the *Phase I - Initial Site Investigation Report*, prepared by ERM and dated 20 May 1996 (updated 30 January 1997).

3.0 UPDATE TO THE PHASE I-INITIAL SITE INVESTIGATION

3.1 OVERVIEW

In accordance with 310 CMR 40.0835(4), this Section updates the status of the Site since filing of the Phase I in May 1996 (as updated 30 January 1997). Changed conditions include property ownership, Site activities and uses, filing of deed restrictions to Site use and the Site regulatory status (e.g., additional release conditions, remedial response actions, permit modifications, compliance deadlines, etc.).

3.2 PROPERTY OWNERSHIP

The Site was owned by Continental Assurance Company (CAC) between 1968 and 1997 and leased to Raytheon. Wayland Meadows Limited Partnership (Wayland Meadows) purchased the property from CAC on 1 October 1997 and subsequently sold the Site to Wayland Business Center, LLC (WBC) on 1 December 1997.

As part of the facility decommissioning, Raytheon closed the Industrial Waste Water Treatment Plant (IWWTP) and allowed the current discharge permit (National Pollutant Discharge Elimination System (NPDES) Permit No. MA0001511) to expire on 12 July 1996. WBC redeveloped the plant for treatment of sanitary wastewater and was issued a NPDES discharge permit for operation on 4 September 1998 (No. MA0039853). The Town of Wayland acquired the plant and permit from WBC under eminent domain on 25 October 1999. The maximum daily permitted discharge limit is 65,000 gallons per day (gpd).

Following transfer of the property to WBC, updated survey plans indicated that a privately owned parcel (i.e., Hamlen Parcel) located within the wetland was located much closer to outfall OF-1 than previously thought (Figure 2). Expansion of the wetland investigation required Raytheon to establish an access agreement with the owner (Devins Hamlen). The access agreement was obtained on 8 April 1999. Wetland investigations on the Hamlen Parcel during the Phase II have identified impacted areas further expanding the Site.

3.3 *SITE ACTIVITIES, USES & USE RESTRICTIONS*

3.3.1 *Changes in Site Activities & Uses*

In 1995, Raytheon began decommissioning the facility. All research, design and light manufacturing equipment was removed from the Site. Remaining buildings and structures were evaluated by Raytheon's Environmental Health & Safety Division, and if necessary, decontaminated. In 1998, WBC redeveloped the building complex and grounds into commercial office space. The complex is currently approximately 70 percent occupied by Polaroid Corporation, five percent by WBC offices and 25 percent unoccupied. The layout of past and current facility structures is displayed in Figure 2.

In December 1998, ERM observed a drill rig on the adjacent downgradient property, the Russell Garden Center, located at 397 Boston Post Road (Figure 2). Based on review of the boring log filed with Department of Environmental Management (DEM), a six-inch diameter boring was advanced to a depth of approximately 900 feet below ground surface (bgs). Bedrock was observed at approximately 60 feet bgs. Steel casing was set to 80 feet bgs (i.e., 20 feet into bedrock) and the remainder of the borehole was left open. Subsequent pumping of the well indicated a sustainable yield of at least ten gallons per minute (gpm) over a pumping period of 24 hours. The well is presumably used for irrigation. No additional information was available from the DEM regarding well usage, yield or ground water quality. No additional private wells have been identified within 0.5 mile of the Site.

On 9 April 1999, a 14.9-mile segment of the Sudbury River, including the reach adjacent to the Site, was added to the national list of Wild and Scenic Rivers and designated "scenic" status. As such, a conservation plan that relies on local and private initiatives is being implemented by the SuAsCo River Stewardship Council to ensure long-term protection of this portion of the Sudbury River.

3.3.2 *Use Restrictions*

Notice of Activity & Use Limitation Filed 21 October 1997

As part of the consideration to CAC for the purchase of the Site, Wayland Meadows filed a Notice of Activity and Use Limitation (AUL) on a portion of the property on 21 October 1997 with the Middlesex County South Registry of Deeds, Book 27793, Page 141 and with the Middlesex Registry District of the Land Court (Middlesex Registry of Deeds). The AUL applies to an approximately 80-acre portion of the property as displayed in Figure 4 (referred to as the "Site-Wide" AUL). The purpose of the AUL was to restrict the activities and uses at the Site to ensure that they are consistent with continued protection of human health, safety, public welfare, and the environment.

Activities and uses specifically allowed by the AUL include commercial or industrial uses including office space, wholesale, retail, manufacturing, etc. Those specifically prohibited include residential, childcare, day care, agricultural, and those activities that could render contaminated media accessible. Since the AUL was filed prior to completion of Comprehensive Response Actions, obligations and conditions set forth in the AUL include provisions for seeking prior approval of the Licensed Site Professional (LSP)-of-Record (i.e., the individual responsible for oversight and certification of response actions) for any modification to the AUL.

This AUL was not filed in accordance with, or to satisfy specific requirements of, the MCP process. As such, the AUL was not submitted to the MA DEP. The AUL is neither compliant with, or in violation of, MCP requirements. The AUL remains as a Site restriction and deed encumbrance.

In addition, an Easement and Restriction Agreement was also filed with the Middlesex Registry of Deeds on 21 October 1997 by Wayland Meadows, granting Raytheon easement to access the Site for investigation and remediation purposes subject to the rights and conditions stipulated therein (Refer to Middlesex County District Registry of Deeds, Book 27793, Page 167, Document No. 1044682 and the Middlesex Registry District Land Court).

Notice of Activity & Use Limitation Filed 13 April 1999

On 13 April 1999, WBC filed a Notice of AUL with the Middlesex Registry of Deeds on an approximately 0.8-acre portion of the Site displayed in Figure 4. This AUL remains on the Site (Book 1181, Page 99, Document No. 1103685) and was filed to support WBC's filing of a Class A-3 Response Action Outcome (RAO) Statement for the release of petroleum hydrocarbons associated with former UST WAY-02 (RTN 3-13302). Site activities and uses allowed, those prohibited, and obligations and conditions set forth to maintain a condition of "no significant risk" are generally consistent with those set forth in the Site-Wide AUL.

A description of response actions conducted to support the RAO filing is provided in Section 3.4. It should be noted that these response actions were conducted by WBC at their sole discretion and were not authorized by, or subject to the approval of, Raytheon. WBC retained Haley & Aldrich, Inc. (H&A) to conduct the response actions and the LSP-of–Record to provide approval of proposed plans, oversight of H&A and certify the RAO filing prepared by H&A.

3.4 SITE REGULATORY HISTORY

In accordance with 310 CMR 40.0835(4) (c), this section updates the Site regulatory history since submittal of the Phase I Report in May 1996. Table 1 provides a chronological summary of the Site regulatory history both pre- and post-Phase I. A chronological description of events occurring post-Phase I follows. The locations of Site events or activities presented in this section are displayed in Figure 5.

May 1996 – Assessment & Abatement of Soil Impacts at Test Pit (TP-3)

As part of the Phase I, seven test pits were excavated to visually inspect and sample subsurface soils in areas of former ground disturbances identified by a review of historic aerial photographs. Test pits were excavated to depths ranging from five to nine feet. Analytical results for a soil sample collected from test pit TP-3 indicated 8,600 milligrams per kilogram (mg/kg) of an "unknown hydrocarbon" exceeding the RC S-1 of 500 mg/kg. Additional analyses conducted in May 1996 indicated the presence of PCBs at concentrations up to 1,050 mg/kg.

In response, Raytheon filed a Release Notification with the MA DEP on 25 July 1996. The MA DEP subsequently issued RTN 3-14042 and requested Raytheon conduct an evaluation to determine the need for an Imminent Hazard (IH) Evaluation. ERM conducted additional assessment of the release condition and filed a report with the MA DEP dated 28 August 1996 concluding that Site conditions did not warrant an IH Evaluation, but that additional remedial response actions would be required.

A RAM Plan was prepared and submitted on 4 October 1996. Removal by excavation resulted in off-Site disposal of 71 tons of remediation waste. Post-removal concentrations of PCBs in soil at TP-3 were below the applicable MCP risk-based Method 1 Standard (S-1) of 2 mg/kg. A RAM Completion Statement was submitted to the MA DEP on 19 February 1997. Residual soil and ground water impacts at TP-3 were addressed as part of the Phase II. Additional details regarding the RAM are documented in the Release Abatement Measure Completion Report, dated 19 February 1997.

June 1996 – Removal of Catch Basin (CB 2.22)

A former stormwater catch basin, CB 2.22, located in the courtyard between Buildings 4 and 5, was inspected by Raytheon in June 1996 and found to contain two inlet pipes, no outlet pipes and an uncontained bottom. Raytheon retained Laidlaw, Inc. (Laidlaw), to collect soil samples for analysis of PCBs, TPH and metals. Results indicated PCBs (Arochlor 1260 at 5.1 mg/kg) and lead (1,060 mg/kg) were present at levels exceeding applicable RCs (i.e., RCS-1).

Laidlaw probed the catch basin and found one foot of sediment, overlying 3.5 feet of clay, overlying one foot of sand. Analysis of the clay/sand at 3.5 feet indicated levels of VOCs, PCBs, TPH and metals below RCS-1 level.

Abatement as a LRA included removal of sediments and soils to a depth of approximately three feet below the bottom of the catch basin. Closure samples from the floor and walls of the excavation confirmed levels of OHM below RCS-1 level. Laidlaw manifested three drums (1,800 pounds) of remedial waste for off-Site disposal. The catch basin was later collapsed and backfilled with two feet of crush stone and 0.5 inch of topsoil.

July 1996 – Abatement of Manhole (W-4)

A former stormwater manhole, W-4, located in the courtyard between Buildings 3 and 4, was inspected by Raytheon in July 1996 and found to contain a heavy oily sediment and hard silt material. Raytheon retained Clean Harbors, Inc. (CHI) on 24 July 1996 to sample the material, which was found to contain elevated levels of chlorinated hydrocarbons including trichloroethene (TCE) at 598,000 μg/L, associated degradation products and semi-volatile organic compounds (SVOCs).

On 1 August 1996, CHI removed three drums of solid waste and determined the manhole had a solid concrete bottom. The manhole was cleaned and 15 drums of fluids were containerized and disposed off-Site. Inspection of the interior of Building 4 revealed a drain labeled "sanitary" that was found to be connected to the manhole. A wipe sample collected from the drain indicated the presence of 613 μg of TCE per 100 square centimeters (cm^2) within the discharge pipe. As indicated in the Phase I Report, this portion of Building 4 had been formerly utilized as a Printed Circuit Board Shop from the 1960s until 1991.

Following cleaning of the drain line and manhole, two holes approximately four inches in diameter were observed in the bottom of the manhole. Water was also observed slowly seeping into the manhole. The water was sampled and found to contain 120,000 μg/L of TCE, 1,100 μg/L of cis-1,2-dichloroethene (cis-1,2-DCE) and 8.2 μg/L of butyl cellusolve. It was unclear what the source of the water was, since the points of seepage were eight to ten feet above the water table. The source of the water may have been a localized perched condition or infiltration of rinse water that leaked out of the manhole during cleaning. The bottom of the manhole was subsequently sealed by Raytheon as part of facility decommissioning.

To evaluate the potential for impacts to soil and ground water from manhole W-4, ERM advanced a soil boring immediately adjacent to the manhole and collected soil samples for visual inspection, field screening and laboratory analysis. Field screening indicated no elevated VOCs in soil. Laboratory analysis of soil collected from six to eight feet in depth (targeting the bottom of the manhole) for VOCs and PCBs also indicated no impact to soil. The boring was advanced to a depth of 21 feet and monitoring well MW-31 was installed with a ten-foot long screen straddling the water table. Analysis of ground water samples from MW-31 indicated TCE at 190 μg/L, suggesting that the manhole was a contributing source of ground water impact previously detected on Site. Additional investigation of the extent of ground water impact beneath Building 4 was conducted in December 1996 (described below). The lateral and vertical extent of ground water impact was defined as part of the Phase II.

August 1996 – Cleaning of Stormwater Discharge Line

As part of facility decommissioning, Raytheon contracted CHI to assist in assessment and cleaning of the stormwater drainage system. This work included collection and analysis of nine wipe samples from within the drainage system, which included 20 catch basins and approximately 3,000 linear feet of storm drainpipe. These wipe samples were submitted to a laboratory for analysis of PCBs and TPH.

PCBs were detected in the wipe sample from manhole W-4. Neither PCBs nor TPH were identified on any other wipe samples at concentrations above the laboratory method detection limit.

CHI then cleaned the storm drain system. Rinsate and sediments were collected at the two stormwater outfalls, OF-1 and OF-2, prior to reaching the discharge swale. Rinsate was stored in a frac-tank and sediment was transferred to a roll-off. A composite sediment sample was collected for laboratory analysis, which indicated the presence of 34.6 mg/kg of PCBs (Arochlor 1260), 113 mg/kg of chromium and 162 mg/kg of lead. Sediments were properly disposed of off-Site. Analysis of the water detected trace concentrations of PCBs and metals. Water from the frac-tank was pumped through carbon and discharged to the stormwater outfall OF-1.

December 1996 – Building 4 Subsurface Assessment

Based on the impact to ground water discovered at MW-31 adjacent to manhole W-4, ERM advanced three soil borings and installed three monitoring wells (B-1, B-2 and B-3) beneath Building 4 to further assess the extent of impact downgradient of manhole W-4. Results of this assessment were summarized in a letter report entitled "Additional Assessment Activities," submitted to the MA DEP on 25 June 1997.

Results of this assessment indicated:

- No significant impact to soil beneath Building 4;
- Impacts to ground water (primarily TCE) beneath Building 4 were consistent with impacts detected at MW-31 (e.g., up to 110 μg/L TCE); and
- There was a low potential for VOCs in ground water to impact indoor air quality within Building 4.

These results were incorporated into the Phase II to support evaluation of the nature and extent of OHM releases to soil and ground water quality (see Section 5.0).

May 1997 – MA DEP Issues Tier IB Permit

Raytheon filed a Tier IB Permit Application for the Site on 2 January 1997 including the following RTNs: 3-13302 (release condition at WAY-02), 3-13574 (release of chlorinated hydrocarbons to ground water) and 3-14042 (release of PCBs to soil at TP-3). In May 1997, the MA DEP issued Raytheon a Tier IB Permit (No. 133939) for performance of Comprehensive Response Actions necessary to satisfy MCP requirements for achievement of a Temporary or Permanent Solution.

August 1998 – US EPA Issues Draft Site Inspection Prioritization Report

As indicated in the Phase I, the United States Environmental Protection Agency (US EPA) listed the Site on the Comprehensive Environmental

Response, Compensation and Liability Information System (CERCLIS) in November 1980 in response to the identification of surface impoundments in aerial photographs associated with the former sanitary treatment plant. Referral of the Site by US EPA to the MA DEP resulted in the initial listing of the Site on the state's list of "Locations to Be Investigated" (LTBI) on 15 January 1987 (RTN 3-1783).

RTN 3-1783 also included a release of butyl cellusolve (estimated at ten pounds) at outfall OF-1 discovered in March 1990 associated with a cross-connection of an industrial wastewater line with the stormwater drainage system. This release was reported to the MA DEP and an assessment of wetland sediment and Sudbury River sediment and surface water was conducted by ERM in April 1990. Results of this investigation were documented in a report entitled, *Sampling and Analysis at Raytheon Equipment Division*, prepared by ERM and dated 25 May 1990. The report concluded that no remediation within the wetland was necessary because potential risks posed by the release were negligible and removal of wetland sediments could have a greater adverse impact to the wetland than no action.

The results of the 1990 investigation were used to support the filing of a report prepared by ERM entitled, *Licensed Site Professional Evaluation Opinion and Supporting Documentation (RTN 3-1783),* dated 31 July 1995. The LSP opinion concluded that response actions conducted for this release and the original US EPA referral/MA DEP listing were sufficient to satisfy the requirements of a Class B-1 RAO Statement, effectively closing out RTN 3-1783.

Continued evaluation of the Site by the US EPA resulted in issuance of a Draft Site Inspection Prioritization (SIP) Report on 21 August 1998. A comment letter was submitted to the US EPA responding to the SIP on, 10 September 1998. No additional information is currently available regarding the SIP Report or further evaluation of the Site under CERCLIS.

May 1999 – WBC files Partial Class A-3 Response Action Outcome for WAY-02 (RTN 3-13302)

A release of No. 6 fuel oil associated with a former abandoned 20,000-gallon UST (WAY-02) was discovered during Phase I. Soil impacts were estimated to extend over an area of approximately 28,000 square feet (ft2) located beneath Building 3 and the adjacent courtyard. Impacts were detected at depths ranging from 5 to 22 feet bgs, resulting in an estimated volume of 8,000 cubic yards (yd^3) of impacted soil. Separate phase product had been detected in monitoring wells at between 0.2 feet and 1.8

feet in thickness. The product was distributed across an area estimated at 10,000 ft2.

Review of facility files indicated that the fuel oil had been occasionally conditioned with tetrachloroethene (PCE). Therefore, at the conclusion of the Phase I, this tank was thought to be the likely source of chlorinated VOC impacts to ground water. Subsequent investigations suggest that manhole W-4, not WAY-02, was the likely primary source of chlorinated VOC impacts to ground water.

In March 1998, WBC retained H&A to perform a RAM to abate the WAY-02 release. WBC also retained ERM as Site LSP to oversee the RAM. Remedial response actions were conducted by WBC at their sole discretion, independent of Raytheon, as the property owner in support of Site redevelopment into an office park. ERM prepared and filed a RAM Plan dated 5 March 1998 and provided WBC with LSP services necessary to oversee and certify response actions implemented by H&A and their subcontractors.

The RAM included abatement of soil and ground water impacts within an excavation approximately 160 feet by 30 feet by 16 feet in depth adjacent to the south wall of Building 3. Approximately 3,300 yd^3 of soil and 2,240 gallons of liquid were removed and recycled off-Site. Closure sampling was conducted to characterize residual petroleum impacts to soil and ground water beneath, and downgradient of, Building 3. A Method 3 Risk Characterization resulted in a finding of a condition of "no significant risk," contingent upon land uses limitations outlined in the Notice of AUL filed 13 April 1999 (see Section 3.3).

A partial Class A-3 RAO was filed for RTN 3-13302 by WBC on 14 May 1999. Additional information regarding the RAM and RAO for WAY-02 is included in the H&A report entitled, Class A-3 Response Action Outcome *Statement - Partial and Release Abatement Measure Completion Report*, dated 14 May 1999. Results of post-abatement sampling and ground water monitoring were incorporated into the Phase II and are presented in Results (Section 5.0) and Risk Characterization (Section 6.0).

March 1999 & April 2000 – Raytheon Files Notices of Delay in Meeting Phase II/Phase III Deadlines

In accordance with 310 CMR 40.0550(5) of the MCP, Notices of Delay in achieving the deadline of 28 May 1999 for the submittal of the Phase II and Phase III Reports were filed with the MA DEP by ERM on 29 March 1999 and 24 April 2000. These notices were necessitated by the need for additional time to complete the Phase II field investigations due to delays associated with weather, changes in property ownership, securing access agreements and property redevelopment. Please note that current compliance deadlines are now set in accordance with the new Tier IB Permit, effective on 28 November 2000 and described below.

April 2000 – Assessment of Potential Imminent Hazard Condition

As part of the Phase II, further evaluation of wetland sediments was conducted including an ecological survey of wetland biota and evaluation of biota, sediment and surface water quality. Results are presented in Section 5.0 and included in the Environmental Risk Characterization (Appendix E). Correlation of areas of sediment impacted by PCBs and metals with the results of vegetative mapping and analysis of plant tissue defined an area of stunted vegetation. This condition constituted a condition of "readily apparent harm," triggering an IH condition as defined by 310 CMR 40.0955(3) and 40.0995(3)(b)(1)(b).

In response to this discovery, Raytheon and ERM verbally notified the MA DEP of the potential IH condition on 26 April 2000 and filed an Immediate Response Action (IRA) Plan on 28 April 2000, pursuant to 310 CMR 40.0412. The MA DEP approved the IRA Plan to include continued assessment of the nature and extent of impact in the wetland and further evaluation of potential risks to human health and the environment consistent with the existing Phase II SOW and addendum (Appendix A).

The MA DEP issued a Notice of Responsibility (NOR) and RTN 3-19482 to Raytheon in May 2000. On 26 June 2000, the Release Notification Form, IH Evaluation and IRA Plan were submitted to the DEP. IRA activities are on going.

May 2000 – Major Permit Modification Application

Pursuant to 310 CMR 40.0530, a Major Permit Modification Application was filed with the MA DEP on 25 May 2000 to upgrade the Site Tier Classification from IB to IA. The permit modification was triggered by revision of the Site Numerical Ranking Score (NRS) based on discovery of the IH condition described above. The application was available for public comment from 30 June to 20 July 2000. An LSP Opinion was submitted with the permit modification requesting the MA DEP's authorization to continue with Phase II Comprehensive Response Actions during the permit review period. Written authorization for continuation of the Phase II was issued by the MA DEP letter received by Raytheon on 30 June 2000.

June 2000 – Petition for Public Involvement

On 24 June 2000, the MA DEP and Raytheon received a notice from certain residents of the Town of Wayland to list the Site as a Public Involvement Plan (PIP) site, under Section 14 (b) of Massachusetts General Laws chapter 21E (M.G.L. c. 21E). In response, Raytheon officially designated the Site as a PIP site on 24 June 2000, requiring the preparation and implementation of a PIP. The draft PIP was placed in the designated public repositories on 24 August 2000. A public meeting to discuss the draft PIP was held on 28 September 2000. The final PIP was submitted to the Department on 10 November 2000. In accordance with the PIP, Raytheon will provide a copy of this Phase II report to the document repositories located at the Wayland Town Library and the Town of Wayland Board of Health.

October 2000 – Buildings 12/21 Subsurface Assessment

As part of potential redevelopment activities for the former Building 12/21 portion of the Site, H&A, on behalf of WBC, collected 16 soil samples from locations in the vicinity of these buildings and ground water samples from existing monitoring wells MW-41 and HA-102 (sampling locations are displayed in Figure 6). Results of this assessment were summarized in a letter report entitled "Soil and Ground Water Sampling Results, Planned Daycare Facility," which was provided to ERM for review on 10 November 2000. The results of H&A's assessment are summarized in Results (Section 5.0) and incorporated into the Risk Characterization (Section 6.0).

December 2000 – Notice of Proposed Permit Decision

In September 2000, the MA DEP issued a Notice of Proposed Permit Decision and Statement of Basis, stating that OHM within the wetland does not pose a threat to potable supplies, and as such, the Site should remain classified as Tier IB. As a result, the MA DEP issued a new Tier IB permit for the Site. The permit was accepted by Raytheon and became effective on 28 November 2000. The permit was issued with three special conditions:

- Raytheon must adequately secure the potentially accessible contamination to prevent trespassing using fencing and signs. The signs must deter trespassers from conducting activities such as fishing or consuming any plant or animal species from the area;

- Raytheon must submit the Phase II Comprehensive Site Assessment and the Phase III Remedial Action Plan within one year of the effective permit date (i.e., by 13 December 2001); and
- Raytheon must submit the Phase IV Remedy Implementation Plan within 1.5 years of the effective permit date (i.e., by 13 June 2002).

Release Tracking Number Summary

A summary of MA DEP release tracking numbers (RTNs) for the Site is presented below.

RTN	Release Condition	Date Issued	Status
3-1783	MA DEP lists Site on LTBI (List of Locations to be Investigated) per US EPA referral. Also included a historic release of butyl cellusolve due to a cross-connection of wastewater treatment lines.	15 January 1987	Closed 31 July 1995 LSP Evaluation Opinion Filed
3-13302	Petroleum hydrocarbons (No. 6 fuel oil) to soil and ground water at WAY-02.	2 January 1996	Closed 14 May 1999 Class A-3 RAO Statement Filed
3-13574	Release of chlorinated hydrocarbons (TCE, PCE) to ground water.	28 March 1996	Open Phase II Tier IB Permit
3-14042	Release of PCBs to soil and at TP-3. RAM completed to abate impact.	25 July 1996	Open Phase II Tier IB Permit
3-19482	Release of PCBs and metals to wetland sediments.	9 May 2000	Open Phase II Tier IB Permit

Note that in addition to the above RTNs, the Site also remains listed on the federal CERCLIS as MAD990685554. Locations of reported release conditions and RTNs are summarized in Figure 5.

4.0 METHODS

4.1 SITE INVESTIGATION STRATEGY

The Phase II investigation was built on the results of previous assessment and remediation efforts to identify key data gaps to be addressed in the Phase II SOW. In particular, several sources of OHM releases had been identified and remedial efforts were undertaken to eliminate potential ongoing sources of release. The Phase II assessment focused largely on residual impacts from historic releases including:

1) Confirming the presence or absence of any additional unidentified disposal areas on Site;

2) Expanding evaluation of the lateral and vertical extent of impact to ground water from chlorinated hydrocarbons, particularly at, and downgradient of, manhole W-4;

3) Evaluating the potential for impact to wetland sediment and surface water associated with former discharges at outfall OF-1;

4) Evaluating the potential risk posed by residual impacts of OHM in soil, ground water, sediment and surface water to human health, safety, public welfare, and the environment; and

5) Determining the need for additional remedial actions, and if so, developing data necessary to support evaluation and selection of remedial alternatives and future risk management decisions.

The Phase II was conducted as a phased investigation involving a series of sequential field assessments conducted between May 1998 and November 2000. Historical data, along with data collected during each phase of the investigation, were used to design the ensuing phase of activities. As the Phase II progressed, the Site conceptual model was refined to enhance our understanding of the nature and extent of OHM impact. The final part of the Phase II was completed under an addendum to the Phase II SOW to support expansion of the wetland assessment, ecological studies and the Environmental Risk Characterization. The following section describes the original Phase II SOW and addendum and provides a chronology of the expansion of the ground water and wetland investigations.

4.2 SCOPE OF WORK & ADDENDUM

The Phase II SOW and addendum consisted of the following primary tasks:

- Task 1: Excavate Test Pits & Collect Soil Samples;
- Task 2: Advance Borings, Conduct Soil & Bedrock Sampling, & Install Monitoring Wells;
- Task 3: Survey, Gauge & Sample Monitoring Wells;
- Task 4: Perform Aquifer Testing;
- Task 5: Conduct Wetland Sediment, Surface Water & Ecological Evaluation;
- Task 6: Conduct Method 3 Risk Characterization; and
- Task 7: Conduct Environmental Risk Characterization

The objectives and methodology employed to complete each task are presented below.

Task 1: Excavate Test Pits & Collect Soil Samples

The purpose of this task was to comprehensively evaluate areas of potential filling along the northern boundary of the Site to determine if OHM release(s) may have occurred within filled or disturbed areas. The test pitting activities were conducted in response to previous findings (see Section 3.4). ERM conducted test pit excavation and sampling activities in accordance with accepted practices outlined in the MADEP *Standard References for Monitoring Wells*, dated April 1991 (updated July 1994).

On 11 and 12 May 1998, ERM excavated 17 test pits (TP-8 through TP-24) in the northern portion of the Site using a grid pattern (Figure 6). Test pits were excavated, by Geosearch, Inc. (Geosearch) of Sterling, Massachusetts, using a backhoe. Test pits were excavated to maximum depths of six to eight feet below grade, but were not advanced to greater depths due to sloughing of material into the excavation. All test pits were excavated into native overburden deposits and several were advanced to below the ground water table. ERM logged each test pit using a modified Burmister soil classification and standard geologic description. Test pit logs are included in Appendix B.

Soil samples were collected from the test pits and field-screened using a photo-ionization detector (PID) equipped with a 10.6ev lamp using the

MA DEP Jar Headspace Method. One soil sample was collected from each test pit and submitted for laboratory analysis of PCBs by EPA Method 8080. No soil samples were submitted for analysis of VOCs, based on field observations and field screening results. Soil analyses were performed by Alpha Analytical Laboratories (Alpha) of Westborough, Massachusetts. Test-pit soil analytical results are presented in Table 2b.

Task 2: Advance Borings, Conduct Soil & Bedrock Sampling, & Install Monitoring Wells

The purpose of this task was to further delineate the lateral and vertical extent of soil and ground water impact. Phase II boring/well locations were selected to investigate soil and ground water quality downgradient of release locations identified in Phase I. Since areas of soil impact identified during Phase I were abated by completion of LRAs and a RAM, limited soil analyses were conducted as part of Phase II.

From May 1998 through April 2000, ERM conducted a series of four drilling programs. All borings were advanced by Geosearch using a truck-mounted drill rig and a variety of drilling techniques. Overburden drilling techniques included hollow-stem auger, drive and wash casing, and/or telescoping casing techniques. Bedrock boreholes were advanced into shallow bedrock using an HV-diameter core.

Soil samples were collected at either five-foot intervals or continuously to the bottom of each borehole using standard split-spoon sampling techniques. At monitoring well clusters, which were installed in phases (i.e., shallow wells installed first and deeper wells installed during subsequent phases), soil samples were collected to the bottom of each boring while avoiding duplication of samples collected from the previous boring(s). Soil samples were field screened using a PID and the jar headspace method. Results of the PID screening are presented in Table 3.

ERM logged each borehole using a modified Burmister soil classification, the Rock Quality Designation (RQD) scheme and standard geologic descriptions, as appropriate. RQDs represent bedrock quality (degree of fracturing) as a percentage ranging from 0% (incompetent, highly fractured rock) to 100% (completely competent, un-fractured rock). A summary of well construction data is presented in Table 4. Well locations are displayed in Figure 6. Boring logs are included in Appendix C.

A sequential description of the four rounds of well installation completed during Phase II follows:

- From 11 to 14 May 1998, ERM supervised the installation of 12 overburden monitoring wells at locations across the Site to evaluate the lateral extent of VOC impacts to ground water in shallow overburden. Eleven (11) of these wells were installed within shallow overburden (MW-32, MW-33S, MW-34, MW-35, MW-36, MW-37, MW-38, MW-39, MW-40, MW-40S and MW-41) and one at an intermediate depth within overburden (MW-33M);
- From 2 to 6 November 1998, ERM supervised the installation of 13 overburden monitoring wells to evaluate the downgradient and vertical extent of VOC impacts to ground water. Six shallow overburden (MW-42S, MW-43S, MW-44S, MW-45S, MW-46S and MW-47S), five intermediate overburden (MW-37M, MW-44M, MW-45M, MW-46M and MW-47M) and two deep overburden wells (MW-44D and MW-47D) were installed as part of this program;
- From 9 through 11 August 1999, ERM supervised the installation of two deep overburden monitoring wells (MW-33D and MW-45D) to evaluate the vertical extent of VOC impact to ground water downgradient of the primary source area (manhole W-4); and
- From 21 through 27 March 2000, ERM supervised the installation of one deep overburden (MW-43D) and two shallow bedrock monitoring wells (MW-33B and MW-45B) to evaluate the vertical extent of VOC impacts to ground water at, and downgradient of, the source area (manhole W-4).

Several wells installed as part of Phase I and Phase II were destroyed during construction or remedial activities (at WAY-02) at the Site. A summary of the operational status of each well is presented in Table 4.

Two soil samples were collected at the ground water table beneath two potential source areas (i.e., MW-33M located beneath former hazardous waste storage area and MW-40 located near former DW-05). Each sample was submitted for laboratory analysis of VOCs by EPA Method 8260. No other soil samples were submitted for laboratory analysis based on field observations and field screening results, suggesting no evidence of OHM impact to soil. Soil analyses were performed by Alpha. Soil analytical results are presented in Table 2.

Task 3: Survey, Gauge & Sample Monitoring Wells

The purpose of this task was to collect the data necessary to evaluate ground water quality and flow patterns. ERM conducted surveying, gauging and ground water sampling activities in accordance with accepted practices outlined in the MA DEP *Standard References for Monitoring Wells*, dated April 1991 (updated July 1994).

To accurately determine ground water flow direction across the Site, ERM completed location and elevation surveys of newly installed monitoring wells following each phase of well installation. Elevations for these wells were surveyed relative to a common Site datum. Ground surface and monitoring well elevation data are presented in Table 5.

As part of Phase II activities, ERM conducted six rounds of ground water monitoring rounds to obtain chemical and hydrologic data necessary to evaluate the nature and extent of impact to ground water:

- May 1998 Comprehensive Round;
- November 1998 Comprehensive Round;
- July 1999 Comprehensive Round;
- September 1999 Partial Monitoring Round;
- April 2000 Comprehensive Round; and,
- July 2000 Partial Monitoring Round.

A summary of the parameters analyzed during these sampling rounds is presented in Table 6.

Prior to collection of ground water samples, water level measurements were made using an electronic water level probe marked in 0.01-foot intervals. Ground water samples were collected from wells using dedicated bailers, submersible electric pumps or peristaltic pumps with dedicated tubing. Prior to sampling, three well volumes were removed from the well to ensure collection of ambient ground water. If the well was pumped dry, the well was allowed to fully recharge prior to sampling. Field parameters (i.e., temperature, specific conductivity, dissolved oxygen, pH and oxidation-reduction potential (ORP)) were measured continuously using a flow-through cell and data logger throughout the tests. Field parameter data are presented in Table 7.

Ground water samples were preserved on ice and sample collection/delivery to the laboratory documented consistent with standard chain-of-custody protocols. Blind duplicate and trip blank samples were collected during each monitoring round for Quality Assurance/Quality Control (QA/QC) purposes. Ground water samples were submitted for laboratory analysis as summarized in Table 6. The majority of samples were analyzed for VOCs by EPA Method 8260 or EPA Method 8021B. Laboratory analyses were performed by Alpha. A summary of ground water analytical results is presented in Table 8.

The August 2001 sampling round included analysis of groundwater collected from an irrigation well at Russell's Garden Center. A grab sample was taken from a spigot connected to the irrigation well, under pumping conditions. The groundwater sample was analyzed for VOCs by EPA Method 8260. See Section 5.3.4 for discussion of results.

Task 4: Perform Aquifer Testing

The purpose of this task was to collect Site-specific hydrogeologic data that will allow for an analysis of ground water and contaminant migration. ERM conducted aquifer testing using slug tests and step-drawdown tests to determine hydraulic conductivity values.

Slug tests were conducted for the following wells on the following dates:

- 6 March 1996: MW-13 and RAY-01;
- 8 & 9 January 1998: HA-101, HA-102, HA-103, HA-104 and MW-10 (conducted by H&A);
- 9 June 1998: MW-32, MW-33S, MW-33M, MW-35, MW-36, MW-37, MW-39, MW-40, MW-40S and MW-41;
- 13 & 14 October 1999: MW-33D, MW-45S, MW-45D, MW-46S, MW-46M, MW-47S, MW-47M and MW-47D; and
- 25 April 2000: MW-33B, MW-37, MW-37M, MW-43S, MW-43D, MW-45S, MW-45M, MW-45B, MW-46S, MW-47S and MW-47D.

Slug tests were conducted in water table wells using rising head slug tests. Deeper wells with fully penetrating screens were tested using both rising and falling head slug tests. Ground water elevation data were collected using a pressure transducer and electronic data logger. The data were analyzed using the Bouwer and Rice method for unconfined aquifers (Bouwer and Rice, 1976; Bouwer, 1989). Estimates of aquifer hydraulic conductivity are presented in Table 9. Slug test data are included in Appendix D.

On 11 July 2000, ERM conducted step-drawdown tests at wells MW-33S, MW-43S, MW-45M and MW-47M to determine the recharge characteristics within the wells containing the highest levels of VOCs detected on Site. Prior to the tests, a pressure transducer and data logger were lowered to the bottom of each well to allow a continuous record of water level elevation. Ground water was pumped from each well at successively higher pumping rates using a submersible pump while discharge volumes and water table elevations were monitored. Field parameters were measured continuously using a flow-through cell and data logger throughout the tests. Ground water samples were collected at intervals throughout the step-drawdown tests for laboratory analysis of VOCs by EPA Method 8021B to evaluate changes in ground water quality with increased duration of pumping.

The well recovery data after pumping was analyzed using a superposition technique and the Theis equation for MW-33S and MW-45M. Only the recovery portion was used to eliminate head losses due to turbulence. As summarized in Table 10, the hydraulic conductivity determined by this method for MW-45M was slightly greater than that determined from the slug test. However, the hydraulic conductivity at MW-33S was estimated to be an order of magnitude greater than that determined using the slug test.

A summary of the observations during the step-drawdown tests and laboratory analyses of ground water samples collected during the tests is presented in Table 10. Further details of the step drawdown analysis are included in Appendix D.

Task 5: Conduct Wetland Sediment, Surface Water & Ecological Evaluation

Potential impacts to sediment from polynuclear aromatic hydrocarbons (PAHs), PCBs and metals were allegedly discovered near the former facility storm/waste water outfall (OF-1) in July 1989 by the US Fish & Wildlife Service (USFWS) as part of a study of the Great Meadows National Wildlife Refuge (GMNWR) (USFWS, June 1991). Subsequent sampling by ERM in April 1990 (for a buytl cellusolve release) and July 1995 failed to confirm the results reported by USFWS. Sampling locations and methods utilized by USFWS could not be determined based on available documentation.

The Phase II SOW excluded additional wetland sediment sampling pending further evaluation of existing Site data generated by both USFWS and ERM. A detailed evaluation of both data sets did not resolve these discrepancies, but indicated issues associated with where each group of samples was collected. Therefore, verification sampling was conducted in November 1998 along a series of 14 transects crossing the drainage swale and trending from outfall OF-1 to the Sudbury River. Results of this sampling effort indicated impacts to wetland sediments from PCBs and metals immediately adjacent to the facility outfall OF-1. These results were previously submitted to the MA DEP.

This task describes activities conducted to further evaluate the nature and extent of impact to wetland sediment and surface water and support performance of the Site Environmental Risk Characterization. Sampling activities were outlined in an addendum to the Phase II SOW dated 20 September 1999. Activities conducted in accordance with, and in addition to the SOW addendum, included: 1) two additional rounds of wetland sediment sampling (October and November 1999); 2) three rounds of wetland surface water sampling; 3) collection and analysis of plant samples; 4) fall and spring ecological surveys of the wetland plant and natural communities; and 5) compilation of Sudbury River gauging data available from the USGS. The results of these investigations are summarized in Results (Section 5.0) and included in the Environmental Risk Characterization (Appendix E). A summary of these activities is provided below.

November 1998 Sediment Verification Sampling

The wetland evaluation began in November 1998 with an initial round of verification sampling of wetland sediments to resolve discrepancies between data collected by USFWS and ERM. ERM established 14 transects (running north to south) located to intersect the drainage swale trending from outfall (OF-1) to the Sudbury River (Figure 7). Transects T-1 through T-7 (closest to OF-1) were spaced at 25-foot intervals, T-7 through T-11 were spaced at 50-foot intervals, and T-11 through T-14 at 100 to 200-foot intervals. From one to five sediment samples were collected along each transect at intervals of 10, 25 and 50 feet. Locations were selected to target one sample within the swale, two along the banks of the swale and two within 25 to 50 feet of the swale bank, if appropriate based on field conditions.

A total of 53 composite sediment samples were collected from 0 to 6 inches depth using a clean stainless steel shovel. The samples were collected in plastic bags to enable thorough mixing before separation into pre-cleaned laboratory containers. Sampling equipment was decontaminated with methanol and de-ionized water prior to collection of each sample. Each sample was submitted to Alpha for analysis of PCBs by EPA Method 8082 and total chromium and copper by inductively coupled plasma (ICP) methods.

October & November 1999 Sediment, Surface Water & Biota Sampling

Based on the results of the November 1998 verification sampling, two additional sampling rounds were conducted in October and November 1999. These efforts focused on expansion of the original sediment sampling grid as outlined in the addendum to the Phase II SOW dated 20 September 1999. Additional activities during these two sampling events included:

- Collection of an additional 125 sediment samples from depth of 0 to 6 inches, 6 to 18 inches and at greater than 18 inches (Figure 7). Laboratory analysis of selected sediment samples for:
  - PCBs by Method 8082 and by GC/MS methods for PCB congeners;
  - Extractable Petroleum Hydrocarbons (EPH) and Volatile Petroleum Hydrocarbons (VPH) by MA DEP Method 98-1;
  - PAHs by EPA Method 8270;
  - 21 target metals by ICP methods and acid volatile sulfide and simultaneously extracted metals (AVS/SEM); and
  - Total Organic Carbon by Method 415.1/SM5310C/EPA9060.
- Collection of three surface water samples and laboratory analysis for PCBs, PAHs, dissolved metals, pH, alkalinity, ammonia, dissolved oxygen and hardness (Figure 8). Specific conductance and temperature were measured in the field; and
- Collection of seven plant samples including cattail roots and button bush seeds for analysis of lipids, PCB congeners and 21 target metals (Figure 8).

The three surface water samples were collected concurrently with sediment samples at selected locations. The low water table conditions limited sampling to small pools or puddles, representing a worst-case scenario of surface water quality. The drainage swale did not flow beyond the area adjacent to the outfall.

Woodlot Alternatives, Inc. (Woodlot) of Topsham, Maine was retained by ERM to conduct an ecological survey of plants and natural communities in the wetland. Emphasis was placed on identifying insectivorous and herbivorous species, including small mammals, birds, amphibians and reptiles. Plant and macro-invertebrate samples were collected from the wetland. Co-located sediment samples were collected concurrently with species sampling. Results of the survey are presented in the Environmental Risk Characterization (Appendix E).

April 2000 Species Survey Update

An update to the October 1999 species inventory was conducted by Woodlot in April 2000 to characterize spring communities. No samples were collected at this time. Results of the survey are presented in the Environmental Risk Characterization (Appendix E).

May 2000 Surface Water Sampling

Five surface water samples were collected during a period of flooding in May 2000. Three upstream locations (near the outfall) and two downstream locations (near the Sudbury River) were chosen to evaluate the potential impact of the wetland sediment on the Sudbury River during periods of inundation (Figure 8). The samples were analyzed for PCBs, dissolved metals and PAHs.

October 2000 Surface Water Sampling

An additional round of surface water samples were collected to confirm the sampling results from the previous fall. The sample results from May 2000 and November 1999 differed by an order of magnitude for some constituents. Samples were collected during a period of low water level at the same locations, or as close as possible, depending on where surface water was available to sample (Figure 8). Samples were analyzed for dissolved metals, dissolved organic carbon and hardness. Field parameters, such as pH, temperature and conductivity were also collected.

Task 6: Conduct Method 3 Risk Characterization

- In accordance with 310 CMR 40.0991, ERM prepared a Method 3 Risk Characterization to evaluate the potential risk of harm posed by Site OHM in soil, ground water, sediment, and surface water to human health, safety, public welfare, and the environment. A Method 3 Risk Characterization was necessitated by the presence of OHM attributable to the Site in wetland sediment and surface water. The purpose of the Method 3 Risk Characterization is to determine if the Site poses a condition of "significant risk," as defined in the MCP, that requires evaluation of remedial alternatives under Phase III, and if feasible, implementation of remedial response actions under Phase IV. The Method 3 Risk Characterization is presented in Section 6.0.

Task 7: Conduct Environmental Risk Characterization

Raytheon retained Entrix, Inc. (Entrix) to conduct the Phase II Environmental Risk Characterization for the Site. The Environmental Risk Characterization was performed in accordance with the MCP and, where appropriate, supplemented with guidance from the US EPA guidance document entitled *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (US EPA, June 1997). The Environmental Risk Characterization is included in Appendix E.

The purpose of a MCP Environmental Risk Characterization is to "characterize the potential risk of harm to habitats and biota to OHM at, or from, the disposal site." The "risk of harm" standard relies on available evidence to determine the likelihood of actual or potential impacts. "Habitats and biota exposed" refers to ecological subpopulations and communities that, under current and reasonably foreseeable future conditions, may or could experience, potential adverse exposure. In accordance with 310 CMR 40.0995, Method 3 Environmental Risk Characterization, the Environmental Risk Characterization is a two-stage process:

- Stage I is a screening level assessment intended to identify potentially significant exposure pathways and/or evidence of "readily apparent harm" to the environment (e.g., stressed vegetation attributable to a release of OHM from the Site). If neither of the above Stage I conditions are met, then conditions are deemed to not pose a "significant risk of harm to the environment" and Stage II is not required; and
- Stage II is a site-specific quantitative evaluation of the potential for adverse exposure to potential ecological receptors that are, or could be, present at the Site.

The Environmental Risk Characterization for the Site included both Stage I and Stage II evaluations. Stage I included the identification of an "area of readily apparent harm" (ARAH) within the wetland based on correlation of chemical analyses and vegetative mapping. Stage I also included a comparison of sediment and surface water data to applicable screening benchmark criteria available in the literature to determine if potentially significant exposure pathways exist that require further evaluation under Stage II. Stage II was conducted consistent with MA DEP and US EPA guidance for a site-specific quantitative Environmental Risk Characterization including:

- **Problem Formulation** - In the problem formulation phase, goals are evaluated, assessment and measurement endpoints are selected and a site conceptual model is developed. Assessment endpoints are clear, specific expressions of the actual value that is to be protected, are the ultimate focus of the Environmental Risk Characterization and act as a link between the risk characterization and risk management process. Measurement endpoints are responses than can be measured to quantitatively or qualitatively assess the effect of site OHM on the assessment endpoints;
- **Analysis Phase** - The analysis phase involves evaluation of the relationship of stressor concentrations and ecological effects by integrating data available regarding chemical toxicity, the spatial distribution and concentrations of chemicals in the environment, spatial and temporal exposure conditions and observations or predictions of adverse effects; and
- **Risk Characterization** - The risk characterization involves estimation of potential risks through the integration of exposure profiles and stressor-response profiles. This was using the Hazard Quotient Method, calculated by dividing the estimated or measured exposure by a toxicity benchmark specific to each potential receptor. In instances where multiple measurement endpoints were evaluated, a weight-of-evidence approach was utilized to determine the outcome.

The methodology, results and conclusions of the Environmental Risk Characterization are presented in a separate report entitled, *Environmental Risk Characterization of the Wetlands Adjacent to the Former Raytheon Facility*, prepared by Entrix, dated 31 August 2001 and included in Appendix E.

5.0 RESULTS

5.1 REGIONAL & SITE GEOLOGY

5.1.1 Bedrock

Bedrock beneath the Site was mapped by the United States Geologic Survey (USGS, 1975) as crystalline metamorphic rock, primarily gneiss, of the Claypit Hill formation (Figure 9). The northeastern edge of the Site is underlain by undifferentiated gabbro and diabase of Carboniferous to Precambrian age.

The Bloody Bluff Fault is the closest mapped fault to the Site, located within one mile, trending southwest-northeast and dipping to the west. Northwest of the Bloody Bluff Fault lies the Dedham Granodiorite formation.

Bedrock mapping by Fortin (January 1981), shows that bedrock elevations range from 20 feet above mean sea level (ASL) at the Sudbury River west of the Site and along the Boston and Maine rail line to 70 feet ASL at the northwestern edge of the Site. Bedrock was encountered in Site borings at a depth of 60 feet to 80 feet bgs.

5.1.2 Soil

The Site is located in a zone of Wisconsin-aged glaciolacustrine (i.e., lake bottom) deposits, as displayed in Figure 10. Field observations indicate that the deposits are primarily stratified fine sands and silt. Recent swamp and alluvial deposits occur west and south of the Site, along the Sudbury River. The wetland portion of the Site is underlain by a silty-clay layer.

Figure 11 presents a generalized geologic cross-section showing overburden stratigraphy at the Site. The following overburden units, listed from top to bottom (i.e., youngest to oldest), have been observed at the Site:

- Brown, fine- to coarse-grained, bedded, sand, which likely represent deltaic or proximal glaciolacustrine deposits. This layer ranges from 30 to 50 feet thick;

- Gray silt, which likely represent distal glaciolacustrine deposits. This layer ranges from 5 to 20 feet thick;
- Gray-brown, fine- to medium-grained sand, which likely represent proximal glaciolacustrine deposits. This layer ranges from five to ten feet thick;
- Brown, fine- to coarse-grained sand and gravel, which likely represents a stream channel deposit. This unit is discontinuous and appears to trend generally east-west beneath the central portion of the Site; and
- Glacial till, consisting of poorly sorted, highly compact sediments with a fine-grained matrix. The till layer is generally less than five feet thick.

5.1.3 Sediments

Wetland deposits at the Site consist of both Recent and Holocene age swamp deposits (USGS, 1974). The following deposits have been observed in the wetland during Phase II sampling:

- Surface to 12 inches - organic, dark brown silty peat with root structure, generally uniform, increasing silt content with depth;
- 12 to 16 inches - dark black organic sediment with fine silt; and
- 18 inches and greater - fine gray silt and clay.

5.2 REGIONAL & SITE HYDROGEOLOGY

5.2.1 Local & Regional Ground Water

Ground water was encountered beneath the Site at depths ranging from 2 to 19 feet bgs. A ground water elevation contour map was developed based on the April 2000 gauging event (Figure 12). The primary direction of ground water flow beneath the Site is southwesterly toward the Sudbury River. A local ground water divide appears to be located beneath the eastern portion of the main building complex trending northeast-southwest. Ground water flow to the west of the divide is generally southwest toward the Sudbury River. Ground water flow to the east of the divide is generally south/southeast toward an unnamed brook/drainage swale bordering the eastern property boundary (Figures 1 and 2).

The MA DEP Geographical Information System (GIS) Site Scoring Map (modified in Figure 13), indicates that the Site is located within the MA

DEP-approved Zone II Wellhead Protection Area for the Baldwin Pond Well Field, located approximately 0.5-mile to the north of the Site. Although the Site is located within the Zone II, the ground water contour map on which the Zone II delineation is based shows that, even after 180 days of pumping at 1,510,000 gpd, the majority of ground water that passes beneath the Site discharges to the Sudbury River (Anderson-Nichols, March 1994). In addition, an apparent southwest-northeast trending ground water divide was inferred to exist along the northern boundary of the Site. Therefore, even when the Baldwin Pond wells are being pumped at their theoretical maximum allowable rate, the Zone II model shows that ground water flow beneath the Site remains south-southwest toward the Sudbury River. The results of the Zone II study are documented in a report entitled, *Report on Conceptual Zone II Study of the Baldwin Pond Wellfield*, dated 31 March 1994.

In December 1998, ERM observed a drill rig on the adjacent downgradient property, the Russell Garden Center, located at 397 Boston Post Road (Figures 2 and 13). Based on review of the boring log filed with the Town of Wayland Board of Health, a six-inch diameter boring was advanced to a depth of approximately 900 feet bgs. Bedrock was observed at approximately 60 feet bgs. Steel casing was set to 80 feet bgs (i.e., 20 feet into bedrock) and the remainder of the borehole was left open. Subsequent pumping of the well indicated a sustainable yield of at least ten gpm over a pumping period of 24 hours. The well is presumably used for irrigation. No additional information was available from the Town of Wayland Board of Health regarding well usage, yield or ground water quality. No additional private wells have been identified within 0.5-mile of the Site.

5.2.2 *Local & Regional Surface Waters*

The Sudbury River abuts the western boundary of the property and is classified as a Class B Surface Water Body. The stream gradient adjacent to the Site is estimated at approximately one foot per 12 miles (Bickford and Dymon, 1990). Based on review of Massachusetts Geographic Information System (Mass GIS) map (Mass GIS, 2000) no Zone A areas for a reservoir are currently located within 500 feet of the Site. The Sudbury River has been posted with signage prohibiting consumption of fish due to mercury impacts associated with the Nyanza Superfund site located approximately six miles (straight-line distance) upstream of the Site.

On 9 April 1999, a 14.9-mile segment of the Sudbury River, including the reach adjacent to the Site, was added to the national list of Wild and Scenic Rivers and designated "scenic" status. As such, a conservation plan that relies on local and private initiatives is being implemented by the SuAsCo River Stewardship Council to ensure long-term protection of this portion of the Sudbury River.

Based on the results of the Zone II delineation, the Sudbury River represents the main discharge zone for ground water beneath, and in the vicinity of, the Site. Site well gauging results also suggests that the majority of ground water flow beneath the Site discharges directly to the Sudbury River. The portion of the Site ground water flow regime located to the east of the inferred ground water flow divide may discharge to the unnamed brook/drainage swale located along the eastern boundary of the Site. This unnamed brook/swale flows south to a confluence with Pine Brook, located approximately 1,000 feet to the south of the Site. Pine Brook in turn flows southwest to a confluence with the Sudbury River, approximately one-half of a mile to the southwest of the Site (Figure 1).

5.2.3 Wetland & Habitats

The western portion of the Site bordering the Sudbury River is occupied by an approximately 15.6-acre wetland owned by WBC and Devins Hamlen (Figure 2). This wetland are part of a large floodplain encompassing approximately 3,000 acres that are part of the GMNWR. The GMNWR includes federally protected woodlands, fields and freshwater wetlands and is designated as a high-density area for nesting wood ducks.

The Site wetland/floodplain is primarily influenced by the water levels of the Sudbury River. Regular inundation of the wetland prevents it from developing into forested or scrub-shrub wetland. Vegetative communities mapped within the Site wetland by Wooodlot are displayed in Figure 14. Emergent marsh dominate the Site wetland, which consists of four communities (classified after Swain & Kearsley, 2000):

- Low Energy Stream Community (i.e., the Sudbury River);
- Deep Emergent Marsh Community;
- Shrub Swamp Community; and
- Alluvial Red Maple Swamp Community.

The frequency and duration of flooding within the wetland was estimated by Woodlot using approximately 20 years of gauging data obtained from the USGS gauging station number 01098530 location in Saxonville, Massachusetts (the closest USGS gauging station to the Site). Based on Site observations made during periods of flooding, the Site wetland is inundated when river flow exceeds 254 cubic feet per second (cfs). During the period from 1980 to 1999, Woodlot estimated that the wetland was inundated for an average of 118 days per year (approximately 30 percent of the year). The most frequent periods of flooding were from late winter to early spring and from late fall to early winter.

According to the MA GIS Map (Figure 13), the Site wetland is classified under the National Heritage Endangered Species Program (NHESP) as Estimated Habitats of Rare Wetlands Wildlife (for use under the Massachusetts Wetlands Protection Act only). Based on Woodlot's ecological surveys, the wetland contains one rare plant species, the River Bullrush, located along the southwest edge of the Site wetland bordering the Sudbury River. The River Bullrush is a species of special concern in Massachusetts. In addition, one sighting of a single Northern Harrier was made during the October 1999 ecological survey downstream of the Site. The northern harrier is currently listed as an endangered species in Massachusetts. The timing of this observation suggested that the individual might have been migrating south.

Additional details regarding Site wetland communities and characteristics are documented in a report entitled, *Raytheon Project Area Ecological Characterization*, prepared by Woodlot dated December 2000 and included in the Environmental Risk Characterization (Appendix E).

5.3 SOURCE, NATURE & EXTENT OF CONTAMINATION

5.3.1 Overview

This section describes the identified sources of OHM release and the nature and extent of OHM releases by media (i.e., soil, ground water, sediment, surface water, and air). The types and levels of OHM in Site soil and ground water are described with respect to applicable MCP RCs for the Site. These thresholds have been adopted to provide the reader with a knowledge of what levels of OHM in soil and ground water at the Site are considered by the state to constitute "contaminated" soil and/or ground water, defined under the MCP as soil or ground water containing levels of OHM in excess of MCP release notification criteria (e.g., RCs).

The MCP does not include OHM-specific RCs for sediment, surface water, air or biota. The type and level of OHM detected in Site sediment and surface water are discussed relative to defined "background" concentrations for sediment and applicable state and federal standards for surface water. Site conditions indicate that no adverse impact to indoor air is anticipated or been identified.

It is important to recognize that MCP RCs for Site soil and ground water are thresholds established by the MA DEP solely for notification of releases of OHM to the Department. Levels of OHM in soil or ground water that exceed a RC do not mean that the condition does, or does not, pose a "significant risk" to human health, safety, public welfare, or the environment or may/or may not require cleanup. The determination of a condition of "significant risk" is based on the results of a risk characterization. Determination of the need for, and level of, abatement necessary to constitute "cleanup" is based on consideration of both risk and feasibility and will be addressed under Phase III.

5.3.2 *Sources of Oil and/or Other Hazardous Materials Release*

As described earlier, sources of OHM release to the environment were associated with historic facility operations that were terminated on or before 1995. Decommissioning of the facility by Raytheon included abatement of residual OHM remaining within former structures. Additional source abatement was conducted during and post-Phase I and during the Phase II. As a result, all confirmed or probable sources of OHM release at the Site have been abated. Residual OHM impacts are largely limited to soil, ground water, wetland sediment and wetland surface water associated with the following former sources:

- Soil impacted by No. 6 Fuel Oil released from WAY-02 located beneath former Building 3 and in the former courtyard between former Building Nos. 3 and 4 (Figure 5);
- Ground water impacted by primarily TCE and associated degradation products, primarily associated with a release from former Manhole W-4 located adjacent to the north side of former Building 4 (Figure 5). Minor residual TCE impacts to ground water have also been detected due to OHM releases discovered at TP-3 and drywell DW-05 (see Figures 3 and 5);
- Wetland sediment impacted by SVOCs, PCBs and metals associated with historic inadvertent, incidental releases to the stormwater conveyance system and discharge at outfall OF-1 (Figure 5); and
- Wetland surface water impacted by metals in wetland sediments within the ARAH (Figure 5). As discussed in the subsequent sections, wetland surface water impacts associated with copper may be attributable to current discharges, since elevated levels of copper occur ubiquitously within the Town of Wayland water supply.

5.3.3 *Soil*

Concentrations of OHM detected in Site soils are presented in Table 2. Shading in Table 2 designates soil results that have been removed during previous remedial actions. A summary of soil field screening results is presented in Table 3. Laboratory reports are included in Appendix F.

As discussed above, several remedial actions (i.e., LRAs and RAMs) have been completed to abate impacts to soil. Therefore, discussion of soil impacts in this section will be limited to those areas where residual impacts in soil exceed applicable RCs (i.e., RC S-1). However, all soil data indicating detectable concentrations of OHM are considered in the Risk Characterization (Section 6.0).

The results of excavation of 17 test pits (locations TP-8 through TP-24) along the northern boundary of the Site indicated no evidence of OHM release based of visual inspection, field screening and laboratory analysis of 17 soil samples for PCBs by EPA Method 8080. Laboratory results are presented in Table 2b.

Headspace field screening of soil samples collected from test borings ranged from zero parts per million (ppm) to 33.2 ppm, with all but one PID reading below 8 ppm. The one soil sample exhibiting a headspace reading of 33.2 ppm was collected from a depth of 25 to 26 feet bgs from the boring for monitoring well MW-43D. No evidence of separate phase product or dense non-aqueous phase liquid (DNAPL) was observed in this sample. Since the sample was collected from below the water table within an area of known ground water impact, it was not submitted for laboratory analysis due to the inability to differentiate between impacts to soil and impacts to ground water at this location.

Based on data collected to date, two areas exist where residual OHM in soil exceed RC S-1, including UST WAY-02 and near surface fill around former Building 12/21. Compounds that exceed RC S-1 in the vicinity of WAY-02 included PAHs and hydrocarbons associated with heavy fuel oil including: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, dibenzo(a,h)anthracene, naphthalene, 2-methylnaphthalene, EPH C9-C18 aliphatics, C19-C36 aliphatics and C11-C22 aromatics.

Residual soil impacts at WAY-02 are generally limited to depths of 14 feet or greater beneath the courtyard between former Buildings 3 and 4 and beneath Building 3. No evidence of residual separate phase petroleum product was observed within the excavation. A more detailed description of the extent of residual petroleum impacts to soil near WAY-02 is provided in the H&A report entitled, *Class A-3 Response Action Outcome Statement - Partial and Release Abatement Measure Completion Report*, dated 14 May 1999.

The following compounds were reported for two shallow soil samples (SS-6 and SS-11 from ground surface to three feet bgs) collected by H&A in Site soil at concentrations above RC S-1 in the vicinity of Building 12/21:

- Sample SS-6 containing EPH, C11-C22 aromatics at 2,400 mg/kg (RC S-1 is 200 mg/kg). Collection of three subsequent samples adjacent to SS-6 (i.e., SS-6A, B and C) indicated EPH, C11-C22 aromatics below detection limits and RC S-1. The original detection at SS-6 was attributed to asphalt in the sample; and
- Sample SS-11 containing benzo(a)anthracene (920 µg/kg), benzo(a)pyrene (1,000 µg/kg) and benzo(b)fluoranthene (1,200 µg/kg) versus a RC S-1 of 700 µg/kg.

No other compounds have been detected in residual Site soils at concentrations above RC S-1. Soil conditions at SS-11 may require either additional assessment/abatement.

5.3.4 *Ground Water*

Ground water monitoring results are presented in Table 8. Laboratory reports are included in Appendix G. As discussed in Update to the Phase I (Section 3.0), abatement of impacts from WAY-02 resulted in localized abatement of ground water. Therefore, discussion of ground water impacts in this section will be limited to those areas where residual impacts exceed applicable RCs (i.e., RC GW-1). However, all ground water data indicating detectable concentrations of OHM are considered in the Risk Characterization (Section 6.0).

Five chlorinated VOCs have been detected in Site ground water at concentrations above RC GW-1 at the following locations:

- PCE (RC GW-1 is 5 µg/L): MW-5, MW-13, MW-31, MW-47M, BW-3, HA-102 and HA-104;
- TCE (RC GW-1 is 5 µg/L): MW-5, MW-6, MW-7, MW-8, MW-11, MW-13, MW-18, MW-30, MW-31, MW-33S, MW-33D, MW-36, MW-37, MW-40, MW-40S, MW-41, MW-43S, MW-45S, MW-45M, MW-45D, MW-45B, MW-46M, MW-47S, MW-47M, MW-47D, MW-TP-3, BW-1, BW-2, BW-3, HA-102, HA-104 and RAY-01;

- cis-1,2-DCE (RC GW-1 is 70 µg/L): MW-13;
- Vinyl Chloride (RC GW-1 is 2 µg/L): MW-13 and MW-31; and
- 1,1-DCE (RC GW-1 is 1 µg/L): MW-7, MW-33S, MW-45M, MW-46M, BW-1 and RAY-01.

The compounds cis-1,2-DCE and vinyl chloride have each been detected at only one and two locations, respectively. Although PCE and 1,1-DCE have each been detected in several wells, average concentrations at each of these wells are within one order of magnitude of the RC GW-1. All of the VOCs listed above were detected at concentrations above RC GW-1 at locations where TCE was also detected above this threshold. With the exception of PCE, these VOCs are degradation products of TCE. PCE was reportedly used as a fuel conditioner and may be associated with the WAY-02 release.

TCE concentrations for the April 2000 monitoring round are shown in plan view (Figure 15) and cross-section (Figure 16). The highest TCE concentrations have been detected in shallow overburden adjacent to manhole W-4 and south of the source area (i.e., vicinity of MW-33 cluster). TCE has been detected at concentrations up to two orders of magnitude above RC GW-1 in intermediate overburden at the MW-47 cluster and in intermediate and deep overburden at the MW-45 cluster. TCE has also been detected in shallow bedrock at an average concentration approximately equal to the RC GW-1 at MW-45B. TCE has not been detected in ground water up-gradient of the source area.

TCE has also been detected at concentrations within one order of magnitude of the RC GW-1 at two secondary sources: TP-3 (i.e., MW-TP-3) and former drywell DW-05 (i.e., MW-40 and MW-40S). Ground water samples collected from wells located downgradient of these secondary sources indicate that minimal, or no significant, TCE transport occurs from these areas.

The highest concentration of dissolved phase VOCs detected at the Site was TCE at 600 µg/L. This concentration is approximately three orders of magnitude less than the solubility limit for this compound (1,400,000 µg/L). Therefore, it is not likely that DNAPL is present at the Site.

Migration of dissolved phase ground water contamination is primarily controlled by ground water flow. The predominant flow direction is from northeast to southwest beneath the Site (Figure 12). Dissolved phase TCE appears to be limited to wells in the vicinity of the source area (i.e., MW-43S) and downgradient wells (MW-33S, MW-47M, MW-45S/M/D, MW-

46M and MW-37). This is supported by the relatively low levels of VOCs detected up-gradient of, and cross-gradient to, the source area.

Downward hydraulic gradients have been measured at all well clusters at the Site, except for the MW-45 cluster. However, the presence of a gray silt layer underlying the source area acts as a semi-confining layer retarding both downward flow and downward vertical migration of TCE. At the MW-33 cluster, elevated TCE concentrations occur only at the shallow well point.

The gray silt layer becomes somewhat coarser to the west of the source area, allowing downward migration of TCE in this portion of the Site. TCE is transported vertically downward as it migrates with ground water flow to southwest from the source area, and has been detected in intermediate overburden at the MW-47 cluster and in intermediate and deep overburden at the MW-45 cluster. TCE has also been detected in shallow bedrock at MW-45B. However, upward vertical ground water flow gradients at the MW-45 cluster likely prevent further dissolved-phase TCE migration into deeper bedrock.

The upward vertical hydraulic gradient measured at the MW-45 cluster is due to the presence of the Sudbury River, which is the regional discharge boundary for the Site. The Russell Garden Center irrigation well is located downgradient within a southwest projection of Site-impacted ground water. The proximity of the irrigation well to the Sudbury River, the upward ground water flow gradients measured at the southwestern edge of the property, and the lack of significant impact to the bedrock aquifer on the downgradient edge of the property, suggest a low potential for adverse impact to ground water within this deep (900 feet bgs) bedrock irrigation well.

Based on sampling results compounds of concern (TCE and its degradation products) were not detected at the irrigation well. Laboratory results are located in Appendix G.

5.3.5 *Sediment*

Concentrations of analytes detected in sediment are presented in Table 11. Laboratory reports are included in Appendix H. The extent of sediment impact is defined relative to both observed areas of impact (defined in the MCP as "readily apparent harm") and background concentrations developed using river sediment samples collected upstream of the Site.

The primary source of impact to wetland sediments appears to be incidental historic releases of OHM to the stormwater conveyance system, discharging at outfall OF-1. The primary COCs identified in source structures (dry wells and manhole W-4) connected to the stormwater conveyance system included PAHs and associated petroleum hydrocarbons, PCBs, and heavy metals (chromium, copper, lead).

Evaluation of the average concentrations of primary COCs versus distance from the outfall indicates concentrations are highest near the outfall, decreasing steeply within 200 feet from the outfall and then flattening to approach background near the Sudbury River (Figures 17a and 17b). The vertical extent of impact appears to be largely limited to the top 18 inches of sediment, confined by an underlying continuous silty-clay unit beneath the floodplain. One exception is elevated EPH detected at location T-3-7 at a depth of greater than 18 inches (Table 11b).

Isoconcentration contour maps were developed to display the lateral distribution of primary COCs and EPH in wetland sediment (Figures 18a through 18f). The distribution between organic analytes (PAHs, PCBs and EPH) is somewhat similar. The highest concentrations are limited largely to the area adjacent to and within 200 feet of the outfall (transect seven or eight) and trending northwest along the drainage swale. One distinct area of elevated PCBs is evident along the drainage swale at transect 10. One distinct area of elevated PAHs is evident trending northwest along the southern end of transects three through eight.

The distribution of inorganic analytes (chromium and copper) appear to extend over a larger area than the organic analytes, reflecting the higher mobility of metals in the wetland environment. The highest concentrations of chromium and copper extend approximately 300 feet from the outfall (to transect 10), reflecting a fairly even distribution.

Correlation of areas of COCs in sediment with the results of vegetative mapping and analysis of plant tissue define an area of stunted vegetation estimated at approximately one-acre in size (Figure 14). This condition constitutes a condition of "readily apparent harm," defined by 310 CMR 40.0955(3) as "stressed vegetation attributable to Site OHM" and may reflect the toxicity of heavy metals (e.g., chromium) to plants.

5.3.6 Surface Water

Concentrations of analytes detected in surface water are presented in Table 12. Laboratory reports are included in Appendix I. Forty OHM compounds, including SVOCs, PCBs, dissolved metals, and total metals have been detected above the method detection limit in surface water.

Detected concentrations of OHM in surface water were compared to federal Ambient Water Quality Criteria (AWQCs) applicable to the protection of aquatic organisms for both acute (short-term) and chronic (life-long) exposures. AWQCs were corrected for Site-specific hardness. In instances where an AWQC was not available (PCBs, antimony, beryllium, and thallium) available literature benchmarks were utilized. Surface water screening benchmarks and hardness corrected AWQCs for both dry (low flow) and flood (inundation/high flow) conditions are summarized in the Risk Characterization (Section 6.0) and included in the Environmental Risk Characterization (Appendix E). A summary of these results is provided below.

None of the AWQCs or screening benchmarks were exceeded for SVOCs or PCBs. AWQCs for four metals (dissolved aluminum, cadmium, copper and zinc) were exceeded under low flow (worst case) conditions. Copper was the only metal to exceed the AWQC under high flow/flood conditions.

Under low flow conditions, dissolved concentrations of aluminum and cadmium exceeded the chronic AWQC, but were below the acute AWQC. Dissolved copper and zinc exceeded both the chronic and acute AWQC under low flow conditions. However, the acute AWQC for zinc was exceeded near outfall OF-1 (i.e., within transect five) and was below the acute AWQC at greater distances from the outfall near the Sudbury River.

Under high flow or flooded conditions copper was the only metal to exceed AWQCs. Concentrations of dissolved copper exceeded both the acute and chronic AWQC during periods of flooding. However, dissolved copper concentrations decrease by approximately an order of magnitude with increasing distance from the outfall and are below chronic and acute AWQCs from transect 12 to the Sudbury River. Therefore, the extent of surface water impact within the wetland appears to be largely associated with areas of residual impact to wetland sediments near the outfall and is reduced to levels protective of the environment before migrating to the Sudbury River.

It is important to note that comparison to AWQCs provides a very conservative estimate of the potential for dissolved metals in surface water to result in adverse impact to aquatic receptors. This is particularly true in the case of low flow or dry conditions, since from a practical standpoint, the wetland is not a suitable habitat for most aquatic receptors. Wetland surface water during dry periods is limited to discontinuous pools or puddles that are not directly connected to the Sudbury River. Therefore, the potential for adverse impact to aquatic receptors during dry conditions is likely to be low.

Based on USGS stream gauging data for the Sudbury River, the wetland is flooded for approximately 30 percent of the year. Water depths during a portion of the flood period are likely to be deep enough to provide suitable habitat for aquatic receptors. Surface water analyses indicate that the only metal that maintains a potential to impact aquatic receptors in surface water during periods of flooding is copper at locations within 200 feet of the outfall. Dissolved concentrations of copper drop below both acute and chronic AWQCs at greater distances to the Sudbury River.

Analysis of a tap water sample (SW-5, Table 12b) collected by ERM within the former Raytheon facility in March 1990 indicates elevated levels of copper in Site drinking water (up to 2,560 μg/L total copper). Review of available data obtained from the Town of Wayland Water Commission indicate that the low pH of the town water supply (less than 6.5) has resulted in widespread leaching of copper from the distribution supply lines. The Town of Wayland Water Commission is in the process of developing corrective measures for this issue. Based on these findings, a portion of the copper in surface water and possibly sediment appears to be related to background or "local conditions" as defined in MA DEP guidance. As such, these finding should be taken into consideration with regard to future risk management decisions for the Site.

5.3.7 Air

No adverse impact to indoor air has been detected during Site investigations. The nature and extent of impact to soil, ground water, wetland sediment and surface water suggest a low potential for residual OHM in these media to adversely impact indoor air quality.

Detected concentrations of TCE, DCE and vinyl chloride in ground water maintain the greatest potential to adversely impact indoor air quality. However, the depth to ground water at locations where these compounds have been detected at elevated concentrations is generally greater than 15 feet bgs, suggesting a low potential for adverse impact to indoor air quality. Nevertheless, the potential for adverse exposure via inhalation of residual OHM on Site is addressed in the Risk Characterization (Section 6.0).

5.3.8 *Biota*

During the ecological inventory performed by Woodlot in November 1999 biota samples were taken and stem count densities established for selected plant species. Stem count data for cattails within the wetland indicated the presence of an approximately one-acre area of stunted vegetation (Figure 14). The growth density of cattails within this area was estimated at 5 stems per square meter (m^2), versus an average stem density of 50+ stems per m^2 within the wetland outside of this area.

Based on these results, samples of edible portions of cattails (i.e., roots) and seedheads of buttonbush were collected from seven locations (e.g., T-1-2, T-3-5, T-3-8, T-5-2, T-7-1, T-9-5 and T-13-4) within the wetland (Figure 8). These locations were selected to transect the inferred concentration gradient for COCs within wetland sediments (e.g., with representative sample from areas of likely impact and areas likely not impacted). Samples of cattail roots collected from within the area of stunted growth indicated uptake of chromium and copper at concentrations up to 62 ppm and 94 ppm, respectively. However, analysis of cattail roots outside of this area indicated uptake of metals at significantly lower levels (up to 1.5 ppm chromium and 12.7 ppm copper). These results suggested that the area of stunted growth was due to the phytotoxicity of metals in sediment. A more detailed discussion of these results is included in Section 4.3.4 of the Environmental Risk Characterization (Appendix E).

5.4 *ENVIRONMENTAL FATE & TRANSPORT OF OIL AND/OR HAZARDOUS MATERIALS*

5.4.1 *Physical & Chemical Properties of Oil and/or Hazardous Materials*

The key parameters impacting a compound's fate and transport in the environment include physical and chemical properties, which in turn determine the compound's persistence and mobility. The physical and chemical properties which may affect the relative mobility, retardation and persistence of chemicals detected on the Site include:

- Solubility in Water;
- Vapor Pressure;
- Viscosity and Density;
- Organic Carbon Partition Coefficient (Koc); and
- Octanol Water Coefficient (Kow).

Table 13 provides a summary of the above chemical-specific properties for COCs detected at the Site.

5.4.2 *Potential Migration Pathways & Fate*

Migration in Soil

The COCs in soil are residual petroleum compounds from the former underground storage tank at WAY-02. These compounds, primarily SVOCs, originate from No. 6 fuel oil. SVOCs have low aqueous solubilities, low vapor pressures, and high soil adsorption coefficients (see Table 13). Therefore, SVOCs are unlikely to leach into ground water, except as micro-emulsions or when associated with suspended particulate matter. SVOCs are also unlikely to volatilize and result in adverse exposures through building foundations and pavement.

Migration in Ground Water

The COCs in ground water are chlorinated VOCs. These compounds have aqueous solubilities ranging from approximately 200 milligrams per liter (mg/L) to 7,000 mg/L under laboratory conditions (see Table 13). VOCs also have the high vapor pressures (ranging from approximately 20 mm Hg to 2,600 mm Hg) and Henry's Law constants (2 to 16 atm-m^3/mol), compared to other types of organic compounds. Therefore, VOCs are likely to be mobile in ground water.

VOCs may be transformed through biological and abiotic reactions. However, at the Site the primary VOCs detected in ground water are parent compounds (TCE and PCE) and, at some locations, lower concentrations of their degradation products (cis-1,2-DCE, 1,1-DCE and vinyl chloride). The persistence of chlorinated parent compounds in ground water at the Site suggests limited natural biotransformation has occurred.

The VOCs in Site ground water are dissolved in water, as evidenced by the fact that the maximum TCE concentration in the source area (i.e., near manhole W-4) was 600 µg/L, which is three orders of magnitude less than the solubility limit for TCE (1,400,000 µg/L). In other words, DNAPL does not appear to exist on Site. The migration of VOCs in ground water occurs primarily via advection, and is controlled by ground water flow. The predominant flow direction is from northeast to southwest beneath the Site (Figure 12). The rate of ground water flow is approximately 0.06 feet per day. Dissolved phase TCE appears to be limited to wells in the vicinity of the source area and downgradient wells, suggesting relatively little transverse dispersion of the plume.

Ground water flow gradients at, and downgradient of, suspected sources are downward, but appear to flatten and become upward at the defined downgradient edge of the plume (MW-45 well cluster). This flow pattern is consistent with the regional pattern of ground water flow and the presence of the Sudbury River as the downgradient ground water discharge boundary.

Applying an attenuation factor of 10 for ground water discharging to surface water (as recommended by MA DEP, April 1994), the projected concentration of TCE in surface water is estimated at 16 ppb. This level would be considered to be protective of the environment (based on a benchmark of 2,000 ppb, a former federal AWQC for TCE adopted by MA DEP in the derivation of Method 1, GW-3 Risk-Based Standards). Therefore, under worst-case conditions, impacts to Site ground water would not be expected to adversely impact surface water in the Sudbury River.

The Russell Garden Center bedrock well is the only potential downgradient receptor. Although this well is located downgradient of the Site, its proximity to the Sudbury River, the upward ground water flow gradients measured at the southwestern edge of the Site, and the lack of significant impact to the bedrock aquifer on the Site, suggest a low potential for adverse impact to ground water within the Russell Garden Center well. Results from sampling conducted in August indicate that compounds of concern (TCE and its degradation products) were not detected at the irrigation well. Therefore, there is a low likelihood for adverse exposure from OHM in Site ground water under current conditions.

Migration in Sediment

The primary COCs in sediment are PCBs, PAHs, EPH and metals (chromium, copper and lead). The distribution of the organic compounds (i.e., SVOCs, PCBs and EPH) generally follows the swale, and trends northwestward from outfall OF-1 (see Figures 18a through 18c). The metals, on the other hand, are more diffusely distributed, with a secondary zone of impact south of the swale (see Figures 18d through 18f). The main zone of organic and inorganic impact is limited to a low-energy environment extending approximately 200 feet from OF-1. This zone of impact correlates with a zone of stunted vegetative growth.

Both the organic and inorganic COCs are bound to the sediment. Because of their low solubilities and high affinities to organic matter, PAHs and PCBs are relatively immobile. The metals, chromium and copper on the other hand, have higher solubilities and have been observed in surface water (see below).

Migration in Surface Water

The primary COCs in surface water are metals (primarily chromium, copper, and zinc). Impacts to surface water are largely limited to the area of sediment impact. Since the main zone of sediment impact correlates to a low-energy (i.e., low-flow) zone, it is unlikely that there would be migration of dissolved metals in surface water to the Sudbury River. These findings reflect the results of surface water monitoring within the wetland. In addition, results of previous investigations by ERM and USFWS suggest it is unlikely that sediment and surface water impacts within the wetland would adversely impact the Sudbury River.

6.0 RISK CHARACTERIZATION

6.1 OVERVIEW

This Method 3 Risk Characterization was prepared to evaluate the risk of harm to human health, safety, public welfare, and the environment. The results of the risk assessment determine if further remedial actions are warranted. In accordance with 310 CMR 40.0991, a Method 3 Risk Characterization was selected because OHM have been detected in media other than soil and ground water (i.e., sediment and surface water).

This risk assessment characterizes the risk of harm to human health (as defined by the MCP in 310 CMR 40.0993); the risk to safety (as defined in 310 CMR 40.0960); the risk of harm to public welfare (as defined in 310 CMR 40.0994); and the risk of harm to the environment (as defined in 310 CMR 40.0995). This risk assessment also considers existing applicable or suitably analogous standards (as defined in 310 CMR 40.0993(3)) and UCLs (as defined in 310 CMR 40.0996).

This Method 3 Risk Characterization evaluates all current and reasonably foreseeable Site activities and uses, excluding consideration of the existing deed restrictions on the Site (i.e., AULs). The risk assessment considers all available soil, ground water, sediment, surface water and biota analytical data generated during the course of Phase II investigation activities as well as previous Site investigations and remedial activities.

Assumptions made in this risk assessment are conservative in order to maintain protection of human health, but realistic to ensure that they are consistent with current and foreseeable future uses of the Site.

6.2 SITE ACTIVITY & USE ASSUMPTIONS

6.2.1 Site Description & Land Use Characteristics

In accordance with 310 CMR 40.0006, the Site is defined to include areas where OHM has come to be located.

As noted in Section 3.3, Wayland Meadows filed the Site-Wide Notice of AUL on an approximately 80-acre portion of the property (Figure 4). WBC also filed a Notice of AUL on an approximately 0.8-acre portion of the property associated with former UST WAY-02 (Figure 4). Activities and uses specifically allowed by the AULs include commercial or industrial uses. Activities and uses specifically prohibited include residential, childcare, day care, agricultural, and those activities that could render contaminated media accessible.

The expected future use of the Site is anticipated to remain as commercial/office space. Although an AUL precluding residential use of the Site has been filed with the Middlesex Registry of Deeds, to present a conservative assessment of potential risks to human health commercial and residential uses of the Site have been evaluated in this risk assessment. However, residential use of the Site will remain prohibited by maintaining a Notice of AUL on the deed to the property.

The Site is located within a MA DEP-Approved Zone II Wellhead Protection Area. Ground water is therefore considered as a potential current and future source of drinking water. However, there is no current use of ground water as a source of drinking water on or surrounding the Site.

As discussed in Section 3.3, an irrigation well is located on the adjacent downgradient Russell's Garden Center property. Based on review of the boring log filed with the DEM, the well is installed in deep bedrock to a depth of 900 feet bgs. Although the well is located downgradient, VOCs in ground water, maintain a low potential to adversely impact ground water withdrawn from this well. Compounds of concern were not detected in sampling data collected inAugust 2001.

The Sudbury River abuts the western portion of the Site and is classified as a Class B Surface Water Body. Based on discussions with the Town of Wayland Commission, no Zone A areas for a reservoir are currently located within 500 feet of the Site. Predominant use of the river is recreational. The river has been posted with signage prohibiting consumption of fish due to mercury impacts associated with the Nyanza Superfund site located approximately six miles (straight-line distance) upstream of the Site.

The portion of the Sudbury River adjacent to the Site was added to the national list of Wild and Scenic Rivers and designated "scenic" status. As such, a conservation plan that relies on local and private initiatives is being implemented by the SuAsCo River Stewardship Council to ensure long-term protection of this portion of the Sudbury River.

The Site wetland abutting the river is part of a large floodplain encompassing approximately 3,000 acres that are part of the GMNWR. The GMNWR includes federally protected woodlands, fields and freshwater wetlands and is designated as a high-density area for nesting wood ducks. The Site wetland is classified under the NHESP as Estimated Habitats of Rare Wetlands Wildlife. Site ecological surveys indicate the presence of one rare plant species, the River Bullrush, located along the southwest edge of the Site wetland bordering the Sudbury River.

The wetland is flooded approximately 30 percent of the year, mostly from late winter to early spring and from late fall to early winter. The transitional nature of this emergent wetland results in a habitat suitable for a limited variety of aquatic and terrestrial receptors during specific times of the year.

6.2.2 *Identification of Soil and Ground Water Categories*

Soil Categories

In accordance with 310 CMR 40.0933, Site soil is classified based on land use characteristics and exposure potential. The MCP includes three categories for classification of Site soil (i.e., S-1, S-2 and S-3) based on MCP criteria for accessibility and frequency and intensity of use. Category S-1 soils are associated with the highest potential for exposure, while Category S-3 soils have the lowest potential for exposure.

Based on current uses, Site soil is classified as Category S-2/S-3 because:

- Adults (e.g., office workers) are present at the Site at high frequency, but low intensity. No children are present at the Site;
- Some soils are considered to be "accessible" since portions of the Site are unpaved;
- Some soils are considered to be "potentially accessible" since portions of the Site are paved;
- Some soils are considered to be "isolated" since they are located beneath the footprint of existing Site buildings; and
- A Notice of AUL filed for the portions of the Site where soil is impacted prohibits activities and use that would result in classification of Site soil as S-1.

Ground Water Categories

In accordance with 310 CMR 40.0932, ground water at the Site is classified based on current and reasonably foreseeable potential future land use. Ground water category GW-1 applies to ground water classified as a current or potential future source of drinking water. Category GW-2 applies to ground water containing OHM that could potentially represent a source of vapors to indoor air. Category GW-3 applies to ground water discharging to surface water. All ground water in the state is classified as GW-3.

Ground water at the Site is classified as GW-1, GW-2 and GW-3. GW-1 is applicable to Site ground water because it is located within a MA DEP-Approved Zone II Wellhead Protection Area. GW-2 is applicable to portions of the Site since OHM has been detected in ground water within 30 feet of existing occupied buildings or structures and where the average annual depth to ground water is less than 15 feet. GW-3 is applicable to all sites.

Consistent with MCP requirements, these soil and ground water categories are applicable based on physical characteristics of the site. The associated Method 1 risk-based standards were not utilized in the risk characterization, since a fully quantitative Method 3 Risk Characterization was performed.

6.3 HAZARD IDENTIFICATION

Hazard identification includes the evaluation of OHM present at the Site based on a media-specific summary of all analytical data collected to date. Background concentrations are also identified and compared to detected OHM concentrations in order to identify COCs to be used in the Method 3 Risk Characterization. Justification is provided for the exclusion of any compound as a COC.

6.3.1 Identification of Oil and/or Hazardous Materials On Site

The identification of OHM on Site considers all available soil, ground water, sediment, and surface water quality data generated during the course of Phase II investigation activities as well as past investigations and remedial action activities.

The nature and extent of OHM impacts are discussed in Section 5.3.

Soil

Remedial activities have been conducted to abate probable sources of OHM release. Analytical results for soil that has been excavated and disposed of off-Site were eliminated from consideration in this risk assessment and are noted in Table 2. Soil data representative of the impacts that remain in place, if any, were carried forward in the Method 3 Risk Characterization.

Following remedial activities completed in the area of WAY-02, a Method 3 Risk Characterization associated with OHM detected in the remaining soils at WAY-02 was completed by H&A (H&A, May 1999). As noted in Section 3.4, a Class A-3 RAO was achieved as a result of both the remedial activities completed in this area and the Method 3 Risk Characterization. As such, soils associated with residual OHM impacts in this area are not considered in this risk assessment.

Summary statistics of the analytical results for soils left in place following remedial activities are presented in Table 14. OHM compounds, including SVOCs, PCBs, EPH, and metals, have been detected in remaining soils at concentrations above method detection limits.

Ground Water

Analytical results of ground water sampling are presented in Table 8. Summary statistics of the analytical results for ground water are presented in Table 15. OHM compounds, including VOCs and metals, have been detected in ground water at concentrations above method detection limits.

As discussed in Section 4.2, step-draw-down tests were conducted at several wells in July 2000 to determine the recharge characteristics within the wells containing the highest levels of VOCs. Because standard well purging protocol were not implemented, ground water samples collected during the test are not considered representative of ambient ground water conditions. These results were eliminated from consideration in this risk assessment and are noted in Table 8.

Sediment

All sediment data considered in this risk assessment were derived from samples collected in the Site wetland. Data reported for sediments from the catch basins were eliminated from consideration in this risk assessment because the sediments were collected from within contained structures, and at some locations, were removed during remedial activities.

Analytical results of sediment sampling are presented in Table 8. Summary statistics of the analytical results for sediments are presented in Table 16. OHM compounds, including SVOCs, PCBs, EPH, and metals, have been detected in wetland sediments at concentrations above method detection limits.

Surface Water

All surface water data considered in this risk assessment are from the drainage swale and other inundated areas within the wetland. Data reported from surface water taken from the Sudbury River were eliminated from consideration in this risk assessment because upstream and downstream samples (SW-1, SW-2) exhibited similar concentrations of OHM, suggesting no impact to surface water in the Sudbury River from the Site. In addition, data for sample SW-5 were eliminated because the sample was taken from a bubbler inside the former plant and is not representative of surface water. These results were eliminated from consideration in this risk assessment and are noted in Table 12.

Summary statistics of the analytical results for surface water are presented in Table 17. OHM, including SVOCs, PCBs and metals, have been detected in surface water from the drainage swale and other inundated areas within the wetland at concentrations above method detection limits.

6.3.2 *Background Concentrations*

The MCP, defines background as, "*levels of OHM that are ubiquitous in the vicinity of the Site and attributable to geologic/ecologic conditions, atmospheric deposition of industrial processes or engine emissions* (310 CMR 40.0006)." Compounds present at levels consistent with background are considered to be at a level of "no significant risk" (310 CMR 40.0902(3)) and are therefore eliminated from consideration in this risk assessment.

The following section describes background concentrations used for comparison of OHM detected in Site soils and wetland sediments in order to eliminate compounds detected at levels below background concentrations from inclusion in the Method 3 Risk Characterization. Background concentrations were not identified for ground water or surface water.

Soil

Background concentrations for selected metals were taken from the MA DEP background soil concentrations as presented in the *Guidance for Disposal Site Risk Characterization, Interim Final Policy* (MA DEP, July 1995).

These background concentrations are included for comparison to Site soil concentrations in Table 14.

Sediment

Site-specific background levels in sediments were determined from samples collected upstream of the Site. Background samples include SS-2 and SS-2D (collected by ERM during 1990 investigation), GMS-7 (collected by USFWS during 1989 investigation), and SU-3 and SU-4 (collected by USFWS during 1987 investigation). The upstream locations of SS-2, and SS-2D are displayed in Figure 8 and GMS-7 is displayed in Figure 7. Samples SU-3 and SU-4 were collected from the Sudbury River further upstream at locations greater than 1,500 river-meters upstream of the Site (USFWS, June 1991).

Table 18 summarizes the upstream sediment samples considered to be representative of background conditions. A comparison of background levels to concentrations in Site wetland sediment is presented in Table 16.

6.3.3 *Selection of Compounds of Concern*

COCs represent the group of chemicals for which the Method 3 Risk Characterization will be performed. A list of COCs identified for each media is presented in Table 19. Compounds detected in each of the media that were excluded as COCs are identified in the following sections.

Soil

Summary statistics of the analytical results for soils left in place following remedial activities are presented in Table 14. Compounds that were excluded from the Method 3 Risk Characterization are identified below.

- Compounds not detected at concentrations above method detection limits;
- Compounds associated with OHM in the area of WAY-02 because a Method 3 Risk Characterization was completed by H&A for soils associated with the residual impacts in the area of WAY-02 and a Class A-3 RAO was achieved;

- Compounds detected at both low frequency and low concentrations as outlined in the Guidance for Disposal Site Risk Characterization, Interim Final Policy (MA DEP, July 1995). Summary statistics for these compounds are presented in Table 14 and summarized below:

Compound	Frequency of Observation	Maximum Concentration Detected (mg/kg)
Benzo (g,h,i) perylene	1 detection/ 27 samples	0.45
Benzo (k) fluoranthene	1 detection / 27 samples	0.45
Indeno (1,2,3-c,d) pyrene	1 detection / 27 samples	0.48
Phenanthrene	2 detections / 27 samples	0.48
Copper	3 detections / 22 samples	27
Nickel	3 detections / 22 samples	16

- Metals detected at levels consistent with the default background soil concentrations (MA DEP, July 1995). Summary statistics for these compounds are presented in Table 14 and summarized below:

Compound	Average Concentration (mg/kg)	Maximum Concentration (mg/kg)	MA DEP Background Concentration (mg/kg)
Arsenic	5.5	13	17
Barium	22	43	45
Cadmium	1.3	2.2	2
Lead	13	80	99
Mercury	0.12	0.18	0.30
Zinc	60	85	116

Ground Water

Summary statistics of the analytical results for ground water are presented in Table 15. Compounds that were excluded from the Method 3 Risk Characterization are identified below.

- Compounds not detected at concentrations above method detection limits;
- Compounds historically detected above the method detection limit but have not been detected in recent monitoring events. The following table summarizes these compounds and justifications for their exclusion:

Compound	Date of Most Recent Detection	Subsequent Sampling Rounds	Frequency of Observation
Naphthalene	Dec 1995	May 1998*	1 detection/ 182 samples
Toluene	Dec 1995	May 1998*	1 detection/ 182 samples
Ethylbenzene	Dec 1995	May 1998*	1 detection/ 182 samples
Xylenes	Dec 1995	May 1998*	1 detection/ 182 samples
Chloroform	Nov 1995	May 1998*	2 detections/ 182 samples
Isopropylbenzene	Jan 1996	May 1998*	2 detections/ 182 samples
Sec-Butylbenzene	Jan 1996	May 1998*	2 detections/ 182 samples
1,3,5-Trimethylbenzene	Dec 1995	May 1998*	1 detection/ 182 samples
1,2,4-Trimethylbenzene	Dec 1995	May 1998*	1 detection/ 182 samples

* Well has been destroyed since last noted sampling round.

Sediment

Summary statistics of the analytical results for sediments are presented in Table 16. Compounds that were excluded from the Method 3 Risk Characterization are identified below.

- Compounds not detected at concentrations above method detection limits;
- Compounds considered to be essential nutrients and naturally abundant (Foth, 1990) and that do not have available toxicity values, including:
  - Calcium;
  - Magnesium;
  - Potassium; and
  - Sodium.
- Compounds detected at levels consistent with the background levels determined from upstream sediments. Summary statistics for these compounds are presented in Table 16 and summarized below:

	Wetland Area*		Background Levels	
Compound	**Average Concentration (mg/kg)**	**Maximum Concentration (mg/kg)**	**Average Concentration (mg/kg)**	**Maximum Concentration (mg/kg)**
Aluminum	9,740	26,000	10,033	18,000
Beryllium	0.8	1.8	0.8	1.1
Selenium	2.2	2.8	3.5	5.0

* Most conservative region (i.e. ARAH or Surrounding Area) used for comparison. However, these compounds were found to be consistent with background across both of these regions within the Wetland Area.

Surface Water

Summary statistics of the analytical results for surface water are presented in Table 17. Compounds that were excluded from the Method 3 Risk Characterization are identified below.

- Compounds not detected at concentrations above method detection limits.;
- Compounds considered to be essential nutrients and naturally abundant (Foth, 1990) and that do not have available toxicity values, including:

- Calcium;
- Magnesium; and
- Potassium.

6.4 DOSE-RESPONSE ASSESSMENT

6.4.1 Toxicological Properties of Compounds of Concern

Summaries of the potential human health hazards posed by each COC are presented in the toxicity profiles included in Appendix J.

Toxicity profiles are included as compound-specific references that summarize available toxicological information for COCs considered in the Method 3 Risk Characterization. Information contained within the toxicity profiles can be used to group compounds by health endpoint and mechanism of toxicity in the estimation of carcinogenic and non-carcinogenic effects. The toxicity profiles also serve as a general reference, summarizing the information regarding potential health impacts associated with each compound.

Table 20 summarizes the available toxicity values and exposures for each of the COCs considered in the Method 3 Risk Characterization. The dose-response assessment describes the observed effects in humans (or laboratory animals when data on humans are not available or incomplete) associated with particular chemical exposure (or doses). Toxicity values are applied in the risk assessment based on the potential receptor, exposure route and duration of exposure in order to quantitatively estimate both carcinogenic and non-carcinogenic risks.

The toxicity values presented in Table 20 were adopted from the following sources:

- EPA Region III: "Risk-Based Concentration Table" (October 2000), if available;
- MA DEP: Background Documentation for the Development of the MCP Numerical Standards (April 1994), if available; and
- MA DEP: Revisions to the MCP - Proposed Changes Related to the VPH/EPH Approach, Public Hearing Draft (January 1997), if available.

Where values for the following compounds were not available from any of these sources, toxicity values from the noted surrogates were used per MA DEP guidance (MA DEP, July 1995).

Compound	Surrogate
1,2,3-Trichlorobenzene	1,2,4-Trichlorobenzene
Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Acenaphthylene, Benzo(g,h,i)perylene, Phenanthrene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Perylene, 1-Methylphenanthrene	Naphthalene
1-Methylnaphthalene	2-Methylnaphthalene

6.4.2 *Relative Absorption Factors*

The Relative Absorption Factor (RAF) is used to adjust the calculated exposure to a given chemical so that it is comparable to the toxicity information for that chemical. The RAF adjusts the exposure (or dose) to a given chemical based on the following factors (MA DEP, July 1995):

- The absorption efficiency for the chemical via the route and media of exposure being evaluated for the disposal Site; and
- The absorption efficiency for the route and media of exposure in the experimental study, which is the basis of the dose-response (i.e., toxicity) value for the chemical in question.

Table 20 summarizes the RAF values and exposures for each of the COCs considered in the Method 3 Risk Characterization. These values are applied in the risk assessment based on the potential receptor and exposure route. The RAF values presented in Table 20 were adopted from the following sources:

- MA DEP: Background Documentation for the Development of the MCP Numerical Standards (April 1994), if available.
- MA DEP: Revisions to the MCP – Proposed Changes Related to the VPH/EPH Approach, Public Hearing Draft (January 1997), if available.
- MA DEP: Guidance for Disposal Site Risk Assessment, Interim Final Policy (July 1995), if available.

As values for the following compounds were not available from any of these sources, RAFs from the noted surrogates were used as per MA DEP guidance (MA DEP, July 1995).

Compound	Surrogate
1,2,3-Trichlorobenzene	1,2,4-Trichlorobenzene
Perylene, 1-Methylphenanthrene	Naphthalene
1-Methylnaphthalene	2-Methylnaphthalene

6.5 EXPOSURE ASSESSMENT

The MCP (310 CMR 40.0923) requires that the Method 3 Risk Characterization consider exposure scenarios for current and reasonably foreseeable future Site uses. MA DEP guidance specifies that future remedial actions or incomplete remedial measures should not be included.

Residual impacts exist in soil, ground water, wetland sediment and surface water at the Site. Therefore, in the absence of additional remedial actions, the potential exists for current and potential future exposure to residual COCs.

In order to evaluate risks to human health and the environment, potential receptors and exposure pathways are identified, and EPCs and exposure doses are calculated.

6.5.1 Potential Receptors & Exposure Points

Potential Human Receptors

Based on the activity and use assumptions presented in Section 6.2, industrial/commercial and recreational uses of the Site were evaluated in this Method 3 Risk Characterization. In addition, residential uses were also considered for exposure OHM in soil and ground water to provide a conservative estimate of potential risk to a residential receptor, even though residential use of the Site will remain prohibited under a Notice of AUL. As such, the following populations of receptors were identified as potentially being exposed to OHM from the Site:

- *Facility Workers*: The Site is likely to remain as office space. As such, adult workers (18-45 years) are both the current and anticipated future population. Facility workers could be exposed to outdoor surface soil as well as ground water vapors which become entrained in the Site buildings. Facility worker exposure to sediment and surface water located within the wetland is not anticipated and therefore was not considered in this risk assessment;

- *Construction Workers*: During potential future activities involving foundation excavation and construction, adult construction workers (18-45 years) could come into contact with OHM located in both surface and sub-surface soils. The duration of exposure for a construction worker would be much less (six months) than that for a permanent facility worker (27 years). Construction worker exposure to sediment and surface water located within the wetland was not considered in this risk assessment since construction within this area is not anticipated due to the Wetlands Protection Act;
- *Trespassers*: Trespassers, most likely older children (6-18 years), could potentially trespass in the Site wetland. Trespassers could be exposed to sediment as well as surface water; and
- *On-Site Residents*: Although an AUL precluding residential use of Site has been filed with the Middlesex Registry of Deeds, potential future residential use of the Site is considered in this risk assessment. To assess the risks associated with future residential use, two sub-populations of residential receptors, children (0-6 years) and adults, were evaluated. Residents are considered to be exposed to residual OHM in surface soil, vapors from VOCs in ground water and VOCs in ground water via ingestion of ground water as drinking water (since Site ground water is classified as GW-1). Residential exposure to sediment and surface water located within the wetland is not considered in this risk assessment. Construction and residential use of wetlands is considered infeasible under current and reasonably foreseeable future conditions (i.e., foreseeable future being within the next 30 years by MA DEP guidance) due to the Wetlands Protection Act, Wild and Scenic Rivers designation and FEMA regulations.

The following populations of receptors were also identified as potentially being exposed to OHM from the Site, but were not considered quantitatively in the Method 3 Risk Characterization since their exposures were considered to be significantly less than those of the receptors noted above. As such, estimated risks to those receptors included in the risk assessment would be conservative of potential risks posed to those receptors not considered.

Potential Receptor (Not Considered)	Surrogate
Visitor	Facility Worker
Utility Worker	Construction Worker
Trespasser (Adult)	Trespasser (Older Child)
Off-Site Resident	On-Site Resident

Potential Environmental Receptors

Environmental receptors were selected that have great likelihood of exposure and sensitivity to chemicals of potential ecological concern (COPECs), ideally with home ranges that are similar to the size of the Site. The following receptors were selected for the Environmental Risk Characterization (Appendix E):

Potential Receptor	Representative Species
Aquatic Invertebrates	No specific target species
Fish	No specific target species
Amphibians	No specific target species
Wetland Plants	No specific target species
Waterfowl	Mallard
Herbivorous Semi-Aquatic Mammals	Muskrat
Small Herbivorous Mammals	Meadow Vole
Large Herbivorous Mammals	White-tailed Deer
Carnivorous Birds	Red-tailed Hawk

6.5.2 *Potential Exposure Pathways*

A summary of the potential exposure pathways for each of the receptors considered in the Method 3 Risk Characterization is presented in Table 21. The following rationale is provided for the selection and exclusion of particular exposure pathways.

- Contact with Soil: Contact with soil (via dermal contact and incidental ingestion) is considered as a potential exposure pathway for facility workers, construction workers and future on-Site residents. Residual soil impacts at the Site are limited to localized areas (e.g., TP-3, Building 12/21, etc.) and the potential for contact is prevented in many of these areas by either the depth of impact or surface covering (e.g., pavement, landscaping or building). However, it is conservatively assumed that facility workers, construction workers and future on-Site residents have the potential for contact with all residual OHM impacts in soil, regardless of depth. As such, estimated risks from contact with soil are likely higher than would be expected;
- Inhalation of Fugitive Dust: Inhalation of fugitive dust is considered as a potential exposure pathway for all receptors with the potential for direct contact with soil (i.e., facility workers, construction workers and future on-Site residents);
- Contact with Ground Water: As ground water is classified as GW-1, the potential for residential use of ground water as a source of drinking water is considered. As such, the ingestion of ground water is considered as a potential exposure pathway for future on-Site residents. Since the average depth to ground water is approximately 15 feet bgs, it is assumed that construction workers will not come in contact with contaminated ground water. In addition, dermal contact with tap water is not considered at this stage of the risk assessment because exposure via the ingestion of ground water is considered to be the primary exposure pathway;
- Inhalation of Ground Water Vapors: Entrainment of vapors in buildings from OHM in ground water beneath Site buildings occupied by facility workers or into the homes of future on-Site residents is considered as a potential exposure pathway. Since the average depth to ground water is approximately 15 feet bgs, it is assumed that construction workers will not come in contact with contaminated ground water, and therefore their inhalation of ground water vapors is not considered. In addition, inhalation of vapors emanating from tap water is not considered at this stage of the risk assessment because exposure via the ingestion of ground water is considered to be the primary exposure pathway;
- Contact with Sediment: Contact with sediment (via dermal contact and incidental ingestion) is considered as a potential exposure pathway for trespassers in the wetland. The inhalation of fugitive dust originating from contaminated sediments is not considered as a potential exposure pathway since sediments are not likely to be dry over any significant period of time; and

- Contact with Surface Water: Contact with surface water (via dermal contact and incidental ingestion) is considered as a potential exposure pathway for trespassers in the wetland. The inhalation of vapors emanating from OHM in surface water is not considered as a significant exposure pathway since OHM in surface water is not readily volatile, volatilization would not take place within a confined space, and the concentrations of OHM in surface water are relatively low.

6.5.3 *Exposure Parameters*

Table 22 summarizes the exposure parameters for each of the potential receptors and exposure pathways considered in the Method 3 Risk Characterization (e.g., body weight, exposure frequency and duration). Default exposure assumptions were obtained from the following sources:

- MA DEP: Guidance for Disposal Site Risk Characterization, Interim Final Policy, Appendix B (July 1995), if available;
- MA DEP: Human Exposures at Industrial/Commercial Properties, Draft (December 1996), if available;
- MA DEP: Background Documentation for the Development of the MCP Numerical Standards (April 1994), if available; and
- US EPA: Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Supplemental Guidance, 'Standard Default Exposure Factors,' Interim Final (March 1991).

Assumptions associated with each potential receptor and exposure pathways are considered conservative in order to maintain protection of human health, but realistic to ensure that they are consistent with current or potential future uses of the Site.

6.5.4 *Exposure Point Concentrations*

Soil

EPCs for COCs identified in soils are presented in Table 23 and were calculated as arithmetic mean (i.e., average) concentrations across Site soils. EPCs for soil were calculated using one-half the sample quantitation limit for non-detect values. All duplicate and split samples were averaged. In addition, samples collected by H&A to confirm the results at location SS-6 near Buildings 21/22 were averaged (see Figure 6).

Although residual soil impacts at the Site are limited to localized areas and the potential for direct exposure is prevented in many of these areas by either the depth of impact or surface covering, it is conservatively assumed that all potential receptors have the potential for contact with all residual soil impacts, regardless of depth.

EPCs for soil were used to calculate EPCs for fugitive dust using the following the MA DEP default method (MA DEP, July 1995):

$$EPC_{s,\,air} = EPC_s * PM_{10} * CF$$

where:

$EPC_{s,air}$ = Exposure point concentration for fugitive dust (μg/m^3)

EPC_s = Exposure point concentration for soil (mg/kg)

PM_{10} = Respirable particulates (μg/m^3)

CF = Conversion factor = 10^{-6} kg/mg

As noted in the Guidance for Disposal Site Risk Characterization, Interim Final Policy (MA DEP, July 1995), PM10 was estimated as 32 micrograms per cubic meter (ug/m^3) for open field exposure and 60 ug/m^3 for exposure during excavation activities. EPCs for fugitive dust were calculated using the open field assumption for facility workers and future on-Site residents, while construction workers were assumed to have greater inhalation exposure due to the intrusive nature of excavation activities.

Ground Water

EPCs in ground water are used to calculate the risks associated with the potential future consumption of Site ground water. As such, monitoring wells with the maximum individual COC concentrations were selected to represent conditions within a potential future supply well. In order to represent concentrations to which the potential receptor would likely be exposed, EPCs were estimated from concentrations detected in these monitoring wells as follows:

- If data were fairly consistent over time, the EPCs were estimated as the average concentration detected over the period of sampling;
- If the data suggested an increasing or decreasing trend, the EPC for that individual COC was estimated as the most recent value detected;

- EPCs for ground water were calculated using one-half the sample quantitation limit for non-detect values; and
- All duplicate and split samples were averaged.

Table 24a summarizes the monitoring wells selected for each COC and provides details as to how EPCs were estimated for ground water.

EPCs for ground water vapors were calculated using the following equation (MA DEP, October 1999):

$$EPC_{gw,air} = [COC]_{gw} * \alpha * d * H * CF$$

where:

$EPC_{gw,air}$ = Exposure point concentration for ground water vapors (ug/m^3)

$[COC]_{gw}$ = Concentration of COC in ground water (μg/L)

α = Attenuation factor = 0.0005 (unitless)

D = Dilution factor = 0.1 (unitless)

H = Henry's Law Constant ($\mu g_{air} / \mu g_{gw}$)

CF = Conversion factor = 10^3 L/m^3

Table 24b summarizes the Henry's Law Constants and EPCs calculated for ground water vapors.

Sediment

EPCs for COCs identified in sediments are presented in Table 25. As noted in Section 5.3, exposure points within the wetland have been divided into the following two regions: ARAH and the Surrounding Area. Therefore, EPCs were calculated separately for each region. EPCs for sediments in both regions were calculated as the arithemetic average concentration for each COC within each area, substituting one-half the sample quantitation limit for non-detect values.

Surface Water

EPCs for COCs identified in surface water are presented in Table 26 and calculated as the average of concentrations detected across the drainage swale and inundated areas within the wetland. For simplicity and added conservatism, EPCs for surface water were calculated without substituting one-half the sample quantitation limit for non-detect values.

6.5.5 Exposure Doses

Exposure doses represent the average daily dose of a COC that a receptor could experience during the period of exposure.

The exposure parameters (as presented in Table 22) and EPCs were used to calculate the exposure doses for each of the potential receptors and exposure pathways considered in the Method 3 Risk Characterization. The resulting exposure doses and equations used to calculate the exposure doses are presented in the following tables:

Receptor	Table Summarizing Calculated Exposure Doses
Facility Worker	Table 27
Construction Worker	Table 28
Trespasser	Table 29
On-Site Resident	Table 30

6.6 HUMAN HEALTH RISK CHARACTERIZATION

The MCP details risk management criteria to be used in determining the need for site remediation. These criteria include the comparison to public health standards (310 CMR 40.0993(3)) and the calculation of Cumulative Receptor Risks.

6.6.1 Applicable or Suitably Analogous Health Standards

Pursuant to 310 CMR 40.0993(6), the characterization of risk to human health includes a comparison of EPCs to existing applicable or suitably analogous standards as defined in 310 CMR 40.0993(3). Two sets of applicable standards were identified and are discussed below.

Drinking Water Quality Standards

The MCP requires that the ground water at the Site be considered as a potential future source of drinking water because the Site is located within the MA DEP-Approved Zone II Wellhead Protection Area. As such, both federal and state drinking water quality standards are applicable.

EPCs for ground water were compared to available federal and state drinking water quality standards (represented by Maximum Contaminant Levels (MCLs)) in Table 24a. The following exceedences were noted:

Compound	**Exposure Point Concentration (µg/L)**	**Drinking Water Standard (µg/L)**
PCE	28	5
TCE	323	5
Vinyl Chloride *	4.5	2

* It should be noted that the EPC for vinyl chloride in ground water represents pre-remedial conditions in the vicinity of WAY-02. The most recent detection of vinyl chloride was noted in May 1998 (this well was subsequently destroyed during remedial activities) and only two detections have been noted in a total of 182 samples collected. Nevertheless, vinyl chloride was carried forward in the analysis for added conservatism since it is a degradation product of TCE.

A condition of "no significant risk" does not exist at the Site because the EPCs for three compounds are above their respective drinking water quality standards.

Surface Water Quality Standards

The Sudbury River is classified as a Class B Surface Water Body. Pursuant to 310 CMR 4.05(5), federal surface water quality standards are applicable. However, data reported from samples collected from the Sudbury River at locations both upstream and downstream of the Site exhibited the same concentrations of OHM, indicating that surface water in the Subury River has not been impacted by the Site. In addition, there are no available federal surface water quality standards for the two compounds detected, bis (2-ethylhexyl) phthalate and bis (2-ethylhexyl) adipate.

6.6.2 *Human Health Risk Estimates*

Cancer Risks

The potential for carcinogenic health effects is characterized in the calculation of Excess Lifetime Cancer Risks (ELCR) for each exposure scenario. In accordance with the methods recommended by the MA DEP and the US EPA, the equation for estimating the ELCR from exposure to carcinogens (by COC and exposure pathway) is:

$$ELCR = ED * CSF$$

where:

ELCR	=	Excess Lifetime Cancer Risk, represents the probability that a receptor will develop cancer during their lifetime as a result of a defined exposure (unitless)
ED	=	Exposure Dose, for each compound and exposure pathway averaged over a lifetime (mg/kg*day)
CSF	=	Cancer Slope Factor, for each compound using exposure pathway as appropriate $(mg/kg*day)^{-1}$

ELCRs are calculated for those COCs at the disposal Site which are considered to be known or probable/possible carcinogens (i.e., US EPA Class A, B or C) and for which adequate toxicity information is available.

Media-specific ELCRs are calculated as the sum of chemical-specific ELCRs, or alternatively as the sum of the route-specific ELCRs. For each potential receptor, the Cumulative Receptor Cancer Risks are calculated as the sum of the media-specific ELCRs where:

$$\text{Total } ELCR_{\text{media-specific}} = \sum \text{Total } ELCR_{\text{chemical-specific}} = \sum \text{Total } ELCR_{\text{route-specific}}$$

$$\text{Cumulative } ELCR = \sum \text{Total } ELCR_{\text{media-specific}}$$

The resulting chemical-specific, route-specific, media-specific, and cumulative ELCRs are presented in the following tables:

Receptor	Table Summarizing Calculated ELCRs
Facility Worker	Table 31
Construction Worker	Table 32
Trespasser	Table 33
On-Site Resident	Table 34

Non-Cancer Risks

The potential for non-carcinogenic health effects is characterized in the calculation of the Hazard Index (HI) for each exposure scenario. In accordance with the methods recommended by the MA DEP and the US EPA, the equation for estimating the HI (by COC and exposure pathway) is:

HI = ED / RfD

where:

HI = Hazard Index, ratio of the estimated exposure dose of a COC to a reference dose judged to be without adverse health effects (unitless)

ED = Exposure Dose, for each compound and exposure pathway averaged over the exposure duration (mg/kg*day)

RfD = Reference Dose, for each compound using exposure pathway as appropriate (mg/kg*day)

HIs are calculated for all COCs at the disposal Site for which adequate toxicity information is available.

Media-specific HIs are calculated as the sum of chemical-specific HIs, or alternatively as the sum of the route-specific HIs. For each potential receptor, the Cumulative Receptor Non-Cancer Risks are calculated as the sum of the media-specific HIs where:

$$\text{Total HI}_{\text{media-specific}} = \sum \text{Total HI}_{\text{chemical-specific}} = \sum \text{Total HI}_{\text{route-specific}}$$

$$\text{Cumulative HI} = \sum \text{Total HI}_{\text{media-specific}}$$

The resulting chemical-specific, route-specific, media-specific and cumulative HIs are presented in the following tables:

Receptor	Table Summarizing Calculated HIs
Facility Worker	Table 31
Construction Worker	Table 32
Trespasser	Table 33
On-Site Resident	Table 34

Massachusetts Risk Management Criteria

The MA DEP has established the following risk management benchmarks, at or below which there is a condition of "no significant risk," above which evaluation of remedial measures is warranted (310 CMR 40.0993(6)):

- Total Cancer Risk Limit for Carcinogenic Exposure = Cumulative **ELCR** of one-in-one hundred thousand (1/100,000, equal to **1E-05** or ten in one million); and
- Total Non-Cancer Risk Limit for Non-Carcinogenic Exposure = Cumulative **HI** of one **(1.0)**.

Pursuant to 310 CMR 40.0993(6), the characterization of risk to human health includes a comparison of estimated Cumulative Cancer and Non-Cancer Risks to the established benchmarks. Cumulative Cancer and Non-Cancer Risks for each exposure population considered in the Method 3 Risk Characterization are compared to benchmark thresholds as presented in Tables 31 through 34. A summary is provided below.

Receptor	Cumulative Cancer Risk (Cumulative ELCR)	Cumulative Non-Cancer Risk (Cumulative HI)
Facility Worker	4.3E-6	3.7E-2
Construction Worker	1.5E-7	6.1E-2
Trespasser	2.6E-6 (Surrounding Area) **1.7E-5 (ARAH)**	1.3E-1 (Surrounding Area) **9.7E-1 (ARAH)**
On-Site Resident	**3.7E-4**	**7.8E+0 (Child)** **2.2E+0 (Adult)**
MA DEP Risk Limit	1.0E-05	1.0E+00

Facility Workers

Cumulative Cancer Risks and Non-Cancer Risks to facility workers are below the respective benchmark thresholds.

Construction Workers

Cumulative Cancer and Non-Cancer Risks to construction workers are below the respective benchmark thresholds.

Trespassers

Within the ARAH, Cumulative Cancer Risks to trespassers exceed the ELCR, while Non-Cancer Risks are below the HI. Those compounds primarily driving the estimated exceedances are PAHs (Benzo(a)pyrene) and PCBs (Arochlor 1260). Risks to trespassers via exposure to surface water do not exceed the benchmark thresholds.

Cumulative Cancer and Non-Cancer Risks to trespassers in the Surrounding Area are below the respective benchmark thresholds.

On-Site Residents

Cumulative Cancer and Non-Cancer Risks to future on-Site residents exceed the benchmark thresholds. The primary drivers of the risks to future on-Site residents are VOCs via the ingestion of ground water.

VOCs primarily contributing to risk include PCE, TCE, DCE, and vinyl chloride. Risks to on-Site residents via exposure to Site soils do not exceed the benchmark thresholds.

6.6.3 *Human Health Risk Summary*

Based upon the criteria described in 310 CMR 40.0993(7), a condition of "no significant risk" of harm to human health does not exist at the Site because:

- EPCs for ground water as a potential source of drinking water exceed drinking water quality standards; and
- Cumulative Receptor Cancer Risks and Non-Cancer Risks exceed benchmark thresholds for future residential consumption of ground water and trespassers in the wetland within the ARAH.

The primary drivers of these risks include:

Media	Compound Of Concern	
Ground water	VOCs	• PCE
		• TCE
		• 1,1-DCE
		• Vinyl Chloride
Sediment	SVOCs	• Benzo(a)pyrene
	PCBs	• Arochlor 1260

6.7 *CHARACTERIZATION OF RISK TO SAFETY*

In accordance with 310 CMR 40.0960, this section of the Method 3 Risk Characterization includes a qualitative evaluation of potential risks to safety. This evaluation is based on current and reasonably foreseeable Site activities and uses (see Section 6.2), exposure information developed and identified in Section 6.5, and criteria required by 310 CMR 40.0960.

Existing Site conditions do not pose a threat of physical harm or bodily injury. There are currently no uncontrolled or rusted drums, containers, open pits, or other dangerous structure on Site. Site conditions do not pose a threat of fire or explosion. There are no uncontained materials on Site which exhibit characteristics of corrosivity, reactivity or flammability as described in 310 CMR 40.0347.

In summary, pursuant to 310 CMR 40.0960(4), conditions at the Site do not pose a significant risk of harm to safety under current or reasonable foreseeable conditions.

6.8 CHARACTERIZATION OF RISK TO PUBLIC WELFARE

In accordance with 310 CMR 40.0994, this section of the Method 3 Risk Characterization includes a qualitative evaluation of potential risks to public welfare. This evaluation is based on current and reasonably foreseeable Site activities and uses (see Section 6.2), exposure information developed and identified in Section 6.5, and criteria required by 310 CMR 40.0994.

Existing Site conditions are not considered to pose a nuisance condition. The breathing zones of both ambient and indoor air are free from persistent or noxious odors. Drinking water is currently accessible from the public supply. There is no threat of loss of active or passive property use. Site conditions do not pose any other non-pecuniary effects not otherwise considered in the characterization of risk of harm to health, safety and the environment.

In accordance with 310 CMR 40.0994(3), the evaluation of risk to public welfare includes a comparison of OHM concentrations in soil and ground water to UCLs. As presented in Tables 14 and 15, none of the UCLs are exceeded in either soil or ground water, respectively.

In summary, pursuant to 310 CMR 40.0994(5), conditions at the Site do not pose a significant risk of harm to public welfare under current or reasonable foreseeable conditions.

6.9 ENVIRONMENTAL RISK CHARACTERIZATION

In accordance with 310 CMR 40.0995, ERM, Woodlot and Entrix collectively characterized the risk of harm to Site biota and habitats by evaluating OHM detected on Site in a staged approach. This section includes a Stage I evaluation and summary of the Stage II prepared by Entrix and included in Appendix E.

Due to the nature of Site impacts and the different associated exposure pathways, this Environmental Risk Characterization is separated into the following habitats:

- Main Site Property: Includes Site-related soil and ground water impacts as well as ground water discharge to surface water; and
- Wetland Area: Includes sediment and surface water impacts associated within the Site wetland.

6.9.1 *Stage I Environmental Screening*

Stage I was performed in order to identify and document conditions which do not warrant a Stage II, either because of the absence of a potentially significant exposure pathway or because environmental harm is readily apparent and therefore additional assessment would be redundant.

This section presents the results of Stage I conducted pursuant to 310 CMR 40.0995(3).

Main Site Property Soil

The main Site property includes developed office space and undeveloped grass and woodlands. Following remedial activities, current residual impacts to Site soil are limited to one localized area beneath Building 3 (i.e., WAY-02). The potential for direct exposure is prevented by the building and depth of impact. As such, exposure to impacted soils on the main Site property is not considered a potentially significant exposure pathway for potential environmental receptors.

Ground Water

The potential for direct exposure to ground water is prevented because the average depth to ground water is approximately 15 feet below ground surface. As such, exposure to impacted ground water on the former property is not considered a potentially significant exposure pathway. A conservative projection of the downgradient extent of the Site ground water plume results in an estimated concentration of 160 μg/L TCE in ground water discharging to surface water.

Applying an attenuation factor of 10 for ground water discharging to surface water (as recommended by MA DEP, 1994), the projected concentration of TCE in surface water is estimated at 16 μg/L. This level would be considered to be protective of the environment (based on a benchmark of 2,000 µg/L, a former federal AWQC for TCE adopted by MA DEP in the derivation of Method 1, GW-3 Risk-Based Standards). Therefore, under worst-case conditions, impacts to Site ground water would not be expected to adversely impact surface water in the Sudbury River. As such, exposure to impacted ground water discharging to surface water is not considered a potentially significant exposure pathway.

Wetland Area

The complete Stage I for the Wetland Area is located in Section 6 of the Environmental Risk Characterization (Appendix E). The Stage I concludes that the potential exists for adverse exposure by environmental receptors to COCs in wetland sediments, surface water and biota. Potential exposure pathways, receptors and risks are developed in the Stage II that is located in Section 7 of the Environmental Risk Characterization (Appendix E).

The identified ARAH, as defined by the MCP, is eliminated from further consideration in the Stage II since further assessment would be redundant.

6.9.2 Stage II Environmental Risk Characterization

Stage II was performed in order characterize the risks posed by exposures identified in Stage I. The complete Stage II report is located in Section 7 of the Environmental Risk Characterization (Appendix E). The Stage II excluded the ARAH in order to focus the evaluation on surrounding areas that are not evidently problematic. The Stage II concluded there is no indication of risk to potential environmental receptors outside of the ARAH, including:

- Aquatic Receptors;
- Wetland Vegetation outside the ARAH; and
- Avian and Mammalian Receptors.

6.9.3 Comparison to Upper Concentration Limits

Main Site Property

In accordance with 310 CMR 40.0995(5), the evaluation of risk to public welfare includes a comparison of OHM concentrations in soil and ground water to UCLs. As presented in Tables 14 and 15, none of the UCLs are exceeded for either soil or ground water, respectively.

6.10 *UNCERTAINTY ANALYSIS*

The purpose of the uncertainty analysis is to document major assumptions and limitations and, if possible, provide an indication of whether they have resulted in an over under-estimation of risk.

In general, the uncertainties inherent in risk assessment can be grouped in two general categories:

1) Missing or ambiguous information on a particular substance; and

2) Gaps in current scientific theory.

These uncertainties will exist in each step of the risk assessment process. In terms of Site risk assessments, the sources of uncertainty can be broken into a number of components:

- Uncertainty in the chemical monitoring data used to characterize EPCs;
- Uncertainty in the environmental parameter measurements;
- Uncertainty in the models used to evaluate contaminant fate and transport and to EPCs in the absence of monitoring data;
- Uncertainty associated with the exposure assessment, including estimations of frequency, duration and magnitude of exposure and designation of exposure parameters to a non-heterogeneous population. Exposure assumptions, generally adopted from MA DEP or US EPA guidance, are conservative in order to ensure the protection of human health. In addition, the conservative nature of the exposure assumptions adopted in this risk assessment result in overestimation of the potential risk;
- Uncertainty in the risk assessment process that reflects errors or uncertainties introduced through combination of the above sources of uncertainty; and
- Uncertainties are also incorporated in the risk assessment when exposures to multiple substances across multiple pathways are summed.

The dose-response assessment is often one of the largest sources of uncertainty in any risk assessment. As noted by the US EPA in the *Risk Assessment Guidance Document for Superfund, Volume I, Human Health Evaluation Manual, Part A, Interim Final* (US EPA, December 1989), sources of uncertainty based on chemical toxicity include:

- Using dose-response information from effects observed at high doses to predict adverse health effects that may occur following exposure to the low levels expected from human contact with the agent in the environment;
- Using dose-response information from short-term exposure studies to predict the effects of long-term exposures and vice-versa;
- Using dose-response information from animal studies to predict effects in humans; and
- Using dose-response information from homogeneous animal populations or human health populations to predict the likely effects to be observed in the general population consisting of individuals with a wide range of sensitivities.

In addition to the uncertainty that exists in evaluating the risk from single chemicals, further uncertainty is introduced in evaluating exposure and risk to multiple chemicals or mixtures. To assess the overall effects of multiple chemicals, the US EPA developed *Guidelines for the Human Health Risk Assessment of Chemical Mixtures* (US EPA, 1998). This guidance states that if sufficient data are not available on the effects of the chemical mixture of concern, or a reasonably similar mixture, the proposed approach is to assume additivity. According to the US EPA, this assumption is expected to yield generally neutral risk estimates (i.e., neither conservative nor lenient).

Uncertainty associated with the ecological assessment is discussed in Section 11.3.3 of the Environmental Risk Characterization (Appendix E).

6.11 LIMITATIONS

Reasonable care has been exercised in performing the analyses in the Method 3 Risk Characterization. This risk assessment was conducted based on all available information concerning existing concentrations of OHM in soil, ground water, sediment, and surface water.

If additional sampling results or chemical analyses become available, or if there are any changes in zoning designations, changes in current or future uses of the Site, modification of conditions in the Notice of AULs, or changes in state or federal policies or procedures for generation of published toxicity information, then the analyses contained in the Method 3 Risk Characterization may also require revision as appropriate to incorporate the new information.

6.12 *RISK CHARACTERIZATION CONCLUSIONS*

Based on the Method 3 Risk Characterization, ERM provides the following conclusions regarding potential risks posed by Site OHM to human health, safety, public welfare and the environment:

1) OHM in Site ground water and wetland sediments pose a condition of "significant risk" to human health. This condition is based on the potential for future exposure by hypothetical future receptors (i.e., trespassers and residents), as these exposure pathways are currently not complete. Ground water is not currently being used as a source of drinking water within the boundaries of defined or projected Site impact. In addition, institutional controls (e.g., deed restrictions, fencing and signage) prohibit Site uses that pose a potential risk until remedial actions can be completed. VOCs in ground water and PCBs and PAHs in wetland sediment pose the greatest potential risk to human health;

2) Site OHM does not pose a condition of "significant risk" to human safety;

3) Site OHM does not pose a condition of "significant risk" to public welfare;

4) With the exception of the ARAH in the wetland, Site OHM does not pose a condition of "significant risk" to the environment; and

5) Stunted vegetation within an approximately one-acre portion of the wetland constitutes conditions of "readily apparent harm" to one wetland plant community (cattails) and "significant risk" to the environment.

7.0 CONCLUSIONS

Based on the results presented in the previous sections, ERM makes the following conclusions regarding the Phase II:

1) All Past Identified Sources of OHM Release Have Been Abated.

Decommissioning of the facility by Raytheon included abatement of residual OHM remaining within former structures (e.g., the stormwater conveyance system, boiler room pit and sump, and manhole W-4). Additional source abatement was conducted during and post-Phase I (LRAs for drywells and the RAM at test pit TP-3) and during the Phase II (RAM for the former No. 6 fuel oil tank WAY-02). As a result, all confirmed or probable sources of OHM release at the Site have been abated.

2) The Extent of Site OHM Impact Appears Limited to Soil, Ground Water and Wetland Sediment.

Residual OHM impacts are largely limited to soil, ground water and wetland sediment associated with the following former sources:

- Soil impacted by No. 6 fuel oil released from WAY-02 located beneath former Building 3 and in the former courtyard between former Building Nos. 3 and 4 (Figure 5). This release (RTN 3-13302) was closed under the filing of a Class A-3 RAO Statement by H&A for WBC in October 1998;
- Ground water impacted by TCE and associated degradation products, primarily associated with a release from former manhole W-4 located adjacent to the north side of former Building 4 (Figure 5). The manhole was connected to piping located within the former Printed Circuit Board Shop within Building 4. Minor residual TCE impacts to ground water have also been detected due to OHM releases discovered at TP-3 and drywell DW-05 (see Figures 3 and 5). The main plume extends southwest from manhole W-4 and appears limited to depths of approximately 50 feet by underlying unconsolidated deposits. Extrapolation of the extent of ground water impact downgradient indicates dilution to levels below detection limits at discharge to surface water. Discharge of impacted ground water to surface water is not expected to adversely impact surface water quality; and

- Wetland sediment is impacted by PAHs, PCBs and metals associated with historic inadvertent, incidental releases to the stormwater conveyance system and discharge at outfall OF-1 (Figure 5). The extent of impact appears limited to between 250 and 450 feet of OF-1. No evidence of adverse impact to the Sudbury River has been detected. Stunted vegetation (cattail growth) attributable to Site OHM has been mapped within an approximately one-acre portion of the wetland adjacent to OF-1 (Figure 14). This condition constitutes a condition "readily apparent harm" that will likely require abatement.

3) Site Ground Water & Wetland Sediments Pose a Condition of "Significant Risk" Under Future Conditions.

OHM in Site ground water and wetland sediments pose a condition of "significant risk" to human health. This condition is based on the potential for future exposure by hypothetical receptors (receptors that maintain a potential for future exposure in the absence of institutional controls or remediation). However, risks to human health posed by the Site under current conditions are considered negligible, since there is currently no complete exposure pathway (i.e., ground water is not a current source of drinking water and access to the wetland area will be restricted by fencing and signage until remedial actions can be completed). VOCs in ground water and PCBs and PAHs in wetland sediment also pose a potential risk to human health.

4) The Site Does Not Pose a "Significant Risk" of Harm to Human Safety & Public Welfare.

Site OHM does not pose a condition of "significant risk" to human safety or public welfare.

5) A Phase III-Remedial Alternative Evaluation is Necessary.

Pursuant to 310 CMR 40.0852, a Phase III evaluation shall be conducted for any disposal site for which a Phase II has been completed and a RAO in accordance with 310 CMR 40.1000 has not yet been achieved. The Phase III will include the identification of remedial alternatives to abate impacts to ground water and wetland sediments that pose a condition of "significant risk." The Phase III will conclude what the preferred remedial alternative(s) for the Site will be. Design and implementation of the remedy will be conducted under Phase IV Remedy Implementation Plan.

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