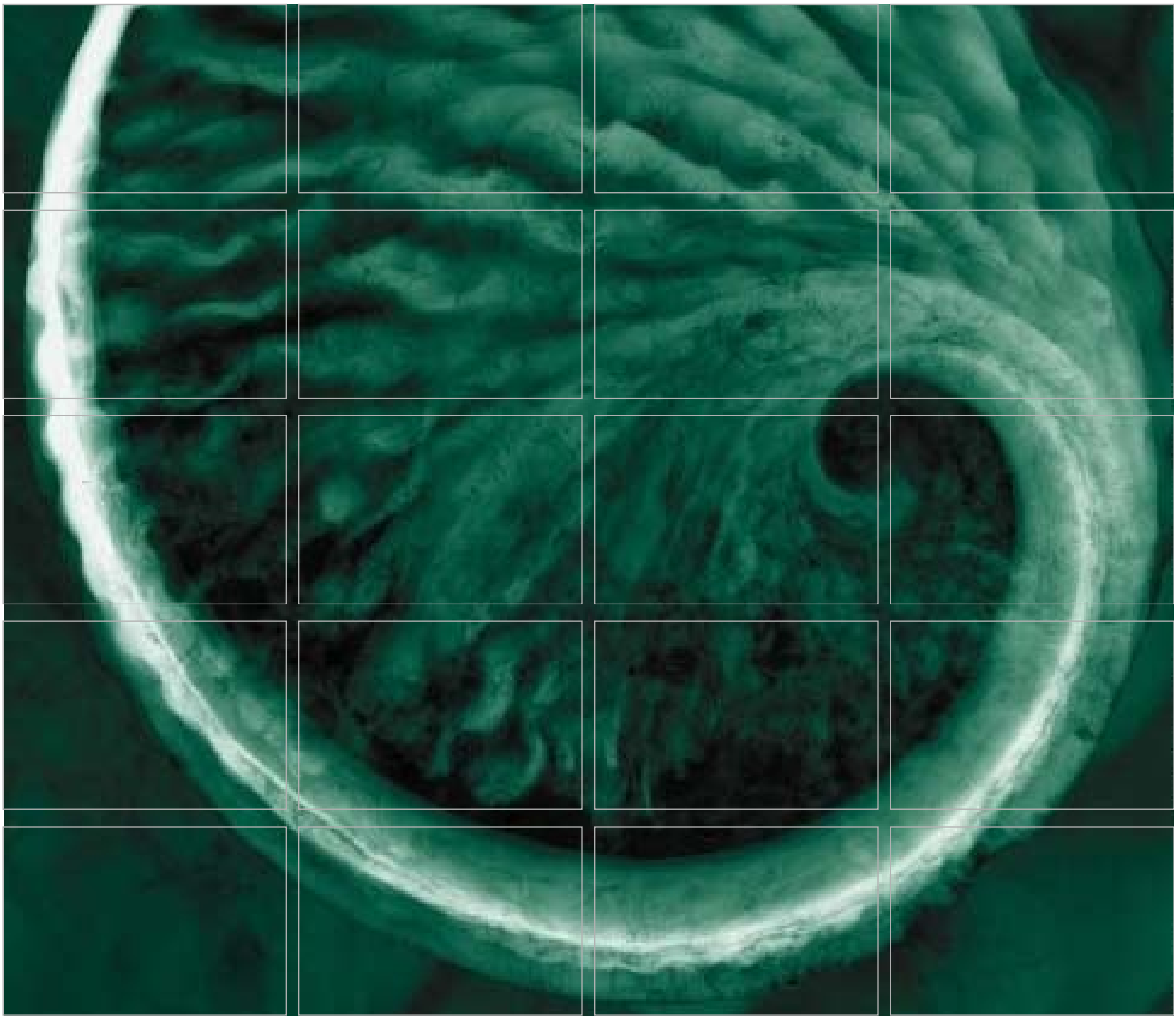

Raytheon Company

DRAFT - Phase II – Comprehensive Site Assessment

Former Raytheon Facility
430 Boston Post Road
Wayland, Massachusetts

RTN 3-22408
Tier 1B Permit Number W045278
ERM Reference 0034350

19 October 2005

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DRAFT REPORT

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LIST OF TABLES *IV*

LIST OF FIGURES *VI*

LIST OF APPENDICES *VII*

LIST OF ACRONYMS AND ABBREVIATIONS *VIII*

EXECUTIVE SUMMARY *X*

1.0 INTRODUCTION *1*

1.1 BACKGROUND *1*

1.2 PURPOSE & SCOPE *2*

1.3 REPORT ORGANIZATION *2*

2.0 SUMMARY OF THE PHASE I- INITIAL SITE INVESTIGATION *4*

2.1 PURPOSE *4*

2.2 CONCLUSIONS *4*

3.0 UPDATE TO THE PHASE I INITIAL SITE INVESTIGATION *6*

3.1 OVERVIEW *6*

3.2 PROPERTY OWNERSHIP *6*

3.3 SITE ACTIVITIES, USES & USE RESTRICTIONS *6*

3.4 SITE REGULATORY HISTORY *6*

3.5 DISPOSAL SITE BOUNDARY *7*

4.0 METHODS *8*

4.1 SITE INVESTIGATION STRATEGY *8*

4.2 SCOPE OF WORK *10*

4.2.1 Assessment of the Potential for Baldwin Pond Wellfield Impacts from the Northern Area *10*

4.2.2 Characterization of Northern Area Source Zone 11
4.2.3 Conduct Additional Delineation of CVOC Impacts to Groundwater 16
4.2.4 Perform Aquifer Testing 17
4.2.5 Gauge and Sample Monitoring Wells 17
4.2.6 Conduct Method 1 Risk Characterization 19

5.0 RESULTS 20

5.1 REGIONAL & SITE GEOLOGY 20
5.1.1 Unconsolidated Deposits 20
5.1.2 Bedrock 21

5.2 REGIONAL & SITE HYDROGEOLOGY 21
5.2.1 Local & Regional Groundwater 21
5.2.2 Local & Regional Surface Waters 22
5.2.3 Wetland & Habitats 22

5.3 SOURCE, NATURE, AND EXTENT OF CONTAMINATION 23
5.3.1 Overview 23
5.3.2 Sources of Oil and/or Other Hazardous Materials Release 23
5.3.3 Nature and Extent of Impacts to Soil 25
5.3.4 Nature and Extent of Impacts to Groundwater 26

5.4 ENVIRONMENTAL FATE & TRANSPORT OF OIL AND/OR HAZARDOUS MATERIALS 27
5.4.1 Physical & Chemical Properties of Oil and/or Hazardous Materials 27
5.4.2 Potential Migration & Fate 28

6.0 RISK CHARACTERIZATION 32

6.1 OVERVIEW 32

6.2 SITE DESCRIPTION & ACTIVITY & USE ASSUMPTIONS 32

6.3 HAZARD IDENTIFICATION 34
6.3.1 Identification of Oil and/or Hazardous Materials On Site 34
6.3.2 Background Concentrations 34
6.3.3 Selection of Compounds of Concern (COCs) 35

6.4 EXPOSURE ASSESSMENT 37
6.4.1 Identification of Potential Receptors 37
6.4.2 Potential Environmental Receptors 37
6.4.3 Identification of Exposure Points 38
6.4.4 Identification of Exposure Point Concentrations 38

6.5 RISK CHARACTERIZATION 39
6.5.1 Comparison to Method 1 Standards 39
6.5.2 Risk Summary 39

6.6 EVALUATION OF RISK OF HARM TO SAFETY 39

6.7 RISK CHARACTERIZATION CONCLUSIONS 40

6.8 LIMITATIONS 41

7.0 CONCLUSIONS 42

REFERENCES 44

LIST OF TABLES

TABLE 1 *SUMMARY OF GROUNDWATER VOC FIELD SCREENING DETECTIONS*

TABLE 2 *SUMMARY OF GRAIN SIZE ANALYTICAL RESULTS*

TABLE 3 *SUMMARY OF MONITORING WELL CONSTRUCTION*

TABLE 4 *SUMMARY OF HYDRAULIC CONDUCTIVITY TESTING RESULTS*

TABLE 5 *SUMMARY OF GROUNDWATER GAUGING DATA*

TABLE 6 *SUMMARY OF VERTICAL HYDRAULIC GRADIENTS*

TABLE 7 *SUMMARY OF GROUNDWATER GEOCHEMICAL PARAMETERS*

TABLE 8 *SUMMARY OF GROUNDWATER VOC ANALYTICAL DETECTIONS*

TABLE 9 *SUMMARY OF GROUNDWATER MTBE ANALYTICAL DETECTIONS*

TABLE 10 *SUMMARY OF GROUNDWATER ARSENIC ANALYTICAL DETECTIONS*

TABLE 11 *SUMMARY OF SOIL VOC ANALYTICAL DETECTIONS – NORTHERN AREA*

TABLE 12 *SUMMARY OF SOIL VOC ANALYTICAL DETECTIONS – SOUTHERN AREA*

TABLE 13 *SUMMARY OF SOIL METALS ANALYTICAL DETECTIONS*

TABLE 14 *SUMMARY OF MNA ANALYTICAL RESULTS*

TABLE 15 *SUMMARY OF SOIL RESULTS – RISK CHARACTERIZATION*

TABLE 16 SUMMARY OF GROUNDWATER RESULTS – RISK CHARACTERIZATION

TABLE 17 SUMMARY STATISTICS FOR SOIL ANALYTICAL RESULTS

TABLE 18 SUMMARY STATISTICS FOR GROUNDWATER ANALYTICAL RESULTS

TABLE 19 COMPARISON OF SOIL EPCS TO METHOD 1 STANDARDS

TABLE 20 COMPARISON OF GROUNDWATER EPCS TO METHOD 1 STANDARDS

LIST OF FIGURES

FIGURE 1 SITE LOCUS MAP

FIGURE 2 SITE MAP

FIGURE 3 UPPER POTENTIOMETRIC SURFACE MAP (SEPTEMBER 2005)

FIGURE 4 LOWER POTENTIOMETRIC SURFACE MAP (SEPTEMBER 2005)

FIGURE 5 CROSS SECTIONS OF NORTHERN AREA GROUNDWATER CVOC CONCENTRATIONS

FIGURE 6 MASSACHUSETTS GIS SITE SCORING MAP

FIGURE 7 PLAN VIEW OF NORTHERN AREA GROUNDWATER CVOC CONCENTRATIONS

FIGURE 8 PLAN VIEW OF SOUTHERN AREA GROUNDWATER MTBE CONCENTRATIONS

FIGURE 9 ORP-PH DIAGRAM FOR ARSENIC IN GROUNDWATER

LIST OF APPENDICES

APPENDIX A	*DEPARTMENT FORMS AND PUBLIC NOTIFICATION*
APPENDIX B	*WATERLOO PROFILER LOGS*
APPENDIX C	*MIP LOGS*
APPENDIX D	*BORING LOGS*
APPENDIX E	*SLUG TEST DATA*
APPENDIX F	*LABORATORY ANALYTICAL REPORTS*
APPENDIX G	*STEADY-STATE EVALUATION*

LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Areas of Concern
ASL	above mean sea level
bgs	below ground surface
BWSC	Bureau of Waste Site Cleanup
cDCE	cis-1,2-dichloroethene
cm/min	centimeters per minute
COC	constituents of concern
CRA	Comprehensive Response Action
CSA	Comprehensive Site Assessment
CVOC	chlorinated volatile organic compounds
DCE	1,1-dichloroethene
DO	dissolved oxygen
EC	electrical conductivity
ECD	electron capture device
EPC	Exposure Point Concentrations
ERM	Environmental Resources Management
EPA	United States Environmental Protection Agency
GMNWR	Great Meadows National Wildlife Refuge
gpm	gallons per minute
GC	gas chromatograph
GC/MS	gas chromatograph and mass spectrometer
GIS	Geographical Information System
ID	inside diameter
Koc	Organic Carbon Partition Coefficient
Kow	Octanol Water Coefficient
LSP	Licensed Site Professional
MCP	Massachusetts Contingency Plan
MIP	Membrane Interface Probe
mS/m	milliSiemens per meter

MTBE	methyl-tert-butyl ether
MW	monitoring well
NELAP	National Environmental Laboratory Accreditation Program
NHESP	National Heritage Endangered Species Program
NOI	Notice of Intent
NOR	Notice of Responsibility
OHM	oil and/or hazardous materials
ORP	oxidation-reduction potential
PCE	tetrachloroethene
PDB	passive diffusion bag
PID	photoionization detector
QA/QC	quality assurance / quality control
RC	reportable concentrations
RCGW	reportable concentrations ground water
RIP	Remedy Implementation Plan
RNF	Release Notification Form
RTN	Release Tracking Number
SOW	Scope of Work
SVOC	semi-volatile organic compound
TCE	trichloroethene
TPH	total petroleum hydrocarbons
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
ug/L	micrograms per liter
uV	microvolts
VC	vinyl chloride
VOC	volatile organic compound

On behalf of Raytheon Company (Raytheon), Environmental Resources Management (ERM) has prepared this Phase II Comprehensive Site Assessment (CSA) (Phase II) report, pursuant to 310 CMR 40.0835, for portions of the Former Raytheon Facility located at 430 Boston Post Road in Wayland, Massachusetts.

On 17 December 2002, Raytheon submitted a Release Notification Form (RNF, BWSC-103) to the Massachusetts Department of Environmental Protection (Department), pursuant to 310 CMR 40.0315(1), for three identified reportable conditions (ERM, 2002a). The three reportable conditions were identified based on the detection of constituents in groundwater at concentrations in excess of applicable Reportable Concentrations (RCGW-1) and include the following:

- chlorinated volatile organic compounds (CVOCs): tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC) in the Northern Area;
- methyl tert butyl ether (MTBE) in the Southern Area; and
- arsenic in the Western Area.

The Department issued a Notice of Responsibility (NOR) and Release Tracking Number (RTN) 3-22408 on 16 January 2003 for these release conditions. A Phase I Initial Site Investigation (Phase I) report, including a Tier Classification Submittal, was submitted to the Department on 17 December 2003 (ERM, 2003b). The Site is classified as Tier IB, Permit Number W0405278.

On 12 August 2005, Raytheon submitted a RNF to the Department, for an additional release condition identified based on the detection of toluene in groundwater at a concentration in excess of the RCGW-1 standard within the Northern Area of the Site. A NOR has not been received for the toluene release notification at the time of this document submittal. Raytheon has requested that the release condition for toluene be incorporated within RTN 3-22408.

These release conditions constitute three distinct and separate Areas of Concern (AOC), based on geographic location and nature of release, and are hereinafter referred to as the Northern Area (CVOCs), Western Area

(arsenic), and Southern Area (MTBE). The composite of these three AOCs is hereinafter referred to in this document as the "Site."

The Phase II investigation strategy was developed to:

- evaluate the potential for impact to the Town of Wayland's Baldwin Pond Wellfield, which is located approximately 3,250 feet north of the Northern Area CVOC plume axis;
- further characterize the Northern Area CVOC source area to support a remedial alternatives evaluation;
- further evaluate the efficacy of biodegradation to abate CVOC impacts to groundwater;
- further define the downgradient extent of the Northern Area CVOC impacts to groundwater; and
- continue to develop a statistically significant groundwater-quality dataset for the entire Site.

Phase II investigation activities included the advancement of the Membrane Interface Probe (MIP), collection of groundwater samples with the Waterloo Profiler, installation of monitoring wells, performing aquifer testing, collection of groundwater gauging and monitoring data, and conducting a risk characterization.

The following conclusions were derived from the data resulting from the Phase II investigation:

- The source, nature, and extent of CVOC impacts in the Northern Area have been defined and delineated.
- Northern Area Source Area investigations have identified the residual source area.
- Northern Area CVOC impacts to groundwater pose minimal current and future potential for risk to the Baldwin Pond Wellfield.
- Release of MTBE from an upgradient property has impacted groundwater quality in the Southern Area.
- Naturally occurring arsenic has impacted groundwater quality in the Western Area.
- Site groundwater poses a condition of "significant risk" under potential future conditions.
- A Phase III 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 (CSA) (Phase II) report, pursuant to 310 CMR 40.0835, for portions of the Former Raytheon Facility located at 430 Boston Post Road in Wayland, Massachusetts (Figure 1).

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- methyl tert butyl ether (MTBE) in the Southern Area (Figure 2); and
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These release conditions constitute three distinct and separate Areas of Concern (AOC), based on geographic location and nature of release, and are hereinafter referred to as the Northern Area (CVOCs), Western Area (arsenic), and Southern Area (MTBE) (Figure 2). The composite of these three AOCs is hereinafter referred to in this document as the "Site."

Comprehensive Response Actions (CRAs) are being conducted at the Former Raytheon Facility in support of two active RTNs (i.e., RTN 3-22408 and RTN 3-13302; Tier IB Permit Number 133939). The Site boundaries for RTN 3-22408 and RTN 3-13302 overlap, based on data available to date. However, the two RTNs are being treated separately under the MCP to minimize delays in response actions. This Phase II report pertains only to RTN 3-22408.

Department transmittal form BWSC-108 and public notification documentation for the Phase II report are included in Appendix A.

1.2 PURPOSE & SCOPE

The purpose of the Phase II is to identify:

- the source(s), nature and extent of release(s) of oil and/or hazardous material (OHM) in potentially affected media (soil and groundwater);
- the potential risk of harm posed by remaining impacts of the release condition to human health, safety, public welfare, and the environment; and
- the need to conduct remedial actions for affected media.

1.3 REPORT ORGANIZATION

This report is formatted consistent with MCP requirements for a Phase II report, pursuant to 310 CMR 40.0835, 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 Final Scope of Work (SOW) (ERM, 2003a) and Phase II SOW (ERM, 2005).

Section 3.0- Update to the Phase I - Initial Site Investigation, updates to the Site status since filing of the Phase I Report in December 2003, including the potential changes in regulatory status (e.g., additional release condition, etc.), property ownership, activities, and uses.

Section 4.0- Methods, presents the methodology to the field investigation as described in the Final Scope of Work (ERM, 2003a) and Phase II SOW (ERM, 2005). 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 1 Risk Characterization including an evaluation of the risk of harm to human health, safety, public welfare, and the environment posed by OHM that remain at the Site. The risk characterization compares Site soil and groundwater concentrations to applicable Method 1 Standards.

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

The purpose of the Phase I was to conduct initial Site investigation activities to facilitate Tier Classification of the Site.

2.2 CONCLUSIONS

The Phase I report (ERM, 2003b), submitted to the Department on 17 December 2003, presented the following conclusions:

1. ***Release of TCE from an unknown historical source has impacted groundwater quality in the Northern Area.***

PCE, TCE, cDCE, and VC were detected at concentrations exceeding RCs in groundwater in the Northern Area. An apparent historical release of primarily TCE occurred in the vicinity of MW-261S and B-241. The source signature also includes significantly lower levels of PCE. Historically, the area has been filled and only transient radar equipment testing was known to have been conducted in the Northern Area of the Site. Therefore, the release mechanism was likely transient and no longer exists. Intrinsic biodegradation of TCE is occurring, resulting in production of cDCE and VC. CVOC impacts to groundwater are confined to a fine sand and silt unit in the Northern Area.

2. ***Release of MTBE from a potential upgradient property may have impacted groundwater quality in the Southern Area.***

MTBE was detected at concentrations exceeding RCs in groundwater in the Southern Area. The source of MTBE in the Southern Area was likely a gasoline release at an upgradient gasoline service station located at 365 Boston Post Road (RTN 3-17974). Pursuant to 310 CMR 40.0180, Raytheon may file a Downgradient Property Status Submittal for the Southern Area.

3. ***Naturally occurring arsenic has impacted groundwater quality in the Western Area.***

Arsenic was detected at concentrations exceeding RCs in groundwater in the Western Area. Naturally occurring arsenic present in soil has been

mobilized as a result of the natural reducing conditions in the wetlands bordering the Sudbury River. The presence of arsenic in groundwater in the Western Area represents a background condition.

4. Impacts to groundwater at the Site maintain a low potential to impact Site occupants or nearby receptors given current or potential future use scenarios.

Preliminary review of potential exposure pathways and receptors at or near the Site suggest a low potential for impact to human or environmental receptors based on current knowledge of Site conditions. However, it is acknowledged that the Site is located within a Zone II aquifer protection area.

5. The Site has been classified as Tier IB.

Completion of the Numerical Ranking System scoresheet resulted in a Site score of 511, which scores the Site as Tier IB.

6. A Phase II Scope of Work was completed.

A Phase II Scope of Work (SOW), dated 25 April 2005, was submitted to the Department for the Phase II activities.

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 report in December 2003 (ERM, 2003b). Changed conditions include property ownership and the Site regulatory status (e.g., an additional release condition).

3.2 PROPERTY OWNERSHIP

The Former Raytheon Facility property was redeveloped as the Wayland Business Center after Raytheon's departure. The current owner of the Former Raytheon Facility property is Wayland Business Associates, LLC. Wayland Business Associates, LLC acquired the property on 25 August 2004. Property ownership prior to 25 August 2004 was presented in the Phase I report (ERM, 2003b).

3.3 SITE ACTIVITIES, USES & USE RESTRICTIONS

Site activities and use have not changed since submittal of the Phase I report (ERM, 2003b). The Former Raytheon Facility property remains redeveloped as an office park, the Wayland Business Center.

The property remains in use only within the Southern Area as a parking lot for the Wayland Business Center. The Northern Area, an open field to the north of a parking lot, and the Western Area, a wetland and field within or proximal to a wetland, are not currently being used. Detailed discussions of historical operations at the Former Raytheon Facility are presented in the Phase I and Phase II reports for RTN 3-13302 (ERM, 1996 and 2001, respectively).

3.4 SITE REGULATORY HISTORY

Since submittal of the Phase I report, Raytheon submitted a RNF dated 12 August 2005, to the Department, for an additional release condition identified based on the detection of toluene in groundwater at a

concentration in excess of the RCGW-1 standard within the Northern Area of the Site.

3.5 DISPOSAL SITE BOUNDARY

Since the Phase I report, additional investigation activities have identified that the Northern Area Disposal Site Boundary extend onto lot 23-52A, which abuts the Former Raytheon Facility property to the north (Figure 2). The current owner of this wooded parcel is the Town of Wayland Conservation Commission (Commission).

4.0 METHODS

4.1 SITE INVESTIGATION STRATEGY

The Phase II investigation strategy was developed to:

- evaluate the potential for impact to the Town of Wayland's Baldwin Pond Wellfield, which is located approximately 3,250 feet north of the Northern Area CVOC plume axis;
- further characterize the Northern Area CVOC source area to support a remedial alternatives evaluation;
- further evaluate the efficacy of biodegradation to abate CVOC impacts to groundwater;
- further define the downgradient extent of the Northern Area CVOC impacts to groundwater; and
- continue to develop a statistically significant groundwater-quality dataset for the entire Site.

As presented in the Phase I Report (ERM, 2003b), MTBE has been detected in groundwater at concentrations up to 6,100 micrograms per liter (ug/L) at a gasoline service station located at 365 Boston Post Road (Strata, 2003). This property is currently in Phase IV of the MCP process and is tracked under RTN 3-17974. MTBE was initially detected at this property in August 2001 and concentrations have subsequently declined (Strata, 2003), suggesting that MTBE has migrated from the source area. Raytheon has collected groundwater samples from the Southern Area since 1999 for MTBE analyses. MTBE was first detected on the Former Raytheon Property in 2002. The highest MTBE concentration detected in groundwater on the gasoline service station property (i.e., 6,100 ug/L) is higher than that detected in groundwater in the Southern Area (i.e., 280 ug/L).

Based on groundwater elevation data, the service station at 365 Boston Post Road is located hydraulically upgradient of the Southern Area. Downward vertical hydraulic gradients exist in the eastern portion of the Former Raytheon Facility. Similar downward vertical gradients were measured on the 365 Boston Post Road site (Strata, 2003).

Collectively, these data suggest that the source of MTBE is likely located on the 365 Boston Post Road site (RTN 3-17974) and that advective groundwater transport has resulted in migration of MTBE into the Southern Area.

Arsenic is a naturally occurring element within the environment, and is ubiquitously detected in soil throughout the Western Area (ERM, 2004a). The availability of arsenic as a dissolved species in groundwater depends on the aqueous and physical geochemistry of an aquifer system. Arsenic concentrations in the groundwater of New England are relatively high and have been the subject of scientific studies. Ayotte et al. (2003) propose that arsenic within New England is "dominantly natural and originates from minerals in the rocks of the region including arsenic-bearing sulfide minerals or trace amounts of the element within rocks (Ayotte et al., 1999).

Studies show high concentrations of arsenic within many river deltas because of the high organic content and reducing geochemical conditions found there (Stronach, 2003). Dissolved-phase arsenic is also commonly found under basic pH conditions (i.e., pH greater than 7; Ayotte et al., 1999; Ayotte et al., 2003). These conditions are present in the Western Area, as described below.

The Western Area is located within and adjacent to wetlands of the Sudbury River. Wetlands, with their naturally high organic content and saturated soils, often display chemically-reduced conditions. Groundwater within the Western Area generally exhibited negative oxidation-reduction potential (ORP) measurements, indicative of chemically reduced conditions. Arsenic oxyanions are known to adsorb to iron hydroxides, present as coatings on sediment (Horesh, 2001). Under reduced conditions, the iron hydroxides become soluble and no longer act as sorption sites for the arsenic oxyanion (Horesh, 2001).

Based on a review of historical chemical usage at the Former Raytheon Facility (ERM, 1996) and current chemical usage at the Wayland Business Center, arsenic does not appear to have been used at the facility. Based on the absence of an apparent anthropogenic source, the abundance of naturally occurring arsenic in soil across the property and the geochemical environment of the Western Area, ERM believes that the detections of arsenic in groundwater in this portion of the Site represent a naturally occurring background condition.

The MCP defines background as levels of OHM as those that are "*ubiquitous and consistently present in the environment at and in the vicinity of the site of concern; and attributable to geologic or ecologic conditions, or*

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 presence of arsenic in the Western Area of the Site is consistent with background conditions and is eliminated from further consideration.

Continued monitoring of MTBE and arsenic impacts to groundwater was conducted as part of the Phase II investigation for the purpose of developing a statistically significant groundwater-quality dataset for these constituents.

4.2 SCOPE OF WORK

Two SOW (i.e., Final SOW and Phase II SOW) were prepared to detail investigation activities for CVOC impacts within the Northern Area of the Site. The objectives and methodology employed to complete each task detailed in the SOW are presented below:

4.2.1 Assessment of the Potential for Baldwin Pond Wellfield Impacts from the Northern Area

The purpose of this task was to evaluate the potential for CVOC impacts to groundwater in the Northern Area to impact the Baldwin Pond Wellfield. Based on data collected to date, the CVOC plume is generally migrating westward toward the Sudbury River. The hydraulic-gradient and contaminant-concentration historical datasets support this westward transport pathway.

The potential for a shift in transport direction to the north/northeast and into the capture zone of the Baldwin Pond Wellfield was evaluated. To evaluate this plume transport pathway, a vertical groundwater profiling program was conducted (i.e., Waterloo Profiler tool) using north-south and east-west transects that would intersect the CVOC plume if a transport pathway to the wellfield exists. The completed transects, located to the north of the Northern Area, are represented by the B-400 series Waterloo Profiler borings presented in Figure 2.

The Waterloo Profiler is a direct push groundwater sampling tool that allows for the collection of discrete groundwater data from a 5 cm vertical interval, including:

- hydraulic head;

- physio-chemical parameters (i.e., specific conductance, pH, oxidation-reduction potential (ORP) and dissolved oxygen); and
- groundwater samples for analyses of COCs.

The profiler also provides a continuous log of the Index of Hydraulic Conductivity (Ik). The Ik is determined by measuring the flow rate and pressure of water injected into the formation as the tool is driven. The vertically continuous Ik data provide high-resolution information on stratigraphic changes in real-time. The two primary uses of these data are to:

1) aid in real-time decision making (e.g., select sampling depths or identify the presence of an aquitard that should not be penetrated) and
2) allow for Site-wide interpretation of the hydrogeologic stratigraphy in three dimensions (Cho et al., 2004). However, Ik data are not absolute hydraulic conductivity (K) data, but rather relative K data.

Between 24 February and 17 March 2004, 15 Waterloo Profiler borings (B-411 to B-426) were advanced to the depth of tool refusal. Tool refusal occurred at bedrock, till, or relatively coarse grained unconsolidated deposits, depending on the presence and depth of these layers. Prior to initiating the profiling program, a series of seismic refraction transects were conducted to evaluate the depth to bedrock at or near each of the proposed drilling locations (ERM, 2003b). These data were used to evaluate whether tool refusal occurred at bedrock. Hollow stem auger drilling methods were used to aid in the advancement of Waterloo Profiler borings to the depth of bedrock at select boring locations along the north-south transect (B-416, B-417, B-419, B-422, and B-426; Figure 2). This was performed to facilitate sample collection over the entire vertical extent of the overburden unit. One proposed boring, B-423, was not completed due to access restrictions.

A total of 123 groundwater samples were collected and analyzed for VOCs by EPA Method 8260B during this assessment program. Waterloo Profiler analytical results are presented in Table 1. Waterloo Profiler boring logs are included in Appendix B.

4.2.2 *Characterization of Northern Area Source Zone*

The purpose of this task was to further characterize the Northern Area source area (i.e., the vicinity of MW-261S; Figure 2). ERM conducted a dynamic source-area investigation in the Northern Area. Multiple

investigation techniques/tools were employed during the source zone characterization, including:

- Membrane Interface Probe (MIP) – The MIP is a direct-push characterization tool described below.
- Waterloo Profiler – The Waterloo Profiler is a direct-push characterization tool that provides a continuous record of relative hydraulic conductivity data in the saturated zone. It also allows for measurement of discrete-interval groundwater elevation and aqueous geochemistry, and the collection of groundwater samples for laboratory analyses at selected depths below the water table.
- Soil Sample Collection and Analysis – Soil borings were advanced for the collection of soil samples for laboratory analysis of grain size distribution and soil oxidant demand.
- Installation of Groundwater Monitoring Wells – Groundwater monitoring wells were installed at three locations for the collection of groundwater samples for laboratory analysis of VOC concentrations.

MIP Borings

The MIP is a direct push, real-time, direct sensing tool that provides continuous semi-quantitative data on the distribution of VOCs in the subsurface. The probe on the MIP is equipped with a porous polytetrafluoroethene membrane set into a steel plate that is electrically heated to 120 degrees Celsius. The heat volatilizes organic compounds present in the soil and/or groundwater adjacent to the tip. VOCs, up to a maximum molecular size, pass through the membrane by diffusion under a concentration gradient. Once a compound has passed through the membrane, it is picked up by a carrier gas (i.e., nitrogen) running through a tubing loop. The organic compounds are carried to the surface where they pass through serial detectors that include:

- a photoionization detector (PID) to measure aromatic compounds, and
- an electron capture device (ECD) to measure chlorinated VOCs.

Results are reported as detector response in microvolts (uV) and represent relative total VOC concentrations. The ECD is a very sensitive detector and is capable of detecting CVOCs at low concentrations; however, the detector saturates at high concentrations (above approximately 15,000,000 uV, or 15 volts). The PID, which is primarily used to measure aromatic

VOCs, can also detect chlorinated VOCs if they are present at high enough concentrations. Since the concentration ranges for detection of chlorinated VOCs by ECD and PID overlap, the results from the two detectors can be combined to evaluate a broad range of chlorinated VOC concentrations in soil gas, soil, and groundwater.

When a significant peak was observed on the ECD log, a grab gas sample was collected for analysis using a field gas chromatograph (GC). The field GC speciation data are reported in units of micrograms per liter (ug/L), but do not represent a direct soil gas, soil, or groundwater concentration. These data were used to evaluate the chemical "fingerprint" at a discrete depth.

In addition to the membrane and heater, the MIP probe is equipped with an electrical conductivity (EC) dipole array that measures the electrical conductance of the soil and any fluids in the soil in units of milliSiemens per meter (mS/m). By understanding the variability in electrical properties of various geologic media, the electrical conductivity log can provide a good indication of stratigraphic changes in many environments (Schulmeister et al., 2003). However, interferences present at some sites (e.g., high electrical conductivity groundwater) may render interpretation of EC data challenging.

The MIP was advanced using a direct-push drill rig at an approximate rate of 30.5 centimeters per minute (cm/min). Detector response and electrical conductivity data were recorded every 1.5 centimeters (cm). The MIP was used to evaluate both vadose and saturated zones. Concentrations of TCE must be on the order of 200 ug/L in order to be detected by the MIP. Because the MIP provides a continuous log of total VOCs in the subsurface and can complete up to 180 feet of exploration in a day, it was ideally suited for rapidly locating and precisely defining VOC plume cores and source areas at the Site.

The MIP is capable of generating a large amount of detailed three-dimensional data in both high and low hydraulic conductivity media. This capability is particularly important for investigating relatively low permeability media, such as silts and clays, where significant contaminant mass can diffuse into the primary porosity and act as a long-term source of contamination to groundwater. The MIP was used to define vadose and shallow saturated zone source areas at the Site.

Between 27 April and 6 May, 2005, a total of 43 MIP borings (B-501 to B-543) were advanced within the Northern Area source area at locations shown on Figure 2. The MIP investigation was initiated within five feet of

monitoring well MW-261S, the inferred source area. MIP borings were advanced to a depth at which the total VOC response declined to a near-baseline value for the achievement of vertical delineation or to a maximum of 35 feet below ground surface (bgs).

MIP borings were initially advanced radially-outward from MW-261S in different directions, located at pre-determined grid nodes. Subsequent MIP borings were advanced beyond the original grid to the east, in locations selected through the interpretation of existing MIP response data. After baseline MIP response data was achieved east (upgradient) bound of the defined source area, additional MIP borings were advanced to delineate the source area to the north, south, and west. MIP borings were also advanced within the center of the source area in order to define horizontal and vertical contaminant distribution relative to hydrostratigraphy. MIP logs are included in Appendix C.

Waterloo Profiler Borings

Between 27 April and 6 May, 2005, a total of 13 Waterloo Profiler borings (B-501, B-515, B-520, B-529, B-530, B-534, B-540, B-545 through B-550) were advanced around and downgradient of the Northern Area source area (Figure 2). Two Waterloo Profiler borings, WP-520 and WP-529, were advanced within the bounds of the source area, as defined by the MIP investigation, for a quantitative assessment of CVOC concentrations. Three Waterloo Profiler borings, WP-515, WP-530, and WP-534, were advanced along the margins of the interpreted source area for quantitative measurement of CVOC concentrations at the margins of the source area investigation. The remaining eight Waterloo Profiler borings were advanced along the northeast-trending investigation transect located west (downgradient) of the source area. The Waterloo Profiler borings were advanced to provide groundwater samples for quantitative analyses of constituents of interest, measurement of potentiometric head values, measurement of aqueous geochemistry parameters, and a continuous log of relative hydraulic conductivity. This information was collected to support the contaminant distribution information provided by the MIP, and to provide additional hydrogeologic data for source-area characterization.

Fifty-five discrete interval groundwater samples were collected during advancement of the 13 Waterloo Profiler borings. The groundwater samples were submitted for rapid, on-Site analysis for select CVOCs by ASTM method D6520 using a National Environmental Laboratory Accreditation Program (NELAP) certified mobile field laboratory. The field laboratory consisted of a gas chromatograph and mass spectrometer

(GC/MS). One Waterloo Profiler groundwater sample, WP-520, was collected prior to the arrival of the on-Site laboratory, and therefore was submitted to Alpha Analytical Laboratories for analysis of VOCs by EPA method 8260B. One Waterloo Profiler groundwater sample, WP-501, was split and analyzed for VOCs by both the on-Site laboratory and an off-Site laboratory. Waterloo Profiler analytical results are presented in Table 1. Waterloo Profiler boring logs are included in Appendix B.

Soil Boring and Monitoring Well Installations

Upon completion of the dynamic MIP and Waterloo Profiler boring program, a focused, long-term monitoring well network was designed to monitor groundwater elevations and CVOC concentration over time. These monitoring wells will provide groundwater monitoring points for the evaluation of plume concentration reduction as a result of source-zone abatement. One soil boring location was selected near the middle of the transect in an effort to intersect the approximate plume centerline. Two additional soil boring locations were selected along the transect to the northeast and southwest. These two boring locations were selected to provide groundwater monitoring data from the outer edges of the plume.

On 24 May 2005, the three soil borings (MW-551, MW-552, and MW-553; Figure 2) were advanced using a truck-mounted, hollow-stem-auger drill rig. Continuous soil samples were collected from approximately 10 to 25 feet bgs, representing the vertical zone of contaminant transport identified by the MIP and Waterloo Profiler. Soil samples were classified and logged by an on-Site geologist. Select soil samples were sent to a laboratory for analysis of grain size distribution (Table 2). Additional soil samples were collected for the analysis of soil oxidant demand. Soil oxidant demand is used in the evaluation and cost estimation of in-situ chemical oxidation as a remedial action alternative (i.e., to support completion of Phase III).

Based upon the results of the MIP and Waterloo Profiler borings advanced along the transect, single monitoring wells with five-foot screens were installed at each of the three boring locations.

Monitoring wells were constructed using one-inch and two-inch inside diameter (ID), PVC, 0.010-inch machine-slotted well screen, PVC riser pipe, sand filter pack, bentonite seal, concrete surface seal, and locking steel protective standpipes. The three wells were subsequently developed and sampled using low-flow sampling techniques (described in Section 4.2.5). Monitoring well construction details are presented in Table 3. Boring logs are included in Appendix D.

4.2.3 Conduct Additional Delineation of CVOC Impacts to Groundwater

The purpose of this task was to further delineate the horizontal and vertical extent of CVOC impacts in the downgradient portion of the Northern Area. In order to assess the western extent of the plume, ERM advanced three borings and installed nested monitoring wells within the wetlands at locations designed to intersect and delineate the axis of the CVOC plume. The monitoring-well installation activities were proposed in the Final SOW and were again presented within the Phase II SOW.

ERM submitted a Notice of Intent (NOI), dated 26 September 2003, with the Commission and the Department for activities to be conducted within the wetland areas or wetland buffer zones. The Department assigned Wetland Protection Act File No. 322-0564 for these activities. The Commission issued an Order of Conditions for these activities, dated 20 November 2003. ERM notified the Commission of intent to modify the Department File No. 322-0564 in a letter, dated 21 July 2004. The Commission verbally approved the modification, without requiring submittal of a new NOI, during a Commission meeting on 25 August 2004. Drilling activities were originally scheduled for September 2004, but were delayed due to high water conditions in the Sudbury River and bordering wetlands.

In September 2005, a temporary roadway was constructed to each drilling location using wood platforms. Between 12 and 21 September 2005, a truck mounted drill rig was used to advance each boring to the top of bedrock using rotosonic drilling techniques. Continuous soil samples were collected, logged, and screened in the field for total VOCs using a PID and the jar headspace method. Selected soil samples were collected and analyzed for CVOCs using a National Environmental Laboratory Accreditation Program (NELAP) certified mobile field laboratory. The field laboratory consisted of a gas chromatograph and mass spectrometer (GC/MS).

Three to four nested monitoring wells were installed within the borings, based a combination of field screening and geologic stratigraphy, generally as follows:

- shallow well screen within the upper silt and clay unit;
- upper intermediate well screen within underlying fine sand and silt unit;
- lower intermediate well screen within a sand and gravel unit, if present; and

- deep well screen at the top of bedrock within a sand and gravel unit.

Monitoring wells were constructed using one-inch and two-inch inside diameter (ID), PVC, 0.010-inch machine-slotted well screen, PVC riser pipe, sand filter pack, bentonite seal, concrete surface seal, and locking steel protective standpipes. The wells were installed using either five or ten-foot length well screens, depending on the thickness of the targeted geologic unit. Monitoring wells were developed and sampled using low-flow procedures following installation. Monitoring well construction details are presented in Table 3. Boring logs, which include the VOC screening results, are included in Appendix D.

4.2.4 *Perform Aquifer Testing*

The purpose of this task was to collect Site-specific hydrogeologic data to incorporate into numerical estimates of groundwater seepage velocity and contaminant advective transport. ERM conducted aquifer testing (i.e., slug tests) to estimate hydraulic conductivity at various locations within the plume transport pathway. Slug tests were performed on monitoring wells of varying screen depths and representing various geologic units, including MW-261S, MW-262S, MW-264S, MW-264M, MW-265M, MW-266Mb, MW-267D, MW-267S, MW-268D, MW-268M, MW-268S, MW-511, MW-552, and MW-553.

Falling-head and rising-head slug tests were performed on the above referenced monitoring wells. Groundwater elevation data were collected using a down-hole 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). The data from the falling-head and rising-head slug tests were consistent for each monitoring well, therefore only the falling-head data were utilized for estimating hydraulic conductivity (all wells contained fully-saturated screens). The results of the slug test analyses are presented in Table 4. The slug test analytical logs are included in Appendix E.

4.2.5 *Gauge and Sample Monitoring Wells*

The purpose of this task was to continue the evaluation of hydraulic gradients and groundwater quality at the Site. As proposed in the Phase II SOW, a groundwater gauging event was conducted for existing wells in April and September 2005. A groundwater sampling round was conducted in April 2005. To date, a total of eight comprehensive gauging and sampling rounds have been conducted at the Site.

For the purpose of evaluating groundwater flow directions across the entire Former Raytheon Facility property, ERM routinely prepares two groundwater elevation contour maps for each gauging round, representing:

- wells with screens set across the water table or with the top of the well screen located within five feet of the water table; and
- wells with screens set in the deep overburden (defined as the lower fine sand and silt unit in the Northern Area and the fine to medium sand unit in the Southern Area). It is important to note that well screens set within this unit vary significantly in depth. However, head data collected from these wells appear to represent a single hydrologic unit and therefore, represent a single piezometric surface. The lower fine sand and silt unit of the Northern Area is particularly significant because it appears to control CVOC migration in this portion of the Site.

Depth-to-water measurements were collected within all Site wells. Gauging data are presented in Table 5. The upper and lower aquifer potentiometric surface maps for the September 2005 gauging event are shown on Figures 3 and 4, respectively.

In addition to evaluating horizontal groundwater flow, ERM routinely calculates vertical hydraulic gradients for well clusters (i.e., two or more wells installed in close proximity to one another). The vertical gradients are calculated using groundwater elevation data for vertically adjacent monitoring wells. Vertical gradients were also calculated between deep overburden and bedrock wells, where present. The vertical hydraulic gradients calculated using calendar year 2005 potentiometric surface data are presented in Table 6.

Groundwater samples were collected from monitoring wells located within the Northern, Southern, and Western Areas using low-flow or passive diffusion bag sampling techniques. For wells sampled using low-flow sampling techniques, physico-chemical parameters (pH, temperature, specific conductance, dissolved oxygen, and ORP) were monitored during purging until equilibration was achieved, at which time groundwater samples were collected for laboratory analyses. Groundwater samples were analyzed for one or more of the following parameters, determined by the contaminants of interest for that area of the Site:

- VOCs by EPA Method 8260B [newly constructed wells only (MW-551, MW-552, and MW-553)];

- CVOCs by EPA Method 8021B (Northern Area);
- MTBE and benzene by EPA Method 8021B (Southern Area); and/or
- arsenic by EPA Method 6010B (Western Area).

Groundwater geochemical parameter data is presented in Table 7. Groundwater analytical results for VOCs, MTBE, and arsenic are presented in Tables 8, 9, and 10, respectively. Laboratory analytical reports are provided in Appendix F.

4.2.6 Conduct Method 1 Risk Characterization

The purpose of this task was to perform a Risk Characterization to assess the risk of harm to human health, public welfare, safety, and the environment associated with the releases associated with RTN#3-22408. As required by 310 CMR 40.0900, the risk characterization included:

- Site Characterization and Identification of Soil and Groundwater Categories;
- Hazard Identification:
  - Selection of Study Chemicals;
- Exposure Assessment:
  - Identification of Site Activities and Uses,
  - Identification of Potential Human Receptors,
  - Identification of Potential Environmental Receptors,
  - Identification of Potential Exposure Points,
  - Identification of Exposure Point Concentrations;
- Characterization of Risk of Harm to Human Health and Public Welfare and the Environment;
- Characterization of Risk to Safety;
- Conclusions; and
- Limitations.

Based on soil and groundwater data collected to date, ERM performed a Method 1 Risk Characterization, which compares concentrations of OHM detected in soil and groundwater to applicable Method 1 standards.

5.0 RESULTS

5.1 REGIONAL & SITE GEOLOGY

5.1.1 Unconsolidated Deposits

The Site is located in a zone of Wisconsin-aged glaciolacustrine (i.e., lake bottom) deposits (USGS, 1964 and 1974), as shown in Appendix B of the Phase I report. Field observations indicate that the deposits are primarily stratified fine sands and silt. Recent swamp and alluvial deposits occur west of the Site, along the Sudbury River.

A generalized geologic cross-section showing overburden stratigraphy within the Northern Area of the Site is presented in Figure 5. In the vicinity of MW-261S and B-241, the overburden deposits consist of the following units (from top to bottom, based on geologic logging of MW-262):

- Coarse to fine sand, unsaturated;
- Upper fine sand and silt, saturated, moderate conductivity (this unit generally fines to the west, grading into a silt and clay unit);
- Medium to fine sand, saturated, moderate conductivity (this unit fines to the west, grading into a fine sand and silt unit);
- Middle fine sand and silt, saturated, moderate conductivity;
- Gravel, saturated, high conductivity;
- Lower fine sand and silt, saturated, moderate conductivity, discontinuous (this unit pinches out to the west);
- Till, saturated, moderate conductivity, discontinuous (this unit pinches out to the west); and
- Bedrock.

In the western portion of the Northern Area, the overburden deposits consist of the following units (from top to bottom, based on geologic logging of MW-268):

- Coarse to fine sand, unsaturated;
- Upper fine sand and silt, saturated, moderate conductivity;

- Silt and clay, saturated, low conductivity;
- Lower fine sand and silt, saturated, moderate conductivity;
- Gravel, saturated, high conductivity; and
- Bedrock.

Soil samples were collected during Phase II activities for the analysis of grain size. The results of grain size analyses from the Northern Area are summarized in Table 2.

5.1.2 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 as shown in Appendix B of the Phase I report. 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.

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 depths of approximately –80 feet to 50 feet ASL (Figure 5).

5.2 REGIONAL & SITE HYDROGEOLOGY

5.2.1 Local & Regional Groundwater

Groundwater was encountered beneath the Site at depths ranging from 0 to 16 feet bgs in Site monitoring wells on 26 September 2005. The primary direction of overburden groundwater flow beneath the Site is west, potentially controlled by the presence of the Sudbury River.

In general, downward vertical gradients were measured in the eastern portion of the Former Raytheon Facility property. This is generally consistent with the regional hydrogeologic setting, which consists of a local groundwater flow divide located coincident with a topographic high east of the Former Raytheon Facility property and a regional discharge

boundary (i.e., the Sudbury River) located to the west. Vertical gradients are typically downward in the vicinity of a recharge boundary (e.g., area of high ground) indicating that groundwater is seeking to achieve a lower elevation, consistent with the regional water table. As groundwater flows away from the recharge boundary, vertical gradients typically become less downward and transition to upward gradients as groundwater approaches the regional discharge boundary. This transition from downward to upward vertical gradients has been observed in the central, western, and wetland portions of the Former Raytheon Facility property.

Slug test analyses indicate a three order-of-magnitude range of estimated aquifer hydraulic conductivity values, from 2.3×10^{-3} cm/sec to 2.8×10^{-6} cm/sec.

Site groundwater is located within the Department-approved Zone II Wellhead Protection Area for the Baldwin Pond as shown on the Department Geographical Information System (GIS) Site Scoring Map, Figure 7.

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. No Zone A areas for a reservoir are currently located within 500 feet of the Site (Figure 7).

5.2.3 Wetland & Habitats

The western portion of the Site is occupied by wetlands that are bordering the Sudbury River. The Site wetland is classified under the National Heritage Endangered Species Program (NHESP) as Estimated Habitats of Rare Wetlands Wildlife (Figure 7). On behalf of Raytheon, Woodlot Alternatives has performed ecological surveys of the wetlands adjacent to the Former Raytheon Property. The surveys identified one rare plant species, the River Bullrush, within the Site boundary. The River Bullrush is a species of special concern in Massachusetts.

Additional details regarding Site wetland communities and characteristics are documented in a report entitled, *Raytheon Project Area Ecological Characterization*, prepared by Woodlot Alternatives and dated December 2000. This document was included within the appendix of the Phase II Report for RTN 3-13302 (ERM, 2001).

5.3 SOURCE, NATURE, AND EXTENT OF CONTAMINATION

5.3.1 Overview

This section describes the identified sources of OHM releases and the nature and extent of OHM releases by media (i.e., soil and groundwater). The types and levels of OHM in Site soil and groundwater are described with respect to applicable MCP RCs for the Site. RCs for soil and groundwater are thresholds established by the Department solely for notification of releases of OHM to the Department. Levels of OHM in soil or groundwater 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 (Section 6.0).

The applicable RC standards for Site soil and groundwater are RCS-1 and RCGW-1, respectively. The following table presents Site release conditions to groundwater:

Summary of OHM Release Conditions in Groundwater

Analyte	Minimum	Maximum	RCGW 1
Organics (µg/L)			
PCE	ND	2,390	5
TCE	ND	120,000	5
cDCE	ND	10,000	70
VC	ND	520	2
Toluene	ND	2,600	1,000
MTBE	ND	280	70
Inorganics (mg/L)			
Arsenic	ND	0.239	0.050

5.3.2 Sources of Oil and/or Other Hazardous Materials Release

The Site consists of three AOCs, each of which has a distinct and separate release condition. ERM's current understanding of the three releases is summarized below:

- Northern Area: Historical equipment testing was conducted in this portion of the Former Raytheon Facility. It appears that a

release of CVOCs and toluene occurred in this portion of the Site.

- Southern Area: MTBE has been identified at an adjacent, upgradient gasoline station located at 365 Boston Post Road. This property is currently in Phase IV of the MCP process and is tracked under RTN 3-17974. Based on hydraulic gradient and contaminant distribution data, it is likely that the MTBE detected in the Southern Area is attributable to the 365 Boston Post Road Site (see Section 4.1).
- Western Area: ERM has not identified any evidence of historical arsenic use at the Former Raytheon Facility. The arsenic detected in groundwater at the Site is attributed to naturally occurring arsenic present in Site soil that has been and is mobilized by naturally reducing conditions within wetland areas (see Section 4.1).

The Northern Area dynamic Site investigation using the MIP and Waterloo Profiler identified the location of the CVOC source area. The MIP investigation identified the location of the release area approximately 100 feet to the east-southeast of MW-261S (i.e., vicinity of MIP 520 and MIP-529). The release showed a relatively high CVOC response, as well as relatively shallow impacts, suggestive of a potential release area.

ERM defined the three-dimensional architecture of the Northern Area CVOC source area using the MIP. Little or no CVOCs were identified in vadose zone soil. However, CVOCs were identified within saturated zone soils to a maximum depth of approximately 25 feet. A dissolved phase CVOC plume continues to emanate from this source area following the initial release, suggesting that CVOCs remain in the source area as residual mass, sorbed to soil, and/or diffused into fine-grained soil horizons.

CVOC concentrations within groundwater samples collected within the Northern Area source area are presented in cross-sectional view on Figure 5 and plan view on Figure 7. The following table provides a summary of analytical results for groundwater samples collected during source-area characterization activities:

Summary of Groundwater Contaminants of Interest Detections During Northern Area Source Area Characterization Activities

Analyte	Number of Analyses	Number of Detections	Number of Above-RC Detections	Maximum Concentration (ug/L)
PCE	58	48	41	2,390
TCE	58	57	56	120,000
cDCE	58	45	33	7,020
VC	58	8	8	320
Toluene	5	1	1	2,600

Toluene was detected for the first time above the RCGW-1 standard within a single sample collected from Waterloo Profiler boring WP-520 during the source-area characterization activities. A RNF for the release condition was submitted on 12 August 2005. The historical laboratory analytical results for toluene for monitoring wells within the Northern Area of the Site were presented in the Phase I report. Recent laboratory analytical results for toluene for monitoring wells within the Northern Area of the Site are presented in Table 8.

5.3.3 Nature and Extent of Impacts to Soil

Northern Area

A total of 30 soil samples have been collected from depths of 0 to 19.5 feet bgs within the Northern Area of the Site for laboratory analyses of VOCs. No VOCs have been detected in Site soil at concentrations above applicable RCs (Table 11).

Southern Area

Four soil samples were collected from depths of 8 to 18 feet bgs (i.e., above the groundwater table) for laboratory analysis of VOCs. No VOCs, including MTBE, have been detected in these samples at concentrations above laboratory method detection limits (Table 12).

Western Area

Two soil samples (one sample each) were collected from soil borings MW-314D (25 feet bgs) and MW-315D (6 feet bgs) during the installation of monitoring wells within the wetlands in the Western Area. No metals were detected in soil at concentrations above applicable RCs (Table 13).

5.3.4 Nature and Extent of Impacts to Groundwater

The Phase II focused on the characterization and delineation of CVOC impacts to groundwater in the Northern Area of the Site. Groundwater gauging and sampling activities were conducted during the Phase II to continue monitoring MTBE and arsenic impacts to groundwater within the Southern and Western Areas, respectively.

Northern Area

Horizontal and vertical delineation to the RCGW-1 standard has been achieved for VOCs within the Northern Area of the Site as shown in cross-section (Figure 5) and plan view (Figure 7). The northern, eastern, southern, and western boundaries of the CVOC plume were delineated to concentrations below applicable RCs.

ERM conducted an analysis to evaluate whether the Northern Area CVOC plume was in steady state. Based on statistical and chemical data, ERM believes the Northern Area CVOC plume is in steady state (Appendix G). Thus, potential of future migration or CVOCs in groundwater to the Baldwin Pond Wellfield is considered to be unlikely.

Southern Area

MTBE concentrations detected in on-Site wells are attributed to a release at the adjacent gas station Site. Therefore, MTBE impacts have been monitored for the development of a groundwater quality database, but delineation of this contaminant was not completed as part of Phase II activities. A plan view map of Southern Area MTBE concentrations is presented in Figure 8, including historical concentrations of MTBE at the adjacent gas station Site (RTN 3-17974).

Western Area

Due to the presence of arsenic as a naturally-occurring condition, delineation of arsenic concentrations was not conducted. Monitoring wells MW-314S, MW-314D, MW-315S, and MW-315D were not accessible

during the April 2005 sampling event because of the high stage of the Sudbury River. Historically arsenic has been detected in groundwater samples collected from these four wells at concentrations above RCs. Arsenic was not detected in monitoring wells at concentrations above RCs during the April 2005 groundwater sampling round.

An ORP-pH diagram for all arsenic detections within groundwater samples collected within the Western Area is presented in Figure 9. Concentrations of arsenic above RCs were most frequently detected in groundwater samples having relatively low ORPs (i.e., less than 0 millivolts (mV)) indicative of reducing conditions. A subset of these samples also exhibits basic pH values (i.e., greater than 7).

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).

The following table provides a summary of the above chemical-specific properties for contaminants of interest detected at the Site:

Summary of Physical and Chemical Properties of Contaminants of Interest

Property	PCE	TCE	cDCE	VC	Toluene	MTBE	Arsenic
Solubility (25°C, mg/L)	175 [1]	1,100 [1]	3,500 [2]	60 [1]	470 [1]	4,800 [2]	Insoluble [4]
Vapor Pressure (25°C, mm Hg)	14 [1]	20 [1]	200 [6]	2,660 [1]	10 [1]	245 [2]	NA
Viscosity (25°C, cp)	1.93 [1]	0.566 [1]	0.48 [6]	gas	0.552 [1]	0.3 [5]	NA
Density (25°C, g/cm^3)	1.6 [1]	1.46 [1]	1.28 [2]	0.912 [1]	0.867 [1]	0.7 [3]	5.72 [2]
Log K_{oc}	2.45 [2]	2.35 [2]	1.69 [2]	1.99 [2]	1.91 [2]	2.89 [2]	NA
Log K_{ow}	3.40 [2]	2.36 [1]	1.86 [2]	0.92 [1]	2.79 [1]	1.24 [2]	NA

NA = Not Applicable

[1] 2003, GeoRef Systems Ltd., *Envirobrowser*, www.envirobrowser.com

[2] 2005, Agency for Toxic Substances and Disease Registry, www.atsdr.cdc.gov

[3] 2005, National Institute for Occupational Safety and Health, www.cdc.gov/niosh

[4] Insoluble as As

[5] 2003, Lyondell, Arcopure (MTBE), MSDS, www.lyondell.com

[6] 2004, Water Science and Technology Board, *Contaminants in the Subsurface: Source Zone Assessment and Remediation*

5.4.2 *Potential Migration & Fate*

Migration in Soil

No contaminants of interest have been detected in soil above the RCGW-1 standard. Therefore, leaching and migration of the contaminants within the vadose zone is expected to be minimal, if present.

Transport in Groundwater

The primary contaminants of interest in Site groundwater are VOCs. These compounds have aqueous solubilities ranging from approximately 60 milligrams per liter (mg/L) to 3,500 mg/L under laboratory conditions. VOCs also have high vapor pressures, ranging from approximately 20 millimeters of mercury (mm Hg) to 2,660 mm Hg, compared to other types of organic compounds. Therefore, VOCs are volatile and are likely to be relatively mobile in groundwater.

The VOCs in Site groundwater are presumed to be present in the dissolved aqueous phase. The maximum TCE concentration measured within the Northern Area source area was 120,000 ug/L. No direct evidence of residual TCE has been encountered. The transport of dissolved-phase VOCs in groundwater occurs primarily via advective transport. The predominant groundwater flow direction within the Northern Area is to the west.

In general, Northern Area vertical hydraulic gradients within the shallow portion of the overburden are downward, while vertical gradients within the deep overburden are upward. These gradients converge toward the fine sand and silt and/or gravel portions of the overburden, which are downward-dipping to the west (Figure 5).

Using Site measurements of aquifer hydraulic conductivity and hydraulic gradient, estimates of groundwater seepage velocity were calculated using the following equation and values:

Estimated seepage velocity = $K\ i\ /\ n_e$

Where:

K = average hydraulic conductivity of the apparent Northern Area plume transport pathway, as obtained from slug tests performed on MW-261S, MW-265M, and MW-268M;

i = average hydraulic gradient within the apparent plume transport pathway (MW-261S to MW-265M to MW-268M) from the September 2005 gauging event; and

n_e = estimated effective porosity of the aquifer (Freeze and Cherry, 1979)

Estimated seepage velocity = $(7.71 \times 10^{-4}$ cm/sec)(0.0064) / 0.30 =

1.65×10^{-4} cm/sec (or 0.467 ft/day)

As shown in the above calculation, the average groundwater seepage velocity for the Northern Area of the Site is estimated to be approximately 0.5 feet per day.

As presented in the Phase II Report for RTN #3-13302 (ERM, 2001), the average groundwater seepage velocity for Southern Area of the Site is estimated to be 0.06 feet per day.

Fate in Groundwater

CVOCs may be transformed through biological and abiotic reactions. Parent compounds within the Northern Area of the Site (PCE and TCE) make up the majority of contaminant mass near the source area, but daughter products (cDCE and VC) are dominant within the downgradient extent of the plume. This degradation of parent constituents is evidence of intrinsic biodegradation within the Northern Area of the Site. Additionally, samples have been collected for the analysis of natural attenuation parameters within the Northern Area of the Site and are presented in Table 14. The presence of ethene in groundwater indicates that complete intrinsic biodegradation of CVOCs is occurring under natural Site conditions.

MTBE is a gasoline additive used to oxygenate fuel and aid in combustion, and thus is often found within soil and groundwater where a gasoline release to the environment has occurred (Fetter, 1999). MTBE's relatively high solubility, low sorption to soil, and relatively low susceptibility to biodegradation allow the constituent to persist longer and migrate farther than other gasoline constituents. MTBE may be transported at rates nearly equal to the seepage velocity and is often detected at the leading edge of a plume prior to the detection of other gasoline constituents. In some cases, MTBE is the only compound detected at some distance from a gasoline release. Because MTBE is recalcitrant to both physical and chemical degradation processes, it has migrated from an offs-Ste source into the Former Raytheon Facility property and may be expected to persist in the downgradient transport direction. MTBE is subject to natural attenuation mechanisms, but to a relatively low degree.

Arsenic is a naturally occurring element within the environment, and is ubiquitously detected in soil throughout the Western Area (ERM, 2004a). The availability of arsenic as a dissolved species in groundwater depends on the aqueous and physical geochemistry of an aquifer system. The Western Area is located within and adjacent to wetlands of the Sudbury River. Wetlands, with their naturally high organic content and saturated soils, often display chemically-reduced conditions. Groundwater within the Western Area generally exhibited negative oxidation-reduction potential (ORP) measurements, indicative of chemically reduced conditions.

6.0 RISK CHARACTERIZATION

6.1 OVERVIEW

The purpose of this Risk Characterization was to evaluate the risk of harm to human health, safety, public welfare, and the environment posed by OHM that remain at the Site. In accordance with 310 CMR 40.0000, Subpart I, a Method 1 Risk Characterization was selected because the OHM are limited to soil and groundwater, the OHM are not expected to bioaccumulate in the top two feet of soil, and there are not persistent odors in ambient air. This Risk Characterization includes analytical data collected for the investigation of chemicals of interest associated with RTN 3-22408.

6.2 SITE DESCRIPTION & ACTIVITY & USE ASSUMPTIONS

In accordance with 310 CMR 40.0006, the "Site" is defined as areas where OHM have come to be located. The Site encompasses three distinct areas referred to as the Northern, Southern, and Western Areas.

A Deed Restriction has been filed on an approximately 83-acre portion of the Former Raytheon Facility property. Activities and uses specifically allowed by the Deed Restriction include commercial or industrial uses. Activities and uses specifically prohibited include residential, childcare, daycare, agricultural, groundwater uses (except for remediation purposes) and subsurface activities and/or other activities that could render contaminated media accessible.

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, 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 because:

- adults (e.g., office workers) are potentially present at the Site at high frequency, but low intensity;
- children (e.g., trespassers and visitors) are potentially present at the Site at low frequency and low intensity;
- 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;
- Deed Restriction 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.
- based on potential future uses and the limitations of the Deed Restriction, the soil classification is not expected to change and certain areas of the Site should be classified as S-2 under future conditions while others may have the Deed Restriction removed.

Groundwater Categories

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

Groundwater at the Site is classified as GW-1, GW-2, and GW-3 for current and future uses. GW-1 is applicable to all groundwater at the Site because it is located within a MA DEP-Approved Zone II Wellhead Protection Area for the Baldwin Pond Wellfield. GW-2 would be applicable to portions of the Site where OHM has been detected in groundwater within 30 feet of buildings or structures (existing of potential future) and where the average annual depth to groundwater in that area is less than 15 feet. GW-3 is applicable to all groundwater at the Site.

Consistent with MCP requirements, these soil and groundwater categories are applicable based on physical characteristics of the Site. Accordingly, the associated Method 1 risk-based standards are employed in the risk characterization.

6.3 HAZARD IDENTIFICATION

Hazard identification includes the identification of OHM present at the Site. The data is then reviewed to determine what compounds should be carried forward in the Risk Characterization.

6.3.1 Identification of Oil and/or Hazardous Materials On Site

The identification of OHM on Site considers all available soil and groundwater quality data generated during the course of Phase II investigation activities for RTN 3-22408.

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

Soil

As presented in Table 15, VOCs and metals were detected in Site soil. All detected compounds were evaluated in the Risk Characterization.

Groundwater

Groundwater analytical results are presented in Table 16. Compounds detected in Site groundwater included VOCs, SVOCs and metals. All compounds detected in groundwater were evaluated in the Risk Characterization.

6.3.2 Background Concentrations

The MCP defines background as levels of OHM as those that are "*ubiquitous and consistently present in the environment at and in the vicinity of the site of concern; and attributable to geologic or ecologic conditions, or 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. As presented in Section 4.1, the presence of arsenic in the Western Area of the Site is consistent with background conditions and is eliminated from further consideration.

Background soil concentrations are included for comparison to Site soil concentrations in Table 17. Background concentrations for selected metals were taken from the Department's background soil concentrations for "natural" soils as presented in the *Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil* (MA DEP, May 2002).

6.3.3 *Selection of Compounds of Concern (COCs)*

COCs represent the group of chemicals for which the Method 1 Risk Characterization will be performed. COCs are indicated for soil and groundwater in Tables 17 and 18, respectively. Compounds detected in each of the media that were excluded as COCs are identified in the following sections.

Soil

Summary statistics of soil analytical results are presented in Table 17. Compounds that were excluded from the Risk Characterization are identified as follows:

- Compounds not detected at concentrations above method detection limits;
- SVOCs and metals detected with maximum concentrations below the "natural" soil standards (MA DEP, May 2002). Summary statistics for these compounds are presented in Table 14 and summarized below:

Compound	Maximum Concentration (mg/kg)	Department's "Natural" Background Concentration (mg/kg)
Naphthalene	0.009	0.5
Arsenic	5.1	20
Chromium	8.8	30
Copper	14	40
Lead	6.6	100
Nickel	3.5	20
Zinc	6.7	100

Groundwater

Summary statistics of the analytical results for groundwater are presented in Table 18. Compounds not detected at concentrations above method detection limits were excluded from the Risk Characterization. Arsenic

detected in groundwater in the western Area of the Site was not carried forward in the Risk Characterization. Pursuant to 310 CMR 40.0006, arsenic is consistent with background because it is ubiquitous and consistently present in the environment due to reducing wetlands conditions. Compounds with a low frequency of detection that were not related to a Site release were not carried forward in the Risk Characterization. The following table summarizes these excluded compounds:

Compound	Number of Detections	Number of Samples	Frequency of Observation
1,2,3-trichlorobenzene	1	183	0.5%
1,2-dichlorobenzene	1	398	0.3%
1,4-dichlorobenzene	4	398	1.0%
2-Butanone	1	183	0.5%
Carbon Disulfide	1	183	0.5%
Chloroform	1	398	0.3%
Chlorobenzene	3	398	0.8%
Ethyl Ether	5	183	2.7%
Ethylbenzene	1	227	0.4%
p/m-xylene	3	223	1.3%
Tetrahydrofuran	2	183	1.1%

MTBE was detected at MW-220M (260 ug/L) during one sampling event (December 2004). To date, a total of 10 groundwater samples have been analyzed for MTBE at MW-220M and MTBE was below the method detection limit (1 ug/L) in nine of these samples. The elevated detection of MTBE at MW-220M is not representative of groundwater conditions at this monitoring well and based on data quality criteria was determined to not be representative. Therefore, MTBE at MW-220M was not carried forward in the Risk Characterization, but the presence of MBTE in other monitoring wells was evaluated.

6.4 EXPOSURE ASSESSMENT

This section identifies and describes potential human and environmental receptors that are likely to be present at the Site or in the surrounding environment, and who, as a result, could potentially be exposed to residual impacts on-Site. The identification of human receptors is based on populations of individuals rather than specific individuals.

6.4.1 Identification of Potential Receptors

Potential Human Receptors

Under current conditions, potential human receptors on or in the vicinity of the Site could be facility workers, visitors and trespassers. Under future conditions, potential human receptors on or in the vicinity of the Site could be facility workers, visitors, trespassers and construction/utility workers.

6.4.2 Potential Environmental Receptors

Potential environmental receptors in the vicinity of the Site include plants and animals living in the vicinity of the wetlands in the Northern and Western Area.

Environmental receptors were selected that have 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 considered.

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

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 west edge of the Site in the wetland bordering the Sudbury River.

The primary pathway for Site contamination to impact environmental receptors is through migration and discharge of groundwater to surface water.

6.4.3 Identification of Exposure Points

The point where a receptor could come into contact with the COCs is considered as the exposure point. At this Site, residual impacts to soil and groundwater across the Site were considered to be exposure points. "Hotspots" were identified in groundwater for four COCs: trichloroethene (at WP-515, WP-520, and WP-534), tetrachloroethene (at WP-529 and WP-534), cis-1,2-dichloroethene (at B-230, MW-268M, and WP-529), and toluene (at WP-520).

6.4.4 Identification of Exposure Point Concentrations

Soil

Exposure Point Concentrations (EPCs) for soil COCs were calculated as the average concentrations in each of the three exposure areas (Northern,

Southern, and Western Areas). For conservatism, non-detections were excluded from the EPC calculations. Soil EPCs are presented in Table 19.

Groundwater

Groundwater EPCs were calculated for COCs as the temporal average for monitoring wells or the average over a range of depths at Waterloo Profile location. Therefore, EPCs were calculated for each "hotspot" identified in section 6.4.3. Non-detections were excluded from the EPC calculations for added conservatism. Groundwater EPCs are presented in Table 20.

6.5 RISK CHARACTERIZATION

6.5.1 Comparison to Method 1 Standards

Soil

Soil EPCs were compared to S-2/GW-1, S-2/GW-2, and S-2/GW-3 Method 1 Standards. Table 19 presents the comparison to these applicable standards.

Groundwater

Groundwater EPCs were compared to GW-1, GW-2, and GW-3 Method 1 Standards. Table 20 presents the comparison to these applicable standards.

6.5.2 Risk Summary

As indicated in Table 19, no soil EPCs exceeded the applicable Method 1 Standards. However, several groundwater EPCs exceeded the Method 1 Standards. As shown in Table 20, Method 1 Standards were exceeded for PCE, TCE, cDCE, 1,1-dichloroethene (1,1-DCE), VC, MTBE and toluene. Therefore, a condition of no significant risk to human health, public welfare, and the environment has not been achieved.

6.6 EVALUATION OF RISK OF HARM TO SAFETY

The characterization of risk to safety evaluates whether the Site could pose a threat of physical harm or bodily injury to people. The risk characterization only evaluates safety hazards with respect to releases regulated under the MCP.

Existing Site conditions do not currently, and are not expected to, within the foreseeable future, pose a threat of physical harm or bodily injury to people. There are currently no uncontrolled or rusted drums, containers, open pits, or other dangerous structures on Site. Site conditions do not pose a threat of fire or explosion. There are no uncontained materials on Site that exhibit characteristics of corrosivity, reactivity, ignitability, or are considered infectious materials.

Even though Site conditions do not pose a risk of harm to safety, pursuant to 310 CMR 40.0973(7), applicable Method 1 Standards in a GW-1 area were exceeded at the Site and therefore, a condition of no significant risk of harm to safety has not been achieved.

6.7 RISK CHARACTERIZATION CONCLUSIONS

The Method 1 Risk Characterization was performed to evaluate the risk posed by residual concentrations of OHM in soil and groundwater. The results indicate that a level of no significant risk of harm to human health, safety, public welfare and the environment has not been achieved for Site conditions, activities, and uses since groundwater EPCs were greater than Method 1 Standards.

However, significant risk does not exist for current facility workers, visitors and trespassers or future trespassers and construction/utility workers because groundwater impacts are only present at depth. Risk due to the exceedances detailed in Table 20 are only associated with the potential future exposure of facility workers and visitors to COCs in groundwater via drinking water or vapor intrusion pathways. Currently, these pathways are incomplete based on Site activities and uses and therefore not associated with significant risk.

Based on the findings of significant risk, further remedial response actions are warranted. 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., groundwater is not a current source of drinking water) as the risk to Baldwin Pond Wellfield is minimal.

6.8 LIMITATIONS

Reasonable care has been exercised in performing the analyses in this Risk Characterization. This Risk Characterization was conducted based on available information concerning concentrations of contaminants in soil and groundwater detected during Site investigation activities. The conclusions of the Risk Characterization may need to be reviewed if new or changed information becomes available, such as:

- additional or revised sampling results;
- changes in the zoning or current or future use of the Site; and
- revisions to the Deed Restriction.

7.0 CONCLUSIONS

The following provides a summary of Phase II investigation conclusions:

1) The source, nature and extent of CVOC impacts in the Northern Area have been defined and delineated.

Historical equipment testing activities were conducted in the Northern Area of the Site prior to 1995, when Raytheon ceased operations at the facility. An apparent release of TCE occurred, resulting in impacts to groundwater at concentrations exceeding applicable MCP RCs. An extensive source area investigation identified the location of the release point and defined the horizontal and vertical extents of the source zone. The nature of CVOC impacts in groundwater is defined as primarily TCE and its degradation products, cDCE and VC, with some PCE. The horizontal and vertical extents of CVOC impacts to groundwater have been delineated.

2) Northern Area Source Area Investigations have identified the residual source area.

CVOCs were identified in the Northern Area source area within saturated zone soils to a maximum depth of approximately 25 feet. A dissolved phase CVOC plume continues to emanate from this source area following the initial release, suggesting that CVOCs remain in the source area as residual mass, sorbed to soil, and/or diffused into fine-grained soil horizons.

3) Northern Area CVOC impacts to groundwater pose minimal current and future potential for risk to the Baldwin Pond Wellfield.

Groundwater in the Northern Area flows to the west toward the Sudbury River and associated wetlands, which represent the regional hydrologic discharge boundary. The Northern Area CVOC plume migrates from east to west toward the Sudbury River and associated wetlands. The western boundary of the CVOC plume was delineated to levels below applicable RCs within the wetlands east of the Sudbury River. The northern boundary of the CVOC plume was delineated to levels below applicable RCs approximately 0.5 miles south of the Baldwin Pond Wellfield. The plume is currently in steady state. Thus, future potential risk to the Baldwin Pond Wellfield is considered to be minimal.

4) Release of MTBE from an upgradient property has impacted groundwater quality in the Southern Area.

MTBE was detected at concentrations exceeding RCs in groundwater in the Southern Area. The source of MTBE in the Southern Area was likely a gasoline release at an upgradient gasoline service station located at 365 Boston Post Road (RTN 3-17974). Pursuant to 310 CMR 40.0180, Raytheon may file a Downgradient Property Status Submittal for the Southern Area.

5) Naturally occurring arsenic has impacted groundwater quality in the Western Area.

Arsenic was detected at concentrations exceeding RCs in groundwater in the Western Area. Naturally occurring arsenic present in soil has been mobilized as a result of the natural reducing conditions in the wetlands bordering the Sudbury River. The presence of arsenic in groundwater in the Western Area represents a background condition.

6) Site groundwater poses a condition of "significant risk" under potential future conditions.

OHM in Site groundwater (i.e., PCE, TCE, cDCE, 1,1-DCE, VC, MTBE and toluene) poses a condition of "significant risk" to human health as the Site is located in a Zone II. 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., groundwater is not a current source of drinking water) as the risk to Baldwin Pond Wellfield is minimal.

7) A Phase III 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 VOC impacts to groundwater 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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