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1.0. EXECUTIVE SUMMARY

This report describes the results of a marine ecological risk assessment conducted for portions of the Raymark Industries, Inc. Superfund Site which is located adjacent to the lower Housatonic River in the town of Stratford, CT. On behalf of the U.S. Army Corps of Engineers (U.S. ACE), ENSR contracted Science Applications International Corporation (SAIC) to conduct a site-specific ecological investigation and to prepare an Ecological Risk Assessment (ERA) for a portion of the Raymark Site, known as Areas C-F.

The U.S. EPA's ERA framework and applicable U.S. EPA guidance were used to generate and interpret the data required to complete this risk assessment (U.S. EPA 1997, U.S. EPA 1998). The objectives of this ERA were as follows:

- Assess potential ecological risks to the aquatic environments of Areas C-F from chemical stressors associated with the Raymark Site;
- Develop information sufficient to support risk management decisions regarding site-specific remedial options; and
- Support communication to the public of the nature and extent of potential ecological risks associated with the Raymark site.

The following sections summarize the findings of each step of the assessment, including Problem Formulation, Sampling Summary, Site Characterization, Exposure and Ecological Effects Assessments, Characterization of Ecological Risks, and Risk Summary and Conclusions.

1.1. Problem Formulation

For the ERA, Problem Formulation involved determining the nature and extent of contamination of aquatic wetland, marsh, and estuarine (intertidal) media associated with Raymark sources. Specifically, this activity involved identification of contaminated media, identification of contaminants of concern (CoCs), evaluation of the spatial extent of contamination, identification of the ecological receptors potentially at risk from CoCs, and identification of appropriate assessment and measurement endpoints.

The site location is shown in Figure 1.0-1 (note: same as Figure 2.0-1). For purposes of this ERA, the study area includes the wetlands South of the Boat Club (Area C), the marshes north and south of the Boat Launch Area (Area D), the Elm Street Marsh (Area E) and Selby Pond (Area F). The environmental setting of the entire study area was once an extensive salt meadow marsh bordering the Housatonic River. All the areas have been physically altered by development. Areas C and D are directly located on the Housatonic River, and large amounts of fill have been disposed of in the wetlands to create the Housatonic Boat Club (Area C) and the Beacon Point Boat Launch Area (Area D). Area E was presumably part of a larger meadow marsh with a historical connection between Area E and the Housatonic River. Although similarly isolated, Area F has a more natural tidal marsh community dominated by *Spartina alterniflora* and *S. patens* with a hydrologic connection with Ferry Creek.

1.2. Receptors of Concern

Some 53 species of fish and 11 invertebrate species may be expected to use the Housatonic River near Areas C, and D for spawning, adult forage, or as a nursery ground for juveniles. Recreational species includes Atlantic menhaden, black sea bass, bluefish, four species of flounder, American eel, striped bass, white perch, and blue crab. An important commercial larval bed for eastern oyster cultivation in the Housatonic River is present near the mouth of Ferry Creek. The American eel are caught in Area F.

These ecological receptors are exposed to contaminants through several routes. Aquatic organisms can take up toxicants directly from contact with water or sediments. Terrestrial organisms can also take up contaminants from direct contact with contaminated soil in both aquatic and terrestrial systems. Animals can ingest contaminants with surface water, soil, or food.

1.3. Sampling Summary

Sampling was needed to acquire updated chemistry and toxicity data for surficial sediments in the area adjacent to the site, and to gather biological data to assess the potential impact to receptors. A target analyte list was developed in recognition of a number of potential chemical stressors associated with past disposal practices and includes both metals (arsenic, nickel, zinc, copper, cadmium, chromium, lead, and mercury) and organic compounds (PAHs, PCBs, organochlorine pesticides (OCPs)) and dioxins.

A total of 16 stations for the four areas were selected. The stations were selected to confirm previous results of high concentrations of contaminants, to fill data gaps from prior studies and to characterize gradients in contaminant concentrations. Reference data from the Great Meadow station GM-08 was utilized from a prior study. This area is approximately 5 km south of Raymark study area, and does not have a direct hydrographic connection with the Housatonic River system. The stations were sampled for sediment organic and inorganic chemical analysis, porewater analysis, and toxicity studies. Natural populations of ribbed mussels were also collected at a selected subset of stations to allow characterization of contaminant bioaccumulation and trophic transfer effects. Fish samples were planned but were unavailable.

1.4. Exposure Assessment

Exposure Assessments included quantification or estimation of the concentrations of CoCs in environmental media in the exposure pathways from contaminant sources to ecological receptors. Several exposure pathways, which allow contaminant sources associated with historic activities at Raymark to impact biota, were identified. These include contaminant exposure to and bioaccumulation from water, sediments, and porewater through partitioning across organism cell membranes, incidental contact, ingestion of sediments by deposit-feeding invertebrates, and/or consumption of contaminated prey.

1.5. Ecological Effects Assessment

The Ecological Effects Assessment involved a combination of exercises to predict the occurrence of adverse ecological impact. Ecological effects were quantified by determining the relationships between exposure patterns and resulting responses of ecological systems, as determined from the measurement endpoints identified during Problem Formulation. Site-specific evaluations of toxicity were conducted for bulk surface sediments using amphipod mortality tests. Finally, food web modeling was performed to predict effects to aquatic mammal (raccoon) avian predators (black-crowned night heron).

1.6. Risk Characterization

Risk characterization is an integration of the results of the Exposure and Ecological Effects Assessments. A weight of evidence approach was utilized in this ERA, which involved analysis of contaminant concentrations *versus* observations of adverse effects, analysis of contaminant bioaccumulation, comparisons of toxicity evaluations with observed ecological effects, comparisons of exposure point concentrations with established standards and criteria for offshore media, comparisons of exposure point concentrations with published toxicity information and qualitative comparisons of apparent adverse impacts with conditions at reference stations. The results of these analyses were summarized together with information obtained during each study to characterize potential ecological risks associated with the Raymark study areas.

Risk summary Table 1.6-1 presents summary rankings for chemical exposure (Exposure Ranking) and biological effects (Effects Ranking). The application of the ranking criteria results in four tiers of adverse exposure or effects probability; baseline ("-") , low ("+"), intermediate ("++") and high ("+++") based on the evaluation described above. This provides a comparable and consistent approach across various weights of evidence so as to minimize the chance that a particular endpoint would transfer undue weight in the final synthesis of potential risks.

1.6.1. Exposure-Based Weight of Evidence

Exposure-based weights of evidence include assessment of chemical exposure in bedded sediment and organism tissues (bioconcentration).

Bedded Sediment Exposure. Chemical concentrations of CoCs measured in sediments and porewater are compared against benchmarks to predict potential adverse effects on target species from exposure to contaminants in surface sediments. Several stations have contaminant concentrations which exceed sediment and water benchmarks to an extent suggesting intermediate to high chemical exposure (Table 1.6-1). These exceedences were primarily due to PCBs and PAHs in sediment. Exceedences of more conservative criteria continued to occur for copper and zinc throughout the study area, including the reference station. The weight of evidence for indicators of chemical exposure in bedded sediments suggest a high probability of adverse exposure exists for Station D-3, intermediate exposure for five stations (D-5, E-1, E-2, E-3, F-2, F-3) and the reference location. Low or baseline exposure was observed throughout the remainder of the study area.

Bioconcentration. Bioconcentration of CoCs in site receptors was assessed by calculation of a ratio of the contaminant residue found in a receptor organism at the site to that found at the reference location. The metric is intended to predict which CoCs and receptors are chemically enriched at the site relative to regional background conditions. Hence, it is principally an indicator of chemical exposure but does not predict effects. Stations were ranked according to overall exposure and these rankings are presented in Table 1.6-1. Low exposures ("L") were apparent in Area C stations. Four stations in Area D (D-1, D-2, D-4, and D-6) also had overall low exposures to CoCs, as well as Station E-4. High chemical exposures ("H") were apparent for two stations in the Raymark study area, Station D-3 and D-5. All other stations had intermediate ("I") exposures for CoCs.

1.6.2. Effects-Based Weight of Evidence Summary

Sediment Toxicity. In this ERA, the sediment bioassays with the amphipod, *Ampelisca* were used to assess possible impacts from in-place sediments. Laboratory toxicity results generally indicated some degree of sediment toxicity to amphipods throughout the Raymark study site. The overall station-specific laboratory toxicity rankings are summarized in Table 1.6-1. High toxicity was observed at two stations (C-3 and D-6), while intermediate toxicity occurred at six stations (C-1, C-2, D-2, D-3, E-4, and F-1). Eight stations (D-1, D-4, D-5, E-1, E-2, E-3, F-3) had low toxicity to amphipods (including the reference), and one remaining station was non-toxic to amphipods (F-2). As noted in Section 4, exposure response relationships explaining the observed toxicity were not readily evident.

Tissue Residue Effects. Possible impacts of CoC residues on target species were assessed separately through Tissue Screening Concentration (TSC) and Critical

Body Residue (CBR) Hazard Quotients. A summary of these tissue residue-based effects results is presented in Table 1.6-1. The tissue residue effects rankings were baseline for all stations.

Trophic Transfer Effects. Trophic transfer effects parameters, summarized in Table 1.6-1 include avian and mammalian predator effects. The food web modeling for avian and mammalian aquatic predators assumed that Black-crowned night herons and raccoons were feeding maximally on the most contaminated of prey items available at a given station. Despite the conservative assumptions employed, none of the stations had a ranking greater than low effects. Low effects were observed at stations D-5, E-1, F-2, F-3 and reference due to trophic transfer in the avian predator of Total PCBs and DDD, Total PCBs and mercury, chromium, lead, zinc, and DDD, zinc, DDD, and DDE, and chromium, mercury, and zinc, respectively.

Ecological Effects Ranking. Overall effects to biological receptors from CoCs are summarized in Table 1.6-1. None of the stations had a baseline (B) effect rankings. Seven stations in the Raymark study area had a low ("L") effect ranking (Station D-1, D-4, D-5, E-1, E-2, E-3, and F-3). Overall high ("H") effects were observed at Stations C-3 and D-6. The eight remaining stations had overall intermediate ("I") effects.

1.6.3. Synthesis of Exposure and Effects Weights of Evidence

Discussion of each of the weights of evidence and applicable exposure-response relationships has been presented in the previous sections. The focus of this section is to elucidate concordance among exposure-based and effects-based weights of evidence, in order to characterize overall potential risk for the Raymark study area.

High Risk Probability Stations. In the present investigation, only Station D-3 is categorized as a high risk station, given a high exposure and an intermediate effects rankings. In addition, some support for exposure-response relationships were observed given that toxicity was observed and PCB concentrations in sediment were well above ER-M thresholds.

Intermediate Risk Probability Stations. Stations which the WoE demonstrate intermediate risks include Stations C-1, C-2, C-3, D-2, D-5, D-6, E-1 to E-4, F-1 to F-3, and the reference. Multiple exposure- or effects-based weights of evidence were observed in the data, resulting in an intermediate Exposure and/or Effects rankings. However, quantitative exposure-response relationships were found to be lacking.

Low Risk Probability Stations. A low risk probability was indicated for the remaining Raymark stations (D-1 and D-4). Minimal impacts are suggested by the majority of exposure and effects-based weights of evidence, and no exposure response relationships were evident.

Baseline Risk Probability Stations. Baseline risk was not assigned for any of the Raymark stations.

1.6.4. Uncertainty in Risk Estimation

The conclusions drawn in this assessment are based on a database of sediment chemistry, tissue residues and toxicity evaluations, with broad spatial coverage. The presentation of the data provides multiple weights of evidence for assessment of impacts in the Raymark areas, hence there would appear a high probability of accurately concluding the occurrence of potential risk where indicated. The present study was conducted under a comprehensive Work/Quality Assurance Plan, and data validation has been performed and found to meet the study requirements. Potential errors in the study design and protocols were minimized through peer review and evaluation. Data collection activities were reasonably complete. Thus, it is concluded that the overall uncertainty with regard to the accuracy of potential risk estimations has been satisfactorily minimized.

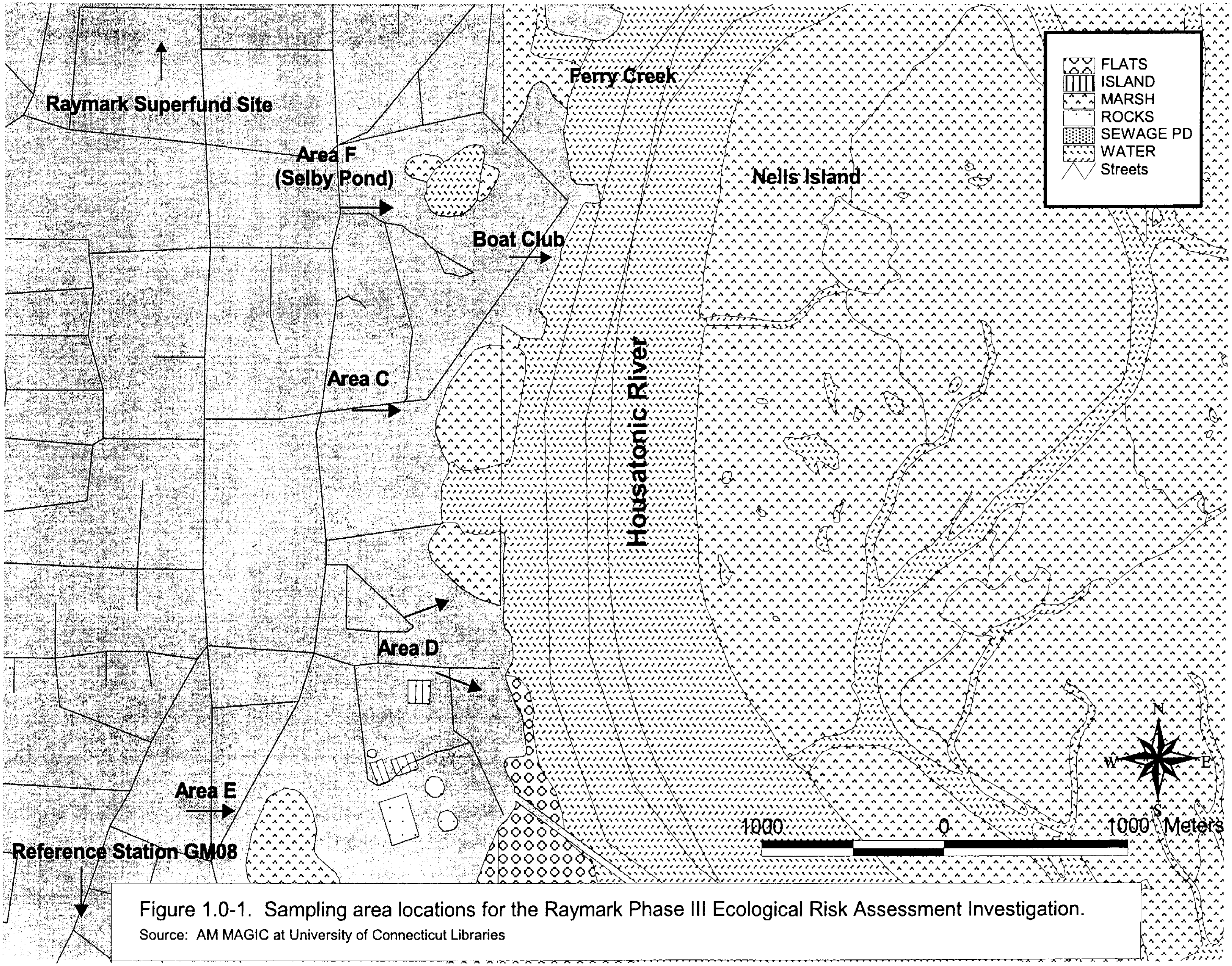

Figure 1.0-1. Sampling area locations for the Raymark Phase III Ecological Risk Assessment Investigation.
Source: AM MAGIC at University of Connecticut Libraries

Table 1.6-1. Overall Summary of Exposure and Effects-based Weights of Evidence and Characterization of for the Raymark Phase III Ecological Risk Assessment Investigation.

WEIGHT OF EVIDENCE SUMMARY								
	CHEMICAL EXPOSURE			BIOLOGICAL EFFECTS				RISK PROBABILITY
Station	Bedded Sediment[1]	Bioconcentration[2]	Ranking[6]	Sediment Toxicity[3]	Tissue Residue Effects[4]	Trophic Transfer Effects[5]	Ranking[6]	Ranking[7]
C-1	-	+	L	++	-	-	I	Intermediate
C-2	-	+	L	++	-	-	I	Intermediate
C-3	+	+	L	+++	-	-	H	Intermediate
D-1	-	+	L	+	-	-	L	Low
D-2	-	+	L	++	-	-	I	Intermediate
D-3	+++	+	H	++	-	-	I	High
D-4	-	+	L	+	-	-	L	Low
D-5	++	+++	H	+	-	+	L	Intermediate
D-6	-	+	L	+++	-	-	H	Intermediate
E-1	++	++	I	+	+	+	L	Intermediate
E-2	++	+	I	+	-	-	L	Intermediate
E-3	++	++	I	+	-	-	L	Intermediate
E-4	+	+	L	++	-	-	I	Intermediate
F-1	+	++	I	++	-	-	I	Intermediate
F-2	++	++	I	-	++	+	I	Intermediate
F-3	++	++	I	+	+	+	L	Intermediate
Reference	++		I	+	++	+	I	Intermediate

1 - Bedded Sediment Exposure Ranking based on sediment Hazard Quotients (HQs), SEM:AVS, and porewater HQs; see Table 6.1-5.
2 - Bioconcentration Ranking based on Tissue Concentration Ratios for ribbed mussels; see Table 6.2-1.
3 - Sediment Toxicity Risk Ranking based on sediment toxicity tests: see Table 5.2-1.
4 - Tissue-based Risk Ranking: Based on risks of CoCs in tissues to aquatic receptors; See Table 6.2-6.
5 - Trophic Transfer Effects Ranking: Based on results of avian and mammalian predator exposures; see Table 6.3-4.
6 - Exposure/Effects (E/E) Ranking: B = Baseline Risk; L = Low Risk Probability; I = Intermediate Risk Probability; H = High Risk Probability. Rankings for stations are equal to the maximum of individual WoE ranking.
7 - Overall Risk Ranking:
Baseline = Baseline (B) ranking for E/E WoE summaries;
Low = No greater than Low (L) ranking for E/E WoE summaries, or Intermediate (I) ranking for one WoE summary and no greater than Low (L) ranking for the other WoE summary;
Intermediate = No greater than Intermediate (I) ranking for E/E WoE summaries, or High (H) ranking for one WoE and Low (L) ranking for the other WoE summary; and
High = High (H) ranking for both WoE summaries or High (H) ranking for one WoE and Intermediate (I) for the other WoE summary.

2.0. INTRODUCTION

This report describes the results of a marine ecological risk assessment conducted for portions of the Raymark Industries, Inc. Superfund Site which is located adjacent to the lower Housatonic River in the town of Stratford, CT. The site location is shown in Figure 2.0-1. Raymark site facts pertinent to need for the ERA investigation include:

- The Raymark Industries, Inc. (1919-1989) site encompasses a 34 acre industrial property located at 75 East Main Street in Stratford, Connecticut where the manufacturing of brakes, clutch parts, and other friction products took place;
- Raymark disposed of its waste as fill at 75 East Main Street as well as 46 residential properties, numerous commercial and municipal properties, and several wetland areas in close proximity to the Housatonic River;
- Prior onshore investigations indicated that elevated concentrations of heavy metals, asbestos, dioxins, PCBs, semi-VOCs, and VOCs were present in surficial soil; and
- Screening level (Phase I) and baseline (Phase II) risk assessments conducted for Ferry Creek (Areas A-B) found unacceptable risk (NOAA, 1998).

The Raymark site must comply with requirements specified under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Contingency Plan (NCP), and Connecticut State Statutes. The Federal regulations mandate assessment of the risk of hazardous waste disposal sites on human health and the environment, and identification of appropriate cleanup levels. On behalf of the U.S. Army Corps of Engineers (U.S. ACE), ENSR contracted Science Applications International Corporation (SAIC) to conduct a site-specific ecological investigation and to prepare an Ecological Risk Assessment (ERA) for a portion of the Raymark Site, known as Areas C-F. The purpose of this report is to communicate the results of the assessment of potential ecological risks to habitats and biota posed by the contaminants associated with the Raymark site.

2.1. Background

The ERA described in this report has been prepared following the Work Plan for Ecological Risk Characterization of Areas C-F, Raymark Superfund Site, Ferry Creek, Stratford, CT (SAIC, 1999a), referred to herein as the "Work Plan". This assessment focuses on the ecological impacts of Raymark-related contaminants on wetland, intertidal, marsh and freshwater habitats of the Raymark Site. This assessment does not consider potential human health risks associated with the site. Furthermore, this assessment only reflects currently existing conditions and levels of activity at the site, and does not address altered risks under potential future use scenarios involving fundamentally different conditions or activities at the site.

The Work Plan provides a description of the analytical methodologies utilized to conduct the ERA. The scope of this report is to present the results of the ERA and includes an overview of the sampling and analysis activities conducted in support of the ERA.

2.2. Report Organization

This ERA report follows the organization suggested in Eco Update (U.S. EPA, 1991a) with appropriate elements from U.S. EPA (1997a, 1998a), and EPA Region I Supplemental Risk Assessment Guidance for the Superfund Program (U.S. EPA, 1989a) and Risk Assessment Guidance for Superfund, Volume II Environmental Evaluation Manual (U.S. EPA, 1989b). These guidance documents recommend a "weight of evidence" approach to assess potential ecological risks. The approach should be based on evaluation of contaminant analytical data relative to environmental benchmarks, direct field observations, selected field and laboratory studies from the scientific literature, potential for bioaccumulation of chemicals and food web exposure modeling. Evaluation of potential risks is based on the preponderance of data; locations where a greater number of endpoints suggest adverse exposure and/or effects are presumed to indicate a greater probability of adverse risk. No preferential priority or weight is given to any particular indicator.

To assure that the required activities were conducted to meet these objectives, the ERA was conducted following general U.S. EPA guidance (U.S. EPA, 1989c, U.S. EPA, 1992a), and input provided by U.S. EPA Region I, the State of Connecticut, and Natural Resource Trustees, representatives of which jointly constitute the Raymark Ecorisk Advisory Group.

The elements of this ERA report include:

- Problem Formulation. This involved determining the nature and extent of contamination of aquatic wetland, marsh and estuarine (intertidal) associated with Raymark sources. Specifically, this activity involved identification of contaminated media, identification of contaminants of concern (CoCs), evaluation of the spatial extent of contamination, identification of the ecological receptors potentially at risk from CoCs, and identification of appropriate assessment and measurement endpoints. The information generated during the Problem Formulation was integrated into a conceptual model which identified the possible exposure scenarios and mechanisms of ecological impact associated with the CoCs. This evaluation addresses only current conditions and levels of activity at the site, and does not address potential future use scenarios involving fundamentally different conditions or activities at the site.

- <u>Exposure and Ecological Effects Assessments</u>. These assessments included collection of information to quantify chemical exposures and observed or predicted ecological effects resulting from exposure. The Exposure Assessment involved quantification or estimation of the concentrations of CoCs in environmental media in the exposure pathways from source to ecological receptors. The Ecological Effects Assessment involved a combination of toxicological literature review, *in situ* characterization of receptor species, toxicity evaluations of exposure media, and modeling exercises to predict the occurrence of adverse ecological impact. Site-specific Exposure and Ecological Effects Assessment activities were determined based on the conceptual model developed during Problem Formulation.

- <u>Characterization of Potential Ecological Risks</u>. Risk characterization is an integration of the results of the Exposure and Ecological Effects Assessments. This represents a weight of evidence approach involving analysis of CoC concentrations versus observations of adverse effects, analysis of CoC bioaccumulation, comparisons of toxicity evaluations with observed ecological effects, comparisons of exposure point concentrations with established standards and criteria for offshore media, comparisons of exposure point concentrations with published information regarding the toxicity of CoCs, and qualitative comparisons of apparent adverse impacts with conditions at reference stations. The results of these analyses are summarized together with information obtained during each study to characterize potential ecological risks associated with Raymark.

- <u>Communication of Study Results</u>. Communication of the study objectives, methods, and findings of the ERA is provided in a format which supports informed risk management decisions for the site. Results of weights of evidence are assembled into a summary risk table in order to further communicate potential risks in support of risk management decisions.

Based on these guidelines, this ERA presents background information integrated with contemporary data to develop the Problem Formulation (Section 3); Exposure Assessment (Section 4); Ecological Effects Assessments (Section 5); Risk Characterization (Section 6); Summary and Conclusions (Section 7); References (Section 8); and Appendices, including raw data for Chemistry Exposure Assessments (Appendix A); Effects Assessments (Appendix B); QA/QC and Data Validation Summary Information (Appendix C); and Ecological Risk Calculations (Appendix D).

2.3. Purpose, Scope, and Objectives

The purpose of this report is to describe information collected for evaluation of potential risks from contaminants associated with Raymark to ecological receptors at the site. The U.S. EPA's ERA Framework (1992a) and applicable EPA Region I guidance were used to generate and interpret the data required to complete this risk assessment. The objectives of this ERA are as follows:

- Assess potential ecological risks to the aquatic environments of Areas C-F from chemical stressors associated with the Raymark Site;
- Develop information sufficient to support risk management decisions regarding site-specific remedial options; and
- Support communication to the public of the nature and extent of potential ecological risks associated with the Raymark site.

This ERA builds upon and incorporates findings of previous studies at Raymark, and specifically addresses three data gaps remaining from these earlier studies. These data gaps are as follows:

- Need to conduct studies on organic and metal contaminants in sediment and porewater in conjunction with toxicity studies to assess the potential toxic effect of contaminated sediments on the biota;
- Need to conduct contaminant studies of receptors to assess the potential impact of contaminated sediments on individual species and the benthic community in the Raymark Study Area;
- Need for trophic transfer modeling to assess the pathways of contaminant movement up the food chain to semi-aquatic mammals and aquatic birds.

The following sections present and discuss the data requirements and data products of the ERA, including Problem Formulation, Exposure and Ecological Effects Assessments, and Characterization of Ecological Risks.

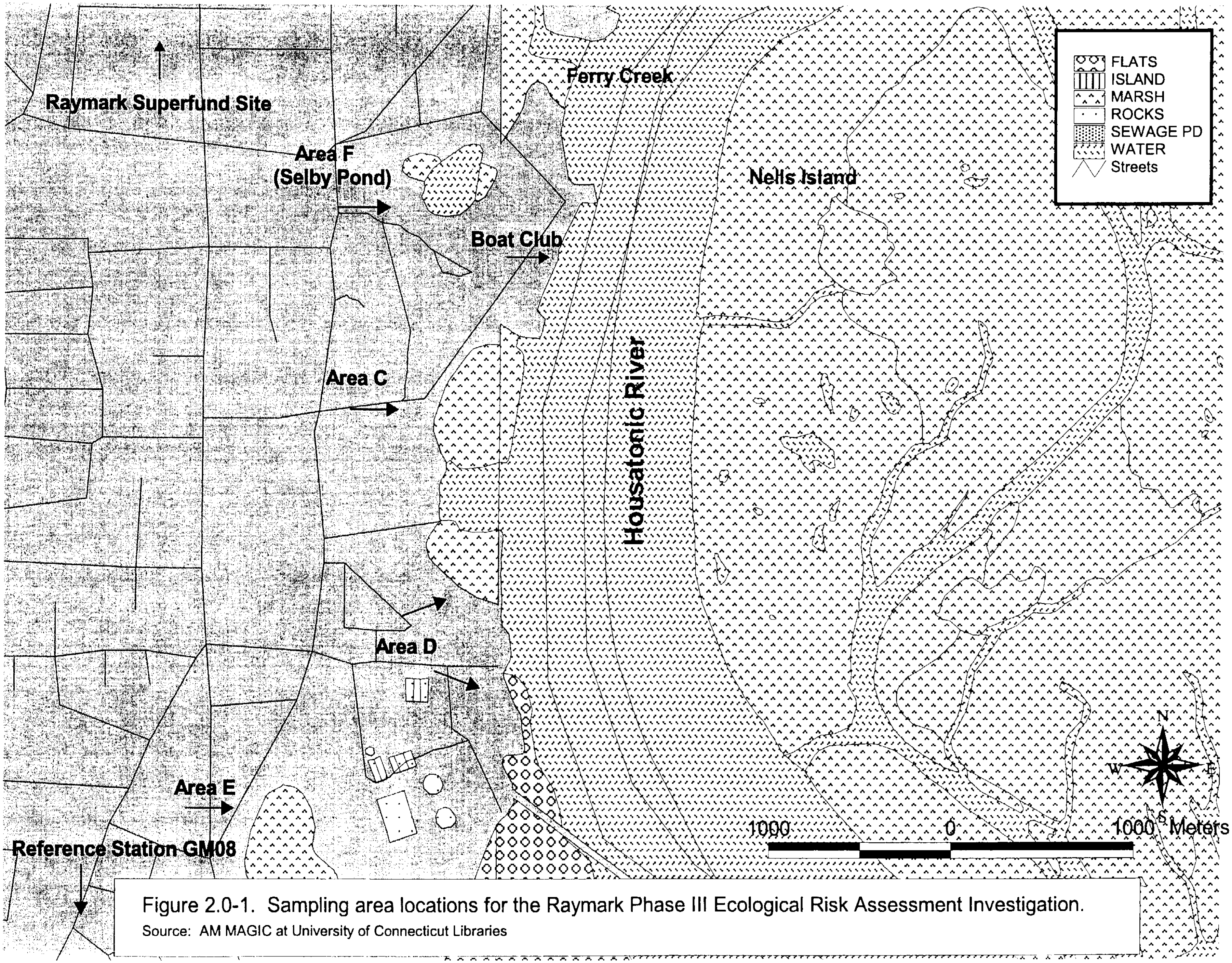

Figure 2.0-1. Sampling area locations for the Raymark Phase III Ecological Risk Assessment Investigation.
Source: AM MAGIC at University of Connecticut Libraries

3.0. PROBLEM FORMULATION

Five principal activities have been conducted in support of the Problem Formulation component for the Raymark study area ERA:

- Characterization of the site by determination of the nature and extent of contamination of aquatic media associated with Raymark study area;
- Determination of appropriate measurement endpoints;
- Identification of Contaminants of Concern (CoCs);
- Identification of the ecological receptors potentially at risk from site-related CoCs; and
- Development of a site-specific conceptual model of potential aquatic ecological risks associated with the Raymark study area.

A summary of sampling and analysis activities related to the ERA effort is also provided (Section 3.6).

3.1. Site Characterization

The primary objectives of the site characterization are to identify the types and spatial extent of habitats that are present in the aquatic environment affected by Raymark activities, identify the species and biological communities that may be exposed to site-related contaminants, and identify contaminants that may pose a threat to these habitats and species. In Section 3.1.1, the general characteristics and background of the study area are described. Section 3.1.2 discusses the habitats and potentially exposed receptors groups within the Raymark C-F study areas.

3.1.1. Study Area Characteristics

For purposes of this ERA, the study area includes the wetlands South of the Boat Club (Area C), the marshes north and south of the Boat Launch Area (Area D), the Elm Street Marsh (Area E) and Selby Pond (Area F). The environmental setting of the entire study area was once an extensive salt meadow marsh bordering the Housatonic River. All the areas have been physically altered by development. Areas C and D are directly located on the Housatonic River, and large amounts of fill have been disposed of in the wetlands to create the Housatonic Boat Club (Area C) and the Beacon Point Boat Launch Area (Area D).

In Area C, fill is seen around the upland boundary of the marsh and Phragmites is a minor component of the marsh community. The marsh is dominated by *Spartina* *alterniflora*, as may be expected under natural conditions in a low marsh. Area D is similar to area C, except that filling along much of the upland boundary of the marsh is not as apparent, a large parking lot divides the marsh into two sections, and a drainage channel from the Stratford publicly-owned treatment works (POTW) runs through the Area D marsh. The upland vegetation in Areas C and D has been displaced by roads, parking lots, and buildings.

Area E was presumably part of a larger meadow marsh. The historical connection between Area E and the Housatonic River is not clear, nut it may have been through a tidal creek flowing from Area D. Most of Area E marshland is a *Phragmites* monoculture. A 600-foot culvert forms the hydrologic connection between Areas E and D, providing some tidal exchange. Although similarly isolated, Area F has a more natural tidal marsh community dominated by *Spartina alterniflora* and *S. patens*. This is most likely due to a hydrologic connection with Ferry Creek that allows sufficient tidal flow to maintain this community. Steep banks along much of the upland boundary indicate probable fill locations around Area F. The upland vegetation consists of mowed grasses and small wood lots in Area F.

3.1.2. Habitats and Potentially Exposed Receptor Groups

Some 53 species of fish and 11 invertebrate species may be expected to use the Housatonic River near Areas B, C, and D for spawning, adult forage, or as a nursery ground for juveniles (NOAA, 1998). Recreational species includes Atlantic menhaden, black sea bass, bluefish, four species of flounder, American eel, striped bass, white perch, and blue crab. The American eel and the eastern oyster are caught commercially. An important commercial larval bed for eastern oyster cultivation in the Housatonic River is present near the mouth of Ferry Creek.

Ecological receptors are exposed to contaminates through several routes. Aquatic organisms can take up toxicants directly from contact with water or sediments. Terrestrial organisms can also take up contaminants from direct contact with contaminated soil in both aquatic and terrestrial systems. Animals can ingest contaminants with surface water, soil, or food. Inhalation and uptake through foliage are also potential routes of exposure for terrestrial life, but they were not considered in the ecological risk assessment, which focused on aquatic pathways and receptors (NOAA, 1998).

3.2. Assessment and Measurement Endpoints

A target analyte list was developed in response to the regulatory requirements of the Remedial Investigation/Feasibility Study (RI/FS) for the Raymark Superfund Site, and through recognition of a number of potential chemical stressors associated with past disposal practices (Table 3.2-1). The list was based on those chemical contaminants detected during previous offshore and on-shore investigations (*e.g.,* TetraTech, 1998), and includes both metals (arsenic, nickel, zinc, copper, cadmium, chromium, lead, and mercury) and organic compounds (PAHs, PCBs, organochlorine pesticides (OCPs), dioxins). The list reflects current understanding of those chemicals which are both of toxicological importance and persistent in aquatic systems. It encompasses selected potentially toxic chemicals which may serve as indicators of human activity (although for different uses) and whose discharge into the environment has been enhanced through industrialization (NOAA, 1991).

In keeping with the requirements of the RI/FS process, and based on the potential ecological effects of the chemical stressors (identified above), a suite of assessment and measurement endpoints were identified as important in the ecological risk assessment. As indicated in Table 3.2-2, these include the vitality of pelagic, epibenthic, and infaunal communities, as represented by common and/or natural resource species in the vicinity of the Housatonic River. Target receptors chosen to be representative of these habitats/trophic modes are discussed in Section 3.4.

Exposure point measurements employed as indicators of the assessment endpoints are presented in Table 3.2-3. The exposure point measurements were selected based on their relevance to:

- The assessment endpoint and receptors of concern, their relevance to expected modes of action, and effects of CoCs;
- Determination of adverse ecological effects;
- Availability of practical methods for their evaluation; and
- Their usefulness in extrapolating to other endpoints.

Most of these measurement endpoints have been used in other studies, and have proven to be informative indicators of ecological status in aquatic and estuarine systems with respect to the stressors identified as important in this assessment. Many serve a dual purpose in that they provide information relevant to two or more assessment endpoints.

In addition to the measurement endpoints used to evaluate the occurrence of, or potential for, adverse ecological effects, exposure point measurements were employed to evaluate exposure conditions. As shown in Table 3.2-3, these exposure point measurements include chemistry measurements made in environmental media (porewater, sediment, and biota), as well as geochemical attributes of exposure media which may influence the availability of contaminants to receptors.

These measurement endpoints will be used as the weight-of-evidence in the exposure assessment component of the risk characterization summary. The protocols and methods used to evaluate measurement endpoints and exposure point measurements are discussed further in Section 4.0.

3.3. Contaminants of Concern

Proposed Contaminants of Concern (CoCs) have been identified for this investigation using a rationale which links the source (Raymark waste) to potential aquatic receptors in Areas C-F through plausible exposure pathways. The selection process involves sequential evaluation of target analyte concentrations, first considering the frequency of detection, then elevation relative to minimum effects benchmarks. For analytes lacking benchmarks, site concentrations were compared against reference concentrations.

Benchmarks are numerical criteria or guidelines which establish chemical concentrations presumed to be protective of biological systems. For derivation of CoCs in this ERA, site sediment concentrations are of primary consideration as sediments are the major reservoir for CoC constituents. Available (*i.e.,* nationally recognized) benchmarks for sediments include the Apparent Effects Threshold (AET; U.S. EPA, 1989d), Effects Range-Low and Effects Range-Median (Long and Morgan, 1990, Long *et al.*, 1995), and Equilibrium Partitioning-based Aquatic Life criteria (EqP-AL; U.S. EPA 1989e, Adams *et al.*, 1992). The AET approach uses data from matched chemistry and biological effects measures, and is the concentration of a selected chemical above which statistically significant biological effects are expected to occur (U.S. EPA, 1989d). Effects Range-Low (ER-L) and Effects Range-Median (ER-M) are benchmarks representing the 10th and 50th percentiles, respectively, of ranked chemical concentrations (predicted or measured) at which biological effects were observed. The Equilibrium Criteria-Aquatic Life Approach (Adams *et al.*, 1992) predicts effects in porewater for non-ionic organic contaminants based on the water quality benchmark, accounting for partitioning between dissolved and particulate phases. For three of the chemicals measured in site sediments for this ERA, the EPA has promulgated criteria known as Sediment Quality Criteria (SQC; DiToro *et al.*, 1991). Each benchmark has advantages and disadvantages as well as differing degrees of applicability for various chemical groups.

For this ERA, the lowest of the matrix-specific benchmarks was used as the screening value for each compound (Table 3.3-1). In most cases, the NOAA ER-L was the minimum benchmark value. For chemical constituents lacking benchmarks, sediment concentrations measured at reference locations were used as the basis of comparison.

Results of the screening process for the development of the aquatic sediment CoC list are summarized in Table 3.3-2. Frequency of detection was calculated as the percentage of total site samples analyzed which had detected concentrations. The range of concentrations reported for site data excludes non-detected values. One-half of the Sample Quantitation Limit was substituted for non-detected values calculating the mean concentration of each compound for both the site and reference stations. The 95% upper confidence limit was calculated according to standard statistical procedures (Snedecor and Cochran, 1980), assuming a one-tailed distribution (*i.e.,* only data exceeding the upper 95% confidence limit are of interest). Where the 95% UCL was greater than the site maximum concentration, the maximum concentration was used to screen against benchmark or reference data. Lastly, information on bioaccumulation persistence and toxicity was also considered in the selection of CoCs.

For metals, all analytes with the exception of arsenic and silver had maximum concentrations in bulk sediments which exceeded reference. All PAH analytes except 2-methylnaphthalene, biphenyl, naphthalene, were found to exceed either benchmarks or reference area concentrations. For PCBs, 23of 27congeners were detected at a frequency >5%, In contrast, only four of 24 pesticides were similarly detected; analytes retained as CoCs include o,p'-DDE, and p,p'-DDD, -DDE and -DDT. It should be noted that this list of CoCs is conservative in that the screening procedure involved maximum contaminant concentrations and conservative benchmark concentrations. Final consideration of CoCs for offshore exposure media will be made following completion of the Exposure Assessment (see Section 4.0 of this report).

3.4. Receptors of Concern

Identification of ecological systems/species/receptors of concern (hereafter collectively termed "receptors of concern") involved evaluations of the importance of each potential receptor (or "candidate") to the ecology of the Raymark study area, its sensitivity to stressors associated with the site, and its aesthetic, recreational, and commercial importance as a natural resource. The site characterization for Raymark study area identified a number of aquatic systems and habitat types (Section 3.1.3). The nature of chemical stressors originating from Raymark study area operations suggests that several ecological receptors may be potentially at risk, including:

- Nearshore habitats directly adjacent to Raymark study area areas;
- Pelagic communities, including plankton and fish;
- Infaunal benthic communities in sediment depositional areas;
- Soft- and hard-bottom epibenthic communities; and
- Commercially, recreational, and/or aesthetically important natural resource species.

The aquatic systems and habitats of Raymark study area include primarily subtidal environments, sand- or silt- bottom, with some eelgrass covering the intertidal environments. The identification of aquatic systems and habitats potentially at risk from Raymark study area contaminants provides a natural progression to the selection of target receptors of concern for this ecological risk assessment (Table 3.4-1). These target receptors, and the rationale for their selection, include:

- Ribbed mussel (*Geukensia demissus*), oyster (*Crassostrea virginica*): These species are locally abundant and ecologically important filter-feeding bivalves found in intertidal and subtidal habitats. It is an important food source for birds, fish, shellfish and aquatic mammals. Mussels and oysters are surrogates for epibenthic species in the intertidal environment, where they are potentially exposed to water-borne and particulate-bound contaminants.

- Mummichogs (*Fundulus heteroclitus)*: These species are locally abundant and ecologically important estuarine fish which feed opportunistically upon both animals and plants, and have limited home range due to territorial behaviors. When abundant, they may be an important food source for birds and other fish, and are a surrogate for other pelagic fish species potentially exposed to water-borne and bulk sediment contaminants.

- Benthic community: The benthic community (including sponges, mollusks, segmented worms, arthropods (including crustaceans), starfish, and chordates (tunicates and fish)) is an ecologically important, potentially rich assemblage of species with numerous life histories and feeding strategies. It is an important food source for birds, fish, and benthic and epibenthic invertebrates. The benthic community is potentially exposed to contaminants in bulk sediments, pore water, and the water column.

Many of these receptors are important resource species for the Housatonic River, but also can be considered surrogate receptors for larger groups of species. For instance, the oyster is an important commercial species for Connecticut, as well as an indicator species for infaunal bivalves in general. However, as discussed in a later section, not all of these species occurred at all of the sampling stations.

Stressors introduced to the bay may indirectly affect avian receptors. For example, bivalves and fish contaminated with chemicals may be consumed by shorebirds, resulting in direct or indirect biological effects. For this reason, avian and mammalian target receptors of concern include:

- Raccoon (*Raydon arduatus*). This species is a common local semi-aquatic mammal which feeds upon invertebrates and fish, in addition to anthropogenic sources. The raccoon is a top-level carnivore and represents other aquatic mammals (*e.g.,* shrew, muskrat, otter, mink) that might occur on site. Impacts on this species will be assessed through food web modeling.

- Black-crowned Night Heron (*Nycticorax nycticorax*). This species is a local avian aquatic predator which feed upon invertebrates and fish. The heron is a top-level carnivore and represents wading shorebirds (*e.g.,* snowy egret, *Egretta thula*) which are principally piscivorus and may also occur on site. Impacts on these species will be assessed through food web modeling.

3.5. Conceptual Models

Conceptual models are developed to provide a framework for hypotheses concerning how a given stressor might cause ecological impacts on receptors of concern (U.S. EPA, 1992a). Two models, comprising the overall conceptual model for this assessment, have been developed; one related to the primary contaminant pathways from the Raymark site and the other, being the generalized exposure scenario for ecological receptors of concern.

The transport pathway model (NOAA, 1998) describes the primary release of contaminants from the Raymark industrial operation in the form of waste materials and site soils used as fill (Figure 3.5-1). Some releases due to direct discharge from waste lagoon may also be involved. The primary receiving media pertinent to aquatic receptors are surface waters, wetland soils and surface sediments. Through chemical partitioning processes (erosion, sorption, bioaccumulation) the CoCs are further disseminated throughout the primary habitat (wetlands, marsh, ponds, riverine sediments). Air transport of chemical pollutants bound to soil and dust particles also may occur, however, this pathway is not addressed in the current investigation.

Conceptual models are developed to provide a framework for hypotheses concerning how a given stressor might cause ecological impacts on receptors of concern (U.S. EPA, 1992a). Four models, comprising the overall conceptual model for this assessment, have been developed using a tiered strategy. Models in the initial tiers are more general and inherently carry greater uncertainty, whereas the more complex fourth-tier models have greater complexity and certainty for the specific pathways being evaluated. In the process of further refinement of models in subsequent tiers, hypotheses are retained or rejected based on existing knowledge of contaminants and receptors of concern. However, as previously indicated, the conceptual model approach in this assessment addresses only current conditions and levels of activity at the site, and does not address future use scenarios involving fundamentally different conditions or activities at the site.

Tier I represents the general north to south gradient of chemical contamination in the Housatonic River adjacent to Ferry Creek (Areas A-B) and areas which are the focus of the present investigation (Figure 3.5-2). Although many sources contribute to this gradient, and local sources may influence specific stressor concentrations anywhere in the river, this model suggests that contaminant concentrations in the immediate vicinity of Areas C-F should be evaluated within the context of the ecology of the entire lower river to evaluate the extent and significance of the Raymark site on the ecology of the river and adjoining wetlands, marshes and ponds.

The second tier model describes details of the aquatic behavior of contaminants hypothesized to exert ecological effects within the system (Figure 3.5-3). The model arrows indicate that the short-term behavior of contaminants in the water column depends on their solubility, degradation rates, and sorption to particulate matter. Bound contaminants may be transported with the current in association with particles, but may also settle to the bottom in localized depositional areas, such as those areas suspected for the Raymark study area. Individual molecules may remain in a dissolved state or will adsorb and desorb in a dynamic fashion, maintaining an apparent equilibrium relative to sorption state. Dissolved contaminants are transported to other parts of the study area by prevailing current patterns.

Once on the bottom, local currents may result in bedload transport of sediment, resulting in a further redistribution of the contaminants. Subsequent deposition of uncontaminated particles may bury earlier settling particles, and eventually block them from contact with ecological systems. Chemical-specific partitioning dynamics will occur in the sediments and interstitial (pore) waters in response to the geochemical conditions (*e.g.,* redox potential) of those sediments. Contaminants may be available to biological systems in the water column, pore water, and surficial sediments, resulting in direct toxicological effects and/or biological uptake and transfer through food webs.

Resuspended sediments can potentially contribute colloidal and/or dissolved organic contaminants to the water column in elutriate preparations and, presumably, during sediment resuspension. This evaluation, however, addresses only current conditions and levels of activity at the site, it does not address future use scenarios involving fundamentally different conditions or activities at the site. One possible zone where such exposure concentrations might temporarily exist is at the sediment water interface during major storm events or during mechanical disruption, in which case CoCs may produce adverse exposure to aquatic receptors.

Based on this generalized conceptual model, ecosystems potentially at risk are hypothesized to include nearshore habitats, pelagic, benthic and epibenthic communities, and natural resource species. In addition, stressor partitioning dynamics suggest that the assessment of potential risks to receptors should focus on CoCs associated with depositional sediments. Stressors which conform to this model of contaminant behavior include metals, organic contaminants such as PAHs, PCBs, and OCPs.

The description of stressor dynamics suggests potential risks to the aforementioned systems to be highest in areas adjacent to Raymark study area. Although risks to other ecological systems present in the study area cannot be dismissed, this conceptual model focuses the assessment on ecosystems considered to be directly influenced by depositional sediments.

The initial two tiers describe the origin, transport and fate of stressors at different spatial and temporal scales. To complete the model, receptors and stressors specific to the Raymark study area are added in the third and final tier, which describes receptor-specific exposure pathways hypothesized for the site for the receptors of concern identified in Table 3.4-1. These models were developed for receptors by ecological habit (pelagic, epibenthic, infaunal, aquatic mammal, avian aquatic predator), and their respective exposure pathways (Figure 3.5-4 to Figure 3.5-7). Measurement endpoints directly evaluating the effects of CoCs on mammals or avian aquatic species are not included in this study. However, an evaluation of the potential impacts to species group from ingestion of prey organisms hypothesized to be part of the exposure pathways to the predator is characterized through measurement of the spatial distribution and residue concentration of the food source. Hence, relevant issues for this trophic group with regard to the ERA framework are addressed from this perspective.

3.6. Sampling and Analysis Summary

This section describes data collection and analysis activities required to develop the information base necessary to complete the ecological risk assessment. As discussed in Section 2, the sampling was needed to acquire chemistry and toxicity data for surficial sediments in the area adjacent to the Raymark study area, and to gather biological data to assess the condition of potentially affected receptors. Measurements of organic and metal contaminant concentrations associated with sediments and organisms, were performed in conjunction with toxicity studies to assess the potential impact of Raymark study area on the biota. All sediment and biota samples were collected April of 1999. In the sections that follow, a brief discussion is presented on station locations and selection rationale, and sampling and analysis methods for chemical, geotechnical and biological endpoints.

3.6.1. Sediment and Biota Collection

Sediments. The locations of the sampling stations in Raymark study area are shown in Figure 3.6-1 to 3.6-5. A total of 16 stations for the four areas were selected. The stations were selected to confirm previous results of high concentrations of contaminants, to fill data gaps from prior studies and to characterize gradients in contaminant concentrations. Reference data from the Great Meadow station GM-08 was utilized from a prior study (SAIC, 1998). This area is approximately 5 km south of Raymark study area, and does not have a direct hydrologic connection with the Housatonic River system.

A sample collection and laboratory analysis summary for the Raymark study area ERA is shown in Table 3.6-1. Surface grabs were collected at all stations and were analyzed for bulk sediment and porewater chemistry (metals and organics), toxicity (amphipod survival), SEM/AVS, grain size, and total organic carbon (TOC).

At each station, surficial sediment (0-15 cm) from an undisturbed area was collected by scoop. The majority of samples were collected at low tide. For non-tidal areas (Areas E and F) approximately 2-3 grabs were needed to collect sufficient sample for both chemistry and toxicity analyses. The grab sampler was "washed-down" with sea water between grabs. Between stations, the sampling apparatus was rinsed in sequence with distilled water, 1:1 nitric acid, methanol and de-ionized water. The material from the samples was returned to the laboratory on ice, composited in a 12-liter polyethylene bucket, homogenized with a titanium stirrer for ~30 seconds, and then subsampled into precleaned containers for organic and inorganic chemistry, SEM/AVS analyses and toxicity studies.

Biota. Biota sampling activity for the Raymark study area investigation is summarized in Table 3.6-1. Target species at the intertidal stations (Areas C and D) were ribbed mussels and mummichogs. However, only ribbed mussels were successfully obtained at all stations except D-5 as mummichogs were not present when samples were collected. Mussels were collected at Station HB-1, adjacent to D-5, as none were present at D-5.

Grain Size. Percentages of sand, silt and clay in sediment samples from each station were determined as described in the Work Plan. Samples were pre-treated for removal of carbonates and organics, and then sieved using the Elzone Model 180XY particle size analyzer. The grain size data were used to assist in interpretation of chemical distribution data for lithologic variation influence.

Total organic content. Estimation of sediment total organic carbon (TOC) content was accomplished by determining the weight lost on ignition at 550°C. Details of the method are contained in the work plan. The total organic content data were used to normalize the organic contaminant data. These measurements were used to assess organic contaminant bioavailability and equilibrium between sediment and porewater.

3.6.2. Sediment and Biota Chemical Analyses

Sediments. The concentrations of selected metals, PCB congeners, pesticides and PAHs in surface and core sediment samples were determined as described in the Work Plan (refer to Table 3 of Work Plan). In addition, the concentrations of Simultaneously Extractable Metals (SEM) and Acid Volatile Sulfides (AVS) in these sediments were determined.

Tissues. Tissue analyses included the same suite as determined in sediments. Shell and exoskeletal material were not analyzed for any species. Bivalve and tissue were frozen whole after collection and analyzed whole. Samples of bivalves from the collection were selected at random and were resected at the organic or inorganic lab depending on the analysis. In addition, the lipid content of the tissue was determined for use in bioaccumulation factor calculations.

Toxicity Testing. All surface grab samples were evaluated for bulk sediment toxicity using the amphipod 10-day acute test. A complete description of these test methods is contained in the Work Plan.