REPORT

Housatonic River - Rest of River Corrective Measures Study Proposal

General Electric Company
Pittsfield, Massachusetts

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Quantitative Environmental Analysis, LLC

ARCADIS BBL
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1. Introduction

1.1 Purpose and Scope

This Corrective Measures Study (CMS) Proposal presents the proposal of the General Electric Company (GE) for a study of potential corrective measures (remedial actions) to address polychlorinated biphenyls (PCBs) and certain other contaminants within the portion of the Housatonic River and its floodplain located downstream of the confluence of the East and West Branches of the Housatonic River (the Confluence). This CMS Proposal identifies the corrective measures that GE proposes to study, provides a justification for selecting those corrective measures, and presents GE's proposed methodology for evaluating those measures.

This CMS Proposal is submitted pursuant to Special Condition II.E of a permit issued to GE by the United States Environmental Protection Agency (EPA) under the corrective action provisions of the federal Resource Conservation and Recovery Act (RCRA) on July 18, 2000. This permit (which constitutes a reissuance of a RCRA permit previously issued to GE in the early 1990s) was issued as part of a comprehensive settlement embodied in the Consent Decree (CD) for the GE-Pittsfield/Housatonic River Site, which became effective on October 27, 2000. This permit is referred to herein as the "Reissued RCRA Permit" or the "Permit." The CD details the terms of an agreement among GE, EPA, the Massachusetts Department of Environmental Protection (MDEP), the Connecticut Department of Environmental Protection (CDEP), and other federal, state, and local governmental entities relating to the cleanup of GE's facility in Pittsfield, Massachusetts, the Housatonic River downstream of GE's facility, and other adjacent and nearby areas.

The Reissued RCRA Permit applies to releases of PCBs and other "hazardous wastes" or "hazardous constituents" that have migrated from the GE facility in Pittsfield to the "Rest of River" area. The Rest of River area consists of the portion of the Housatonic River and its floodplain downstream of the Confluence (located approximately 2 miles downstream from the GE facility) and to which releases of hazardous waste or hazardous constituents from the GE facility are migrating or have migrated. The Rest of River flows through western Massachusetts and Connecticut and is shown on Figure 1-1. The Rest of River area excludes the actual or potential lawn areas of current residential properties, which GE has already agreed to address under the CD through a separate Removal Action.

As provided in the Reissued RCRA Permit and based on both recent and historical data, GE developed a *RCRA Facility Investigation Report* (RFI Report) for the Rest of River area to document the nature, extent, fate, and transport of chemical constituents that have potentially migrated from the GE facility in Pittsfield into the surface water, sediments, floodplain soils, and biota of the Rest of River area, and the concentrations of PCBs in the ambient air of the Rest of River area. The RFI Report was submitted in draft form to EPA in January 2003 and the final RFI Report was issued in September 2003 (Blasland, Bouck & Lee, Inc. [BBL] and Quantitative Environmental Analysis, LLC [QEA], 2003).

As provided in the CD, EPA conducted a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (ERA) of the Rest of River area. Those draft assessments were then subject to peer review. Following the peer reviews, EPA revised the draft risk assessment reports, issuing a revised draft ERA in November 2004 (EPA, 2004d) and a revised draft HHRA in February 2005 (EPA, 2005a). After a public comment period on new information in those revised drafts, EPA issued Responsiveness Summaries for the ERA in March 2005 (EPA, 2005b) and for the HHRA in June 2005 (EPA, 2005c), concluding in both cases that no further changes to the risk assessment reports were warranted and that the November 2004 ERA and February 2005 HHRA, together with the Responsiveness Summaries, should be considered the final risk assessments for the Rest of River.

Following completion of the HHRA and ERA, GE submitted an *Interim Media Protection Goals Proposal* (IMPG Proposal) to EPA in September 2005, which presented proposed interim media protection goals (IMPGs) for PCBs and certain other hazardous constituents in the Rest of River area. The IMPGs will be one of the factors to be considered by GE in evaluating various potential corrective measures during the CMS. In December 2005, EPA disapproved that IMPG Proposal and directed GE to submit a revised IMPG Proposal incorporating a number of revisions specified by EPA. Although GE disagreed with a number of EPA's directives and preserved its position on those issues, the Company submitted a revised IMPG Proposal in March 2006 (GE, 2006) (see Section 3.2 below). EPA approved that revised IMPG Proposal on April 3, 2006.

As provided in the CD, EPA has conducted a modeling study of the fate, transport, and bioaccumulation of PCBs within the Rest of River. The overall objective of the modeling study was to develop a model that could be used to reasonably predict future conditions in the Housatonic River in the absence of any further remedial action and to evaluate the relative effectiveness of various remedial alternatives, particularly with regard to PCB fate and transport. The EPA model consists of the following components: watershed submodel (Hydrological Simulation Program-FORTRAN, known as HSPF), hydrodynamic and sediment/contaminant transport and fate submodel (Environmental Fluid Dynamics Code, known as EFDC), and bioaccumulation submodel (Food Chain Model, known as FCM, derived from QEAFDCHN Version 1.0). The modeling study was conducted in three phases: model framework design (EPA, 2004b), model calibration (EPA, 2004f), and model validation (EPA, 2006a). Each phase included an independent scientific peer review. The issuance of the Final Model Documentation Report (FMDR; EPA, 2006c) marked the completion of EPA's modeling effort. On November 29, 2006, EPA notified GE of the Agency's determination that the peer review process on validation of EPA's model had been completed. The model will be used in evaluating remedial alternatives during the CMS proposed herein.

Following EPA's approval of this CMS Proposal, GE will conduct the evaluation of corrective measures (i.e., the CMS) and develop a CMS Report, which will provide the information specified in Special Condition II.G of the Permit. EPA will then approve, conditionally approve, or disapprove that report, as provided in Special Condition II.H of the Permit. Thereafter, EPA will select and propose corrective measures, along with associated Performance Standards and applicable or relevant and appropriate requirements (ARARs), for the Rest of River as a modification to the Permit, and will solicit public comments on that proposed permit modification. EPA then will issue a modification of the Permit specifying the corrective measures for the Rest of River, which will be subject to appeals in accordance with the Consent Decree. Following any appeals, the selected corrective measures (with any modifications stemming from the appeals) will be implemented as a remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Consent Decree.

1.2 Report Organization

The content and structure of this CMS Proposal are based on the requirements of Special Condition II.E of the Reissued RCRA Permit and are outlined below.

- Section 1 presents relevant background information.
- Section 2 describes the environmental setting of the Rest of River, including an overview of the site history, the physical location and extent of the site, the nature and extent of contamination within the Rest of River, and an overview of the conceptual site model. This section also summarizes the removal actions taken within the upper 2 miles of the Housatonic River and adjacent areas, as well as the estimated mass of PCBs contained within sediment, riverbank soil, and floodplain soil within the Rest of River area.
- Section 3 presents remedial goals for the Rest of River, including preliminary remedial action objectives (RAOs) and a summary of the IMPGs and other target levels established for the Rest of River.

- Section 4 identifies and screens the technologies and process options for addressing in-river sediment, riverbanks, and floodplain soil. This section also includes an identification and screening of technologies and process options for handling removed sediment and soil.
- Section 5 describes the methodology for evaluating potential corrective measures for sediment and floodplain soil and includes an identification of a number of potential corrective measure alternatives that will be evaluated and a description of how the fate, transport, and bioaccumulation model and other tools will be applied to facilitate the evaluation. Section 6 also describes the criteria by which each alternative will be evaluated.
- Section 6 describes the general content of the CMS Report that will be developed, and presents a proposed schedule for completing the CMS and submitting the CMS Report.
- Tables and figures are referenced throughout this CMS Proposal and provide important supporting information.
- Appendices A through D provide supporting documentation as referenced in this CMS Proposal.

2. Site Description

Presented below is a summary of the salient Housatonic River characteristics that may influence the development and evaluation of potential corrective measures for the sediments, riverbanks, and floodplain soils. A more detailed description of site characteristics, including the nature and extent of contamination, is contained in the RFI Report (BBL and QEA, 2003).

2.1 Site History

GE has owned and operated a manufacturing plant along the bank of the East Branch of the Housatonic River in Pittsfield, Massachusetts since the early 1900s (Figure 1-1). GE's primary industrial activities at this plant included the manufacturing and servicing of power transformers (GE Transformers), defense and aerospace operations (GE Ordnance), and the manufacture of plastics (GE Plastics). GE no longer conducts such manufacturing activities at this plant. The release of PCBs to the Housatonic River was primarily associated with the former GE Transformer Division's activities, which included the construction and repair of electrical transformers utilizing dielectric fluids containing PCBs. GE manufactured and serviced transformers containing PCBs at this facility from approximately 1932 through 1977. During this period, releases of PCBs reached the East Branch of the Housatonic River and Silver Lake through the facility's wastewater and storm water systems.

In the late 1930s or early 1940s, approximately one mile of the Housatonic River in Pittsfield was straightened and rechannelized by the City of Pittsfield and U.S. Army Corps of Engineers to reduce flooding. This resulted in the isolation of 11 former oxbows from the River channel. Some of these oxbows were filled with material from GE and others that was later found to contain PCBs.

PCBs were initially discovered in sediments and fish in impounded lakes along the Housatonic River in Connecticut in the mid-1970s. Since that time, numerous investigations have been conducted by GE and others to assess the presence and extent of PCBs and other hazardous substances in various media in both the Massachusetts and Connecticut portions of the Housatonic River, including the Rest of River area.

Major investigations undertaken along the Rest of River portion of the Housatonic River include:

1. Studies performed during the 1970s by the Connecticut Department of Environmental Protection (CDEP), United States Geological Survey (USGS), and Connecticut Agricultural Experiment Station (CAES);
2. An investigation by GE in the early 1980s pursuant to Consent Orders executed by GE with EPA and the Commonwealth of Massachusetts in 1981;
3. Additional investigations by GE in the 1990s pursuant to an Administrative Consent Order (ACO) executed by GE and the MDEP in 1990 pursuant to the Massachusetts Contingency Plan (MCP) and the prior RCRA Permit issued by EPA to GE in February 1991 and reissued effective January 1994;
4. Ongoing investigations by GE in Massachusetts since 1996, including data collection to support modeling efforts, a water column monitoring program, floodplain property characterization, young-of-year (YOY) fish monitoring, and sampling related to human health and ecological risk assessment activities;
5. Investigations of PCB concentrations in fish and benthic insects in the Connecticut portion of the River, which have included biennial fish monitoring performed by the Academy of Natural Sciences of Philadelphia (ANSP) on behalf of GE since 1984 under Cooperative Agreements between GE and CDEP, as well as benthic insect monitoring performed by CDEP from 1978 to 1990 and by ANSP since 1992; and
6. A multi-year sampling effort by EPA, which commenced in 1998 to support the RFI, HHRA, ERA, and modeling in anticipation of and pursuant to the CD.

As part of these investigations, sediment, surface water, floodplain soils, biota, and ambient air samples were collected from the Rest of River area for analyses of PCBs and other constituents. Extensive sediment reconnaissance and probing efforts were also undertaken, and samples were collected for geotechnical analyses to characterize sediment composition.

2.2 Site Description

2.2.1 Watershed Characteristics

The headwaters of the Housatonic River are located in the Berkshire Mountains of western Massachusetts. The Rest of River is formed by the confluence of the East and West Branches (the Confluence), which converge in the City of Pittsfield. The East Branch flows past GE’s facility, approximately 2 miles above the Confluence. Below the Confluence, the River generally flows south through Berkshire County for approximately 10 miles to Woods Pond, the first significant impoundment. Downstream of Woods Pond, the River continues south/southeast through western Massachusetts and south/southeast through Connecticut before emptying into Long Island Sound at Stratford, Connecticut (Figures 1-1, 2-1, 2-2), a total of 135 miles.

The total watershed of the Housatonic River and its tributaries covers 1,950 square miles – 500 in Massachusetts, 218 in New York, and 1,232 in Connecticut (Lawler, Matusky & Skelly [LMS], 1985). Figure 1-1 illustrates the watershed of the Housatonic River Basin in Massachusetts, New York, and Connecticut. Housatonic River Basin elevations range from sea level at the mouth of the River to over 2,600 feet, based on National Geodetic Vertical Datum (NGVD) 1929, at Brodie Mountain, Massachusetts, in the northwest portion of the basin. The topography of the Housatonic River Basin in western Massachusetts is characterized by rough, glaciated terrain. The area contains highlands to the east, the Taconic Range to the west, and the main valley of the Housatonic River and its tributaries in the central portion of the basin (Norvitch et al., 1968). The topography of the basin in northwestern Connecticut is comparable to that in western Massachusetts. The region consists of hills and ridges aligned in a north-south orientation, with locally rugged areas along the major watercourses (Wilson et al., 1974). However, the extreme southern portion of the basin in Connecticut is characterized by flatlands of the Atlantic coastal plain.

2.2.2 River Characteristics

2.2.2.1 River Reach Designations

For purposes of this CMS Proposal, the Rest of River area is identified according to river reach designations established by EPA in the Site Investigation Work Plan (SI Work Plan) (EPA, 2000) and Model Validation Report (EPA, 2006a). The reaches are:

- Reach 5, from the Confluence downstream to Woods Pond (the first significant impoundment);
- Reach 6, Woods Pond;
- Reach 7, Woods Pond Dam to Rising Pond (the next significant impoundment);
- Reach 8, Rising Pond;
- Reach 9, Rising Pond Dam to the Connecticut border; and
- Reaches 10-17, Connecticut border to Long Island Sound. However, EPA has not included Reach 17 in its studies of the Rest of River because that reach has received inputs of PCBs and other contaminants from industries in the immediate area.

Several landmarks, River mile (RM) points, and associated River reaches are shown in Table 2-1, and reach locations are also shown on Figures 2-1 and 2-2. The RM index presented below uses the River mouth on Long Island Sound (RM 0.0) as a reference and provides a convenient means of locating various points of interest along the River.

Table 2-1
River Mile Locations of Landmarks[1]

Landmark	River Mile	River Reach[2]
Coltsville USGS Gaging Station	140.6	Reach 1
Dawes/Pomeroy Avenue Bridge[3]	135.4	Reach 4
Confluence of East and West Branches (start of Reach 5/5A – beginning of Rest of River)	135.1	Reach 5
Holmes Road Bridge	134.1	
Pittsfield Wastewater Treatment Plant (WWTP) (start of Reach 5B)	130.1	
New Lenox Road Bridge	129.2	
Roaring Brook (start of Reach 5C)	128.0	
Woods Pond Headwaters (surface water sample location)	125.4	
Start of Woods Pond (start of Reach 6)	125.0	Reach 6
Woods Pond Footbridge	124.6	
Woods Pond Dam (start of Reach 7)	124.4	Reach 7
Schweitzer Bridge	124.2	
Columbia Mill Dam	122.1	
Willow Mill Dam	115.6	
Glendale Dam	109.0	
Rising Pond Headwaters (start of Reach 8)	106.0	Reach 8
Rising Pond Dam (start of Reach 9)	105.2	Reach 9
Great Barrington USGS Gaging Station	104.2	
MA/CT Border (start of Connecticut portion of River and Reach 10)	81.2	Reach 10
Falls Village Dam (start of Reach 11)	74.0	Reach 11
Cornwall Bridge (start of Reach 12)	63.0	Reach 12
Bulls Bridge Dam (start of Reach 13)	49.0	Reach 13
Bleachery Dam (start of Reach 14)	37.6	Reach 14
Shepaug Dam (start of Reach 15, impounds Lake Lillinonah)	25.2	Reach 15
Stevenson Dam (start of Reach 16, impounds Lake Zoar)	15.0	Reach 16

Table 2-1 (continued)
River Mile Locations of Landmarks[1]

Landmark	River Mile	River Reach[2]
Derby Dam (impounds Lake Housatonic, end of Reach 16 and Rest of River area included in EPA's studies, start of Reach 17 and tidally-influenced portion of the river)	9.1	Reach 17
Long Island Sound	0.0	Reach 17

Notes:
[1] River miles measured in geographic information system (GIS), and represent distance from the River mouth on Long Island Sound.
[2] From Supplemental Investigation Work Plan (EPA, 2000) and HHRA (EPA, 2005a).
[3] Dawes Avenue Bridge is located at RM 135.7 and Pomeroy Avenue Bridge is located at RM 135.4. RM 135.4 has been assigned to the combined upstream data location.

The primary focus of much of the investigations conducted on the river has been the reach of the River between the Confluence (RM 135.1) and Woods Pond Dam (RM 124.4), which is known as the Primary Study Area (PSA). The portion of the River from the Confluence to Woods Pond (Reach 5) was further divided into three subreaches: 5A, 5B, and 5C (Figure 2-3). Reach 5A is approximately 5 miles long and extends from the Confluence at RM 135.1 to the Pittsfield WWTP (RM 130.1). Reach 5B is about 2 miles long and defined as the region from the Pittsfield WWTP to Roaring Brook (RM 128.0). Reach 5C extends 3 miles from Roaring Brook to the start of Woods Pond at RM 125.0. The Woods Pond reach (Reach 6) extends to the dam, a distance of approximately one-half mile. As part of the Agency's modeling study, EPA has further divided the portion of the River from Woods Pond Dam to Rising Pond (Reach 7) into eight subreaches (see Table 2-2 below and Figure 2-4).

Table 2-2
Reach 7 River Mile Locations of Landmarks[1]

Landmark	River Mile	River SubReach[2]
Woods Pond Dam	124.4	7A
Former Niagara Mills Dam	122.9	
Columbia Mills Dam	122.1	7B
Former Lee/Eagle Mills Dam	121.3	7C
Willow Mill Dam Headwaters	116.2	7D
Willow Mill Dam	115.5	7E
Glendale Dam Headwaters	109.6	7F
Glendale Dam	109.0	7G
Rising Pond Headwaters	106.3	7H

Notes:
[1] River miles measured in GIS, and represent distance from the River mouth on Long Island Sound.
[2] From *Model Validation Report* (EPA, 2006a).

2.2.2.2 River Hydrology

The flow rate of the Housatonic River is monitored by USGS, which maintains a total of five flow gaging stations on the River (two in Massachusetts and three in Connecticut). The first station in Massachusetts, on the East Branch of the Housatonic River in Coltsville, is approximately 5.5 miles upstream of the Confluence and has an associated drainage area of 57.6 square miles (Bent, 1999). Hydrologic data recorded at Coltsville during the period of 1941 to 2005 (beginning with the year common to the five gaging stations) indicate a mean annual flow rate of 105 cubic feet per second (cfs).

The second gaging station on the Housatonic River in Massachusetts is located in Great Barrington, approximately 20 miles downstream from Woods Pond. The River drains an area of approximately 282 square miles above this point (Bent, 1999). USGS reports a mean annual flow rate at 522 cfs for the Housatonic River at Great Barrington, based on data recorded from 1941 to 2005.

In addition, USGS operates three flow gaging stations on the Housatonic River in Connecticut: one at Falls Village near the Massachusetts state line, one at Gaylordsville, and one at Stevenson. The mean annual flow rates during the period of 1941 to 2005 are: 1,104 cfs at Falls Village (634 mi^2 drainage area); 1,692 cfs at Gaylordsville (996 mi^2 drainage area); and 2,662 cfs at Stevenson (1,544 mi^2 drainage area).

The flow rate in the River is variable, with the maximum recorded value at Coltsville being 6,400 cfs in September 1938. Typical flow rates at Coltsville during low-flow periods in the summer are approximately 20 cfs. The 7-day, 10-year (i.e., 7Q10) low-flow rate is 12 cfs at Coltsville. Variability in the Coltsville hydrograph is illustrated on Figure 2-5, which presents daily average flow rates from 1980 to 2005.

Flood frequency analyses were conducted using annual instantaneous peak flow rates measured by USGS at the Coltsville and Great Barrington gaging stations. The analyses were conducted based on the Log Pearson Type III distribution (e.g., Bedient and Huber, 1992). The results are summarized in Table 2-3.

Table 2-3
Housatonic River Flood Frequencies at Coltsville and Great Barrington

Flood Return Period (years)	Flow Rate at Coltsville (cfs)	Flow Rate at Great Barrington (cfs)
1	510	1,690
1.5	1,370	3,150
2	1,730	3,720
5	2,780	5,320
10	3,580	6,520
25	4,720	8,200
50	5,650	9,570
100	6,660	11,060

Note:

Flows based on annual instantaneous peak flow rates (i.e., peak stream flow, as reported by USGS) for water years 1936-2005 (Coltsville) and 1914-2005 (Great Barrington).

To provide an indication of River flow variability, Table 2-4 provides the average daily flow, the 90th percentile, 99th percentile, and maximum observed daily average flows for the USGS gage at Coltsville. The 90th and 99th percentile flows represent the daily average flows that have been exceeded 10% and 1% of the time, respectively, for a particular month, based on the period of record through September 30, 2005. For example, in the month of June, the long-term daily average flow is 86 cfs. However, on 10% of days in June, the daily average flow is expected to exceed 170 cfs, and 1% of the time it will exceed 663 cfs. The maximum daily average flow provides the upper bound of flow conditions for that month observed over the period of record through September 30, 2005.

Table 2-4
Daily Average Flows in the Housatonic River at Coltsville by Month[1]

	Average (cfs)	90th Percentile (cfs)	99th Percentile (cfs)	Maximum (cfs)
January	95	174	696	1820
February	94	183	500	1190
March	183	374	1040	4460
April	262	515	1220	2860
May	138	269	628	2750
June	86	170	663	1890
July	52	91	392	1500
August	48	87	371	2010
September	55	89	515	3110

Table 2-4 (continued)
Daily Average Flows in the Housatonic River at Coltsville by Month[1]

	Average (cfs)	90th Percentile (cfs)	99th Percentile (cfs)	Maximum (cfs)
October	72	134	526	1800
November	97	190	577	1900
December	103	193	594	4350

Note:
[1] Flows based on time period from March 8, 1936 to September 30, 2005.

2.2.2.3 Backwaters

The Housatonic River contains numerous backwater areas, defined as quiescent areas adjacent and hydraulically connected to the main channel of the River. A majority of the backwaters are located within the lower half of Reach 5, between New Lenox Road and Woods Pond, as shown on Figure 2-3. This reach of the River (i.e., 5C) is dominated by a broad wetland floodplain, which ranges from 800 feet to 3,000 feet wide, and includes the numerous backwater areas, as well as side channels and meanders (EPA, 2000). The backwater areas along this reach of the River generally range from 3 to 5 feet in depth and cover a total area of approximately 80 acres. Widths of the backwaters vary from approximately 10 to 950 feet. The bed elevations along the section of the River where the backwaters are predominant generally range from approximately 948 feet NGVD at the upper end of the reach to approximately 940 feet NGVD at the lower end. The channel gradient increases significantly below Woods Pond and fewer backwater areas are present in the stretch between Woods Pond Dam and Great Barrington (i.e., Reaches 7 and 8). The section of the River that stretches from the Great Barrington gaging station to just into Connecticut (Reach 9) flows along a relatively flat floodplain that includes many meanders and oxbows, as well as some backwater areas.

2.2.2.4 Sediment Dynamics

Watershed sediment loading to the River is relatively low (~15 to 30 MT/mi^2-yr [metric tons per square mile per year]) and consistent with a largely forested (71%) drainage area (BBL and QEA, 2003). The River channel is characterized as sinuous in Reach 5A and minimally to moderately meandering in Reaches 5B and 5C. Overall, the main channel appears to be relatively stable, with significant meandering occurring over timescales greater than 50 years (BBL and QEA, 2003; EPA, 2006c). However, a few specific subreaches, which are relatively small compared to the entire reach, experience more active channel movement. Bank erosion occurs along a large fraction of the channel shoreline in Reaches 5A and 5B and may produce significant sediment loads to the system, particularly during high-flow events (BBL and QEA, 2003).

Sediment transport in Reach 5A is dominated by suspended and bed load transport of non-cohesive sediment (BBL and QEA, 2003). The sediment bed in this reach appears to be in dynamic equilibrium (i.e., erosion and deposition approximately balance one another), with certain areas being net erosional and others net depositional. A small percentage of the total sediment load entering Reach 5A from the East Branch is bed load. As the channel gradient decreases between the upstream and downstream limits of the reach, the sediment bed becomes finer and bed load transport decreases, with less (if any) bed load occurring at and downstream of New Lenox Road Bridge, except during very high flow conditions. Cohesive sediment transport becomes more important in Reach 5B, but the sediment bed is still primarily non-cohesive, although finer than that in Reach 5A because of the lower channel gradient. In most of Reach 5B, the channel is likely in dynamic equilibrium or depositional. Deposition is dominant in Reach 5C and Woods Pond, where most of the sediment bed is composed of cohesive sediment (BBL and QEA, 2003). The floodplain and backwaters are important during overbank floods, which occur almost annually. These areas act as sinks for suspended sediments because the presence of floodplain vegetation and submerged aquatic vegetation in the backwaters reduces water velocities and makes these areas conducive to deposition.

Within Woods Pond and the nearby backwaters, internal biological production (e.g., phytoplankton, periphyton, and macrophytes) enhances deposition (BBL and QEA, 2003). Significant growth of periphyton, phytoplankton, and macrophyte populations during the summer occurs in response to nutrient inputs from the Pittsfield wastewater treatment plant (WWTP) located at the beginning of Reach 5B; during the fall die-off period, a large fraction of the associated solids and organic matter is returned to the sediment bed where they are subject to decomposition. The depositional nature of Woods Pond is evidenced by the radioactive Cs-137 dating analyses, which indicate a net deposition rate of approximately 0.5 centimeter per year (cm/yr) in that impoundment (BBL and QEA, 2003). The deposition in Woods Pond and upstream backwaters is likely a combination of solids entering these reaches from upstream (i.e., Reaches 5A and 5B), growth of algae and macrophytes, and solids delivered by the tributaries (i.e., Roaring Brook and Yokun Brook).

Downstream of Woods Pond, the River is likely in a state of dynamic equilibrium in the free-flowing reaches. Additional solids inputs from tributaries cause the in-river suspended sediment loading to increase with downstream distance. The River is net depositional within the impoundments associated with the various dams in these reaches (BBL and QEA, 2003).

2.2.3 Floodplain Characteristics

As defined in the CD, the Rest of River includes portions of the River's floodplain (Figures 2-1 and 2-2). Between the Confluence and Woods Pond Dam, the Rest of River floodplain is defined as the area extending laterally to the 1 milligram per kilogram (mg/kg) PCB isopleth. The 10-year floodplain in this stretch and the 1 mg/kg PCB isopleth are shown on Figure 2-3. As shown on Figures 2-1 and 2-3, the bed of the railroad line that runs north from Woods Pond forms a berm, limiting the western extent of the 1 mg/kg PCB isopleth along an approximately 2.5-mile reach of the River. The floodplain extends beyond the railroad bed due to the presence of several bridges and culverts along this reach that allow water to flow past the bed during flood conditions. Downstream of Woods Pond Dam, the Rest of River floodplain is defined as those floodplain areas containing PCBs.

The floodplain of the River is relatively narrow adjacent to the GE facility in Pittsfield and begins to widen in the southern portions of Pittsfield near Pomeroy Avenue and the Confluence. Between Pomeroy Avenue and New Lenox Road, the floodplain widens significantly to follow the gentle slope of the local topography. South of New Lenox Road to Woods Pond Dam, the floodplain widens slightly again. Approximately ½-mile south of New Lenox Road, the floodplain along the east bank of the River is confined by October Mountain, while the west bank of the River has a relatively flat topography resulting in an extended floodplain. The floodplain between Woods Pond Dam and Rising Pond Dam is relatively narrow except for areas where large tributaries join the Housatonic River (i.e., confluence with Hop Brook). South of Rising Pond to the Connecticut border, an extended floodplain is evident as a result of relatively flat topography. This type of floodplain continues south through Connecticut where it narrows as the River runs through hilly terrain until it widens again as it enters the tidal estuary in Stratford and Milford.

The area and width of the floodplain in Reaches 5 and 7 are listed in Table 2-5 (below). Floodplain topography between the Confluence and Woods Pond is presented on Figure 2-6.

Table 2-5
Floodplain Geometry

Reach(es)	Floodplain Area [1] (acres)	Minimum Floodplain Width [1] (feet)	Maximum Floodplain Width [1] (feet)
5A	325	100	2,480
5B	146	110	2,060
5C	255	1,050	2,220
7A-7E	1,765	120	1,800 [2]
7E-7H	1,551	150	800 [2]

Notes:

[1] Values based upon the 1 mg/kg PCB isopleth for Reach 5 and the 100-year floodplain in Reach 7.

[2] Floodplain width in Reach 7 increases to > 4,000 to 5,000 feet, where tributaries (Washington Mountain Brook, Hop Brook, Konkapot Brook, Agawam Brook, and Larrywaug Brook) enter the River.

Vegetation in the floodplain varies from short grasses to mature trees. As part of the ecological characterization of the Housatonic River between the Confluence and Woods Pond Dam, performed by Woodlot Alternatives, Inc. (Woodlot) on behalf of EPA (Woodlot, 2002), 14 palustrine and terrestrial vegetation community types were identified within the study area. The communities and relative area of each type are listed in Table 2-6 (below) and are shown on Figure 2-7. Palustrine communities cover approximately 87% of the floodplain between the Confluence and Woods Pond Dam, while terrestrial communities cover approximately 13% of the floodplain. Detailed natural community mapping was not performed downstream of Woods Pond; however, land use information in those reaches indicates a mixture of forested and agricultural lands, with increasing fractions of developed land within town centers along the river.

Table 2-6
Vegetation Coverage between the Confluence and Woods Pond Dam

Vegetation Community Name	Total Area (acres)	Percent Area in Community Category	Percent Area in Floodplain
PALUSTRINE COMMUNITY CATEGORY			
Black ash-red maple-tamarack calcareous seepage swamp	117.13	12.76	11.06
Deep emergent marsh	53.13	5.79	5.02
High-terrace floodplain forest	10.87	1.18	1.03
Red maple swamp	151.23	16.47	14.28
Riverine pointbar and beach	0.99	0.11	0.09
Shallow emergent marsh	74.87	8.16	7.07
Shrub swamp	256.50	27.94	24.22
Transitional floodplain forest	207.82	22.64	19.62
Wet meadow	45.47	4.95	4.29
Total Palustrine Community Area	**918.01**	**100**	**86.68**

Table 2-6
Vegetation Coverage between the Confluence and Woods Pond Dam

Vegetation Community Name	Total Area (acres)	Percent Area in Community Category	Percent Area in Floodplain
TERRESTRIAL COMMUNITY CATEGORY			
Cultural grassland	54.36	38.53	5.13
Northern hardwoods-hemlock-white pine forest	60.05	42.56	5.67
Red oak-sugar maple transitional forest	16.31	11.56	1.54
Rich mesic forest	4.94	3.50	0.47
Successional northern hardwoods	5.44	3.86	0.51
Total Terrestrial Community Category	**141.1**	**100**	**13.32**

Note:
Table condensed from Table 1-2 in *Ecological Characterization of the Housatonic River*. (Woodlot, 2002).

2.3 Description of Removal Actions in Upper 2 Miles

GE has undertaken and is continuing to undertake numerous source control and other remediation activities in and along the Housatonic River. Historically, GE conducted a number of remedial measures in the River and its floodplain in the late 1980s and early 1990s under EPA and/or MDEP oversight. These remedial measures included:

- The design and construction of the new Woods Pond Dam as well as improvements to the raceway structure adjacent to the dam;
- Performance of short-term measures (STMs) and immediate response actions (IRAs) in the floodplain, including the posting of signs, installation of exposure barriers, and/or removal and replacement of PCB-containing soil at a number of residential and non-residential properties in the floodplain upstream of the Confluence; and
- Posting of warning signs at numerous locations along the riverbanks concerning potential exposure to PCBs and/or the biota consumption advisories issued by Massachusetts, and preparing signs, flyers, and pamphlets describing the advisories in Connecticut and providing them to CDEP for posting and distribution.

More recently, activities that GE has undertaken in or near the 2-mile reach between the GE facility and the Confluence have included:

- Source control activities at and near the GE facility to prevent or control the migration of PCBs and other chemical constituents present in non-aqueous-phase liquid (NAPL) into the River;

- Sediment and bank soil remediation projects in the Upper ½-Mile Reach of the River, including the Building 68 Area Removal Action and the Upper ½-Mile Reach Removal Action;
- Additional investigations and remediation activities in floodplain and former oxbow areas adjacent to the River as necessary to meet Performance Standards set forth in the CD; and
- Investigations and initiation of remediation activities at Silver Lake (which discharges to the River) under the CD.

In addition, under the CD, EPA performed an extensive sediment/bank soil remediation project in the 1½-Mile Reach of the River between Upper ½ Mile and the Confluence. The recent source control and remediation activities performed by GE and EPA are described further below.

2.3.1 NAPL Recovery and Control Activities At and Near GE Facility

NAPL monitoring, recovery, and control activities have been performed by GE for over 40 years for some portions of the site adjacent to the Housatonic River. The results of those activities have been documented in numerous reports prepared under the MCP and RCRA Corrective Action Programs prior to fall 2000 and under the CD thereafter. More detailed information can be found in the document titled *Baseline Monitoring Program Proposal for Plant Site 1 Groundwater Management Area* (BBL, 2000a) and in subsequent semi-annual reports submitted to EPA on GE's NAPL monitoring and recovery efforts.

In general, GE's NAPL recovery program includes operation of several automated hydraulic control and NAPL recovery systems, supplemented by routine manual monitoring and recovery operations for light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL). Automated recovery systems are operated in portions of the GE Plant adjacent to the Housatonic River (notably, the areas referred to as East Street Area 1-North, East Street Area 1-South, and East Street Area 2-South) and at certain former oxbow areas (notably, the Lyman Street Area and Newell Street Area II). Each recovery system consists of one or more recovery wells or caissons that serve as the point of collection for groundwater, LNAPL, and/or DNAPL. Groundwater collected during operation of the automated recovery systems is pumped to GE's 64G groundwater treatment facility, where it is treated and discharged to the River in accordance with GE's National Pollutant Discharge Elimination System (NPDES) permit (MA0003891, effective February 7, 1992). (GE is currently in the process of renewing this permit.) In addition, a portion of the treated groundwater is discharged to a groundwater Recharge Pond in East Street Area 2-South to maintain a hydraulic mound associated with this pond, which assists in preventing NAPL migration toward the River. The manual NAPL monitoring/recovery program involves the routine collection of groundwater elevation and NAPL thickness measurements on a weekly to semi-annual basis, followed by manual removal of NAPL if the observed thickness is greater than location-specific criteria.

In addition to the active recovery systems, several physical barriers have been constructed to control groundwater flow and/or restrict NAPL migration. These features include a 350-linear foot, V-shaped subgrade slurry wall in the southeastern portion of East Street Area 2 South, a series of sheetpile containment barriers, and the Groundwater Recharge Pond. An LNAPL recovery caisson is located immediately upgradient of the center of the slurry wall, while the Groundwater Recharge Pond is located to the west. Additional recovery systems are located downgradient of the slurry wall to recover LNAPL present between the slurry wall and the River. The permanent sheetpile barrier walls were installed adjacent to the River during the Building 68 Area and Upper ½-Mile Reach Removal Actions (discussed below) to prevent the migration of NAPL to the River.

2.3.2 Building 68 Area Removal Action

Between June 1997 and July 1999, GE implemented a Removal Action to address the presence of PCBs in the riverbanks and sediments at the Building 68 Area, which is located along the Housatonic River at the GE facility. This Removal Action was performed in accordance with the First Unilateral Administrative Order for Removal Action (the Building 68 Area Order) issued by EPA to GE on December 18, 1996 under CERCLA, as well as work plans prepared by GE and approved by EPA.

As part of this Removal Action, GE removed certain River sediments from an approximate 500-foot stretch of the River generally located in the vicinity of Building 68. In all, approximately 5,000 cubic yards (cy) of PCB-containing sediment were removed and disposed of off site. Sediment removal was performed while the River was being actively diverted and groundwater was being extracted from the removal area, using sheetpiling positioned within the River to isolate the sediment removal areas. Subsequent to sediment removal, the River bottom was restored to original grade using a multi-layer backfill system including geotextile, sand, and riprap.

In addition, approximately 1,100 cy of PCB-containing soil were removed from an approximate 170-foot portion of the riverbank in the vicinity of Building 68 and disposed of off site. Upstream of the former Newell Street parking lot pedestrian footbridge, DNAPL was observed emanating from the north bank of the river during sediment excavation activities. In response to this observation, approximately 180 feet of impermeable barrier sheetpile were installed in the riverbank and additional lower bank soil and sediment excavation was performed. In addition, areas of the upper bank were excavated to depths of 1 to 3 feet consistent with proposed bank soil removal activities associated with the Removal Action for the Upper ½-Mile Reach of the River scheduled to begin in 1999. The additional bank and sediment material removed during these two activities amounted to 1,230 cy, so that the total volume of sediment and bank soil removed during this Removal Action amounted to 7,330 cy. The riverbank was restored, and run-off control and scour protection measures were installed to provide protection of the bank area adjacent to the sediment removal area. Results of monitoring performed as part of this effort, as well as documentation of the Building 68 area removal activities, were provided in the report titled *Completion of Work Report for Building 68 Removal Action* (BBL, 2000b).

2.3.3 Upper ½-Mile Reach Removal Action

Pursuant to the CD, GE implemented a Removal Action to remediate the sediments and bank soils in the Upper ½-Mile Reach (excluding the Building 68 Area). GE agreed to begin this Removal Action prior to entry of the CD in accordance with the *Removal Action Work Plan – Upper ½-Mile Reach of Housatonic River* (Upper ½-Mile Work Plan) (BBL, 1999a), which was an attachment to the CD. Work commenced during October 1999 and was substantially completed in August 2002. The final plantings were installed in September 2002 and long-term monitoring and maintenance activities are ongoing.

As described in the Upper ½-Mile Work Plan, the action involved removal and restoration of select sediments and bank soils from portions of the Upper ½-Mile Reach (BBL, 1999a). In the majority of areas where sediment removal was undertaken, the removal depth generally ranged from 1.5 to 2 feet, with removal to greater depths (as much as 8 to 9 additional feet) at a limited number of areas due primarily to the presence of NAPL. The general sediment removal and restoration approach involved diverting the River around established work areas in a phased, area-by-area approach using steel sheetpiling, dewatering the work cell in which work was to be performed, treating the water as required, and performing sediment removal, replacement, and restoration activities “in the dry.” The removed sediment was permanently consolidated with other site-related materials at EPA-approved On-Plant Consolidation Areas (OPCAs) at the GE Pittsfield facility, with the exception of NAPL-impacted sediment, which was disposed of off-site at an approved disposal facility. Following removal, the sediment removal areas were restored using an engineered multi-layer cap system. As part of the Natural Resources Damages (NRD) settlement under the CD, aquatic enhancement structures were also installed as part of the Upper ½-Mile Reach restoration activities to increase the variability in water flow and depth and to enhance in-stream habitat. The spatial average PCB concentration for the top foot of sediment in the Upper ½-

Mile Reach prior to commencement of removal activities was approximately 55 mg/kg. After removal and replacement of sediment with the highest PCB concentrations, the spatial average PCB concentration in the surficial sediment (top foot) was reduced to less than 1 mg/kg. A total of 12,800 cy of sediments were removed during this project.

Bank soil removal activities were conducted in coordination with the sediment removal and restoration activities. Bank soil removal generally occurred to a maximum depth of 3 feet to achieve spatial average PCB concentrations less than 10 mg/kg in the top foot and less than 15 mg/kg in the 1- to 3-foot depth increment in each of the averaging areas described in the Work Plan. Following removal, impacted areas were backfilled and the bank habitat restored using soil and vegetative cover, except along the lower banks at the toe of the slope, where armor stone was placed for erosion protection. As with the sediments, the removed soil was permanently consolidated on-site with other site-related materials, with the exception of NAPL-impacted materials, which were disposed of off-site. A total of 6,700 cy of bank soils were removed during the project.

As part of the preparation for the Upper ½ Mile Removal Action, two approximately 400-foot long impermeable sheetpile barriers were installed adjacent to the north bank of the river. Small amounts of NAPL were encountered in most of the work cells during removal activities. At several locations more significant amounts of NAPL were found. These NAPLs were predominantly coal-tar NAPL related to a former manufactured gas plant located on the GE facility, although several PCB NAPLs were found as well. In order to address the areas where NAPL was found, five impermeable sheetpile walls were installed on the north bank of the river adjacent to where the NAPL was observed. The NAPL-impacted sediment was successfully removed in all but two locations. At these two locations, an impermeable cap and NAPL observation/recovery well were installed in the River. Since completion of restoration activities, NAPL has not been observed in the observation/recovery wells. Similar to the in-river observation/recovery wells, recoverable quantities of NAPL have not been observed since return to normal hydraulic conditions; however, trace amounts of NAPL have been occasionally observed in monitoring wells along the bank during routine monitoring activities.

2.3.4 1½-Mile Reach Removal Action

For the 1½-Mile Reach, which is located between the Upper ½-Mile Reach and the Confluence, the CD provided that EPA would complete an Engineering Evaluation/Cost Analysis (EE/CA) under CERCLA to evaluate potential removal actions for the sediments and bank soils in this reach, and EPA would then conduct a Removal Action, as selected in an Action Memorandum, to address those sediments and bank soils. EPA presented data collected from sediment and bank soils in the 1½ Mile Reach, along with an assessment of potential sediment/bank remedial alternatives, in *Final Draft Engineering Evaluation/Cost Analysis for the Upper Reach of the Housatonic River* (EE/CA Report) (EPA, 2000b) and the *Final Addendum to the Engineering Evaluation/Cost Analysis for the Upper Reach of the Housatonic River* (EE/CA Addendum) (EPA, 2000c).

Based on its evaluation, EPA issued an Action Memorandum, dated November 21, 2000, selecting a Removal Action that consisted of the excavation and disposal of approximately 95,000 cy of sediments and bank soils (EPA, 2000d). The selected remedy involved sediment and bank soil removal in-the-dry using sheetpiling and pump bypass, and disposal consisting of consolidation of up to 50,000 cy of material at the OPCAs and off-site disposal of the remaining material. Habitat restoration included a combination of regrading, revegetation, bioengineering, and potential installation of habitat improvements such as low-stage dams and boulders.

Removal activities were conducted in five phases, with excavation proceeding in an upstream to downstream manner. Phase 1 construction began in September 2002 (upon completion of excavation and riverbed restoration activities in the Upper ½-Mile Reach) and lasted 8 months. The next phases followed subsequently, with Phase 2 lasting 17 months, and Phases 3A, 3B and 3C lasting a total of 21 months, for a total of 46 months. Sediment removal activities were, for the most part, conducted "in the dry" using sheetpile and, where bedrock was shallow, a "gravity-bypass" technique that included construction of a dam and use of bypass piping. Sediments were removed to depths of up to 14 feet below the original grade to achieve spatial average PCB concentrations of less than 1 mg/kg (based on the 95% upper confidence limit [UCL]) and to address the presence of coal-tar NAPL in some areas.

An on-site water treatment system was set up to process water pumped from the removal areas. Areas were encountered where excavation activities were required to be conducted "in the wet." Water from these excavation areas was treated in the water treatment system before being discharged back into the River. NAPL encountered during removal activities was removed and shipped off-site to an approved disposal facility. In areas where bedrock was in contact with NAPL-impacted material, the area was power washed and the water was processed through the water treatment system. Following removal activities, removal areas were backfilled.

Bank soil removal activities were conducted in coordination with the sediment removal and restoration activities. Bank soil removal generally occurred to a maximum depth of 3 feet to achieve spatial average PCB concentrations of less than 10 mg/kg in the top 3 feet in areas specified as recreational by EPA, and less than 2 mg/kg in the top 3 feet (with soils below 3 feet cleaned up to meet an average PCB concentration of 10 mg/kg and not to exceed a concentration of 50 mg/kg for any one sample) in areas specified as residential by EPA. Coal-tar NAPL was encountered in the first two phases, and different techniques were used to isolate and remove the material, including removing soil to a deeper depth than originally specified to mitigate the NAPL concern, installing permanent sheetpile cells to contain the NAPL and control migration into the River, and/or applying a 2-inch-thick grout to the toe of the riverbank to encapsulate any residual NAPL-impacted material that may have been left in place. Following removal activities, excavated areas were backfilled and restored with vegetative cover. Riprap swales were occasionally installed along the riverbank to prevent erosion due to stormwater.

A total of approximately 92,000 cy of material (bank soil and sediment) were removed during the 1½-Mile Reach Removal Action. Of this material, approximately 13,350 cy of material were classified as material regulated under the Toxic Substances Control Act (TSCA); EPA sent this material to the GE plant site OPCA approved in the CD for disposition of such material. Approximately 71,400 cy of material were classified as non-TSCA material; EPA sent a portion of this material to the GE OPCA designated for non-TSCA material, and it disposed of the remainder at approved off-site facilities. The remaining 6,950 cy consisted of NAPL-impacted material, which EPA disposed of at an off-site disposal facility.

2.3.5 Floodplain Properties Adjacent to 1½-Mile Reach

Several floodplain properties adjacent to the 1½-Mile Reach are also addressed in the CD. These properties are included in two Removal Action Areas (RAAs) designated in the CD and accompanying *Statement of Work for Removal Actions Outside the River* (SOW) (BBL, 1999b), which are: (1) Floodplain Current Residential Properties Adjacent to 1½-Mile Reach – Actual/Potential Lawns; and (2) Floodplain Non-Residential Properties Adjacent to 1½-Mile Reach (Excluding Banks). These RAAs are jointly referred to as the 1½-Mile Floodplain RAAs. The 1½-Mile Floodplain RAAs cover portions of numerous floodplain properties located adjacent to or in close proximity to this River reach. For this purpose, the SOW defines the "floodplain" of this reach as the area between the top of the riverbank and the approximate 1 mg/kg PCB isopleth. These properties were divided into four phases (based on location along the River) for investigation, evaluation, and remediation purposes to facilitate coordination with the 1½-Mile Reach Removal Action being performed separately by EPA. For each Floodplain Removal Action, the CD and SOW established Performance Standards that must be achieved.

The portions of the properties within the 1½-Mile Floodplain addressed under these RAAs consisted of the Actual/Potential Lawns (as defined in the CD) of 38 current residential properties and the non-riverbank portions of 10 non-residential properties (consisting of eight recreational properties and two commercial/industrial properties). As of February 2007, GE has completed the soil investigations and most of the necessary remediation activities at the properties within the 1½-Mile Floodplain RAAs. GE anticipates submitting Final Completion Reports for these RAAs to EPA later in 2007.

2.3.6 Silver Lake Area

Silver Lake is located adjacent to the GE Pittsfield facility and is one of the RAAs designated in the CD and accompanying SOW. An outfall from the GE Pittsfield facility discharges to Silver Lake, and the lake discharges to the East Branch of the Housatonic River through a 48-inch diameter concrete pipe in the southwest portion of the Silver Lake. Included in the Silver Lake Area RAA are sediments within the lake and soils located in certain areas adjacent to the lake. The CD and SOW establish Performance Standards for the remediation at the lake and at the adjacent properties.

Silver Lake Sediments

The three primary response actions for sediments within Silver Lake, as set out in the CD, are summarized below:

1. remove *in situ* sediment from the lake in the general vicinity of the existing outfall from the GE Pittsfield facility, replace removed sediment, and restore and vegetate portions of the affected area that are not under water;
2. install a cap over the entire bottom of Silver Lake; and
3. periodically inspect and monitor the cap to assess effectiveness.

Pre-design investigations related to Silver Lake sediment resulted in the collection of additional sediment samples, as well as numerous surface and pore water samples, for chemical and/or geotechnical analysis. Additionally, a bench-scale study was performed in 2005 to investigate the performance of a sand-based cap in isolating constituents found in Silver Lake sediments, and to further understand the potential sediment responses to cap placement. Following performance of the bench-scale study, a pilot study was proposed to EPA to investigate the constructability of a field-scale sediment cap within Silver Lake. The pilot study was conducted in October and November 2006, and monitoring associated with the pilot study is expected to continue until May/June 2007. Results from the bench- and pilot-scale studies will further define the geotechnical and chemical responses to cap placement anticipated in Silver Lake sediments, and will inform the final cap design process for the entire lake.

Silver Lake Adjacent Soils

In addition to the sediments within the lake, the Silver Lake Area RAA includes the soils on the banks of several properties adjacent to the lake, including seven residential properties, nine commercial/industrial properties, and an unimproved strip of land (considered to be in "recreational" use) along the northern and eastern sides of the lake, much of which is owned by the City of Pittsfield. This RAA also includes the soils within certain non-bank portions of some of these properties. Investigations performed by both GE and EPA have resulted in the collection and analysis of numerous soil samples from and adjacent to these properties. The results of these investigations have been submitted to EPA in a series of reports and are nearly completed. Following completion of all investigations, GE will submit a Conceptual Removal Design/Removal Action (RD/RA) Work Plan evaluating the need for and scope of soil remediation actions at these properties to achieve the Performance Standards set forth in the CD. GE anticipates submitting that work plan in May 2007.

2.3.7 West Branch of the Housatonic River

The West Branch of the Housatonic River is currently being addressed by GE under a separate Administrative Consent Order (ACO) executed by MDEP and GE in November 2000. Various investigations have been performed by EPA (in 1999), MDEP (in 2000), and GE (most recently in 2005-06), and have included collection of a significant number of riverbank soil, sediment, and surface water samples for analysis of PCBs, with limited sampling for other constituents. Investigations have focused largely on the stretch of the West Branch between the Confluence of the East and West Branches and Dorothy Amos Park (located just upstream of the West Street Bridge). The most intensive sampling was conducted on the lower riverbanks and sediments in the area adjacent to Dorothy Amos Park (at which GE had conducted remediation of the upland area and upper banks in 1998).

Based on a review of the available sampling data, GE concluded, with MDEP concurrence, that remedial actions were not necessary in the West Branch except in the area adjacent to Dorothy Amos Park. For the latter area, although GE has not conceded that the PCBs found in the West Branch and the Park derived from fill materials or other waste materials that may have originated at the GE facility in Pittsfield., GE has agreed to carry out certain remedial actions within the lower riverbanks and sediments of the West Branch adjacent to the Park under the ACO. On October 27, 2006, in accordance with a directive from MDEP, GE submitted a revised conceptual remediation proposal providing for the removal of PCB-containing sediments from an approximate 350-foot reach of the West Branch adjacent to Dorothy Amos Park, as well as the removal and replacement of certain lower riverbank soils in that area. The MDEP provided conditional approval of that proposal on November 22, 2006; and GE anticipates submitting to MDEP a detailed Remedial Action Work Plan for that remediation in the near future, likely in April 2007.

2.4 Nature and Extent of Constituents

A number of investigations have been conducted since the mid-1970s by GE, EPA, and others to characterize the nature and extent of contaminants in the Rest of River portion of the Housatonic River. The results of these investigations have indicated that PCBs are the primary constituent of concern. This section therefore focuses primarily on the nature and extent of PCBs in the Rest of River media. Other constituents are briefly discussed in Section 2.4.4.

The CMS evaluation will focus on current conditions in the various media of the River. Consequently, older data sets (e.g., those containing sample data in the late 1970s and early 1980s), which may not be representative of current conditions, will be disregarded in favor of the more recent data. The data sets utilized in this CMS Proposal to describe nature and extent of PCBs are generally consistent with those described in the RFI Report (BBL and QEA, 2003) and in EPA’s human health and ecological risk assessments and its modeling study. Where appropriate, data collected since the issuance of the above reports have been included in the data assessment contained herein. These data sets will also form the basis for the evaluations that will be conducted to evaluate potential corrective measures during the CMS.

2.4.1 PCBs in River

2.4.1.1 Sediment PCBs

As described in the RFI Report, the 1998-2002 EPA data set (combining EPA’s systematic and discrete sampling results) is an appropriate data set for characterizing current sediment conditions in the River (BBL and QEA, 2003). This data set: 1) provides the most recent sediment PCB measurements; 2) contains the greatest number of samples; 3) provides the most comprehensive spatial coverage; and 4) contains the most consistent vertical segmentation scheme. In addition, the GE/BBL data collected in December 1997 through 1998 were included in the evaluation of nature and extent for reaches downstream of Woods Pond Dam as these data represent a significant fraction of the available PCB data in these areas, particularly downstream of Rising Pond. Thus, the sediment data sets proposed for use in evaluating sediment corrective measures during the CMS will consist of the EPA systematic and discrete samples from 1998-2002 downstream of the Confluence, and the 1997-1998 GE/BBL data for reaches downstream of Woods Pond Dam.

The average and median PCB concentrations in the top three feet of sediments are shown, by reach, on Figure 2-8. In general, average sediment PCB concentrations are highest in Reaches 5A and 6 (Woods Pond) ranging between 15 and 40 mg/kg; somewhat lower average concentrations are observed in Reaches 5B and 5C and the backwaters upstream of Woods Pond, ranging from 5 to 25 mg/kg. Downstream of Woods Pond Dam, average PCB concentrations in Reach 7 are lower than those observed in Reaches 5 and 6 (approximately 1 to 2 mg/kg). In Rising Pond (Reach 8), average 0- to 6-inch sediment PCB concentrations (~2 mg/kg) are lower than those in Reaches 5 and 6. Some locally higher PCB concentrations occur in relatively slow-moving portions of the River such as backwater areas and areas immediately upstream of dammed portions of the channel such as Woods Pond (Reach 6) and Rising Pond (Reach 8). These dammed areas and backwater reaches are low energy environments that promote the deposition of fine-grained sediments and associated PCBs.

Sediment depth profiles of PCB concentrations are highly variable. In Reaches 5A and 5B, average PCB concentrations show no clear pattern in the top three feet of sediment. In Reach 5C, Woods Pond, and the backwaters, highest average PCB concentrations are generally observed in the top foot of sediments (0- to 6-inch and 6- to 12-inch depths), with lower concentrations observed in deeper intervals (Figure 2-8). In Rising Pond (Reach 8), average PCB concentrations generally increase with depth within the top 3 feet of sediment (Figure 2-8); this profile indicates a temporal decline in particulate-phase PCB concentrations on depositing particles. Due to the higher rates of deposition occurring in the backwaters and dammed portions of the River (such as Woods Pond and Rising Pond), PCBs in these areas are found at greater depths than in other portions of the channel.

As discussed in the RFI Report, sediment PCB concentrations appear to relate to a number of variables, including percent solids, grain size, and total organic carbon (TOC). While there is considerable variability in the data, higher PCB concentrations are generally found in areas with finer-grained sediments containing lower percent solids and higher TOC, such as areas behind dams and in backwater areas.

2.4.1.2 Surface Water PCBs

As discussed in the RFI Report, spatial and temporal trends in surface water PCB concentrations can be characterized by the monthly and bi-weekly water column monitoring collected by GE and EPA since 1996. These data have been collected between the Dawes/Pomeroy Avenue Bridge station in Pittsfield and the Division Street Bridge station in Great Barrington. This sampling began in 1996 as part of the MCP Supplemental Phase II/RFI activities, and provides the most comprehensive and consistent sampling of the Housatonic River for evaluating the spatial distribution of water column PCBs. Discussion of water column PCB spatial patterns presented in the RFI Report and Modeling Framework Design (MFD; EPA, 2004b) used data collected between 1996 and 2002; since that time, approximately 3 years of additional water column data have been collected by GE (2003 through 2005). The evaluation of water column PCB concentrations summarized below has been updated to include these additional data.[1] Thus, the water column data collected by GE and EPA between 1996 and 2005 will be used to characterize water column concentrations during the CMS.

An extensive data set from six river monitoring stations is available from the downstream terminus of the East Branch and within the Rest of River region (see Figures 2-2, 2-3, and 2-4) for assessing the nature and extent of water column PCBs: 1) Dawes/Pomeroy Avenue Bridge (East Branch) 2) Holmes Road Bridge, 3) New Lenox Road Bridge, 4) Woods Pond Headwaters, 5) Schweitzer/Lenoxdale Bridge, and 6) Division Street Bridge (see Figure 2-3 and 2-4). These sampling locations were selected as they provide the most consistent, comparable, and broadest sampling record for Reaches 5 through 9.

Average water column PCB concentrations (1996-2005) generally increase with distance downstream between the Confluence and Reach 5C from approximately 60 nanograms per liter (ng/L) at Holmes Road to 110 ng/L at Woods Pond Headwaters (Figure 2-9). Deposition of particulate phase PCBs within Woods Pond reduces average PCB concentrations observed downstream of the Pond (i.e., Schweitzer/Lenoxdale Bridge) to approximately 65 ng/L. Dilution by tributary waters produces an additional reduction in average PCB

[1] The inclusion of data from 2003 to 2005 in this analysis does not significantly change the observed water column spatial patterns presented in the RFI Report. One exception is the observed spatial pattern between Dawes/Pomeroy and Holmes Road where, prior to inclusion of the 2003-2005 data, average water column PCB concentrations increased between Dawes/Pomeroy and Holmes Road. In the updated analysis, the average concentration at Dawes/Pomeroy is somewhat higher than that observed at Holmes Road, likely due to upset conditions associated with the remediation in the 1½-Mile Reach during this period, as discussed in Section 2.3.4.

concentration at the downstream-most station near Great Barrington at Division Street to approximately 25 ng/L.

In addition to the Rest of River stations described above, a number of stations within the 2-mile reach of the East Branch between GE's Pittsfield plant and the Confluence have been sampled for various periods between 1996 through 2006. These stations include Hubbard Avenue Bridge, Newell Street Bridge, Newell Street Footbridge, Lyman Street Bridge, and the Elm Street Bridge (see Figure 2-2). Data from these stations were used during the Building 68 Area, Upper-½ Mile Reach, and 1½-Mile Reach Removal Actions (see Section 2.3) to monitor the effects of those remediation activities. Since the completion of these activities, the PCB data from these stations have been largely below the detection limit of 22 ng/L.

The West Branch of the Housatonic River has also been sampled on a number of occasions. It was sampled by GE in the 1990s and by EPA during the 1998-1999 period at one station to quantify PCB loading into the Rest of River region. In addition, in 2005, GE collected surface water samples at three locations on the West Branch (one upstream and one downstream of Dorothy Amos Park and one near the Confluence) on four occasions. Apart from one sampling event, in which the results were considered anomalous due to the detection of PCBs in the rinse blank, the results from these recent sampling events showed no detected PCBs in either unfiltered or filtered samples, with the last two events using a detection limit of 22 ng/L for surface water samples.

2.4.2 PCBs in Floodplain/Riverbank Soil

High-flow events in the River periodically cause flooding of the lower elevations of the Rest of River study area. During these flood events, particulate phase PCBs are transported into the River floodplain and deposited onto floodplain soils. A number of studies have been conducted since the late 1980s to characterize PCB concentrations in floodplain and riverbank soils within the Rest of River area. Between 1988 and 1998, GE collected over 1,000 floodplain soil samples along the Massachusetts portion of the Rest of River. Between 1998 and 2002, EPA collected more than 5,000 floodplain soil samples. EPA's sampling in Reach 5 also included several vernal pools located within the floodplain (as identified by EPA). In 2005, GE collected approximately 100 soil samples to further characterize the extent of PCBs in select areas of Reaches 5A, 7B, 7C, and 7D.

The above-described soil data collected from the Rest of River area floodplain, riverbanks, and vernal pools will form the basis for the corrective measures evaluations conducted during the CMS. This data set is more inclusive than that used to assess sediment and water column PCB conditions since the floodplain soils are not as dynamic a medium as surface water or sediment, and thus floodplain soil PCB concentrations are not expected to change as much over time. Moreover, the size of the floodplain area warrants the use of the broadest coverage of data available.

The average and median floodplain, riverbank, and vernal pool soil PCB concentrations are shown, by reach, on Figure 2-10. The highest average PCB concentrations in floodplain and riverbank soils occur in Reaches 5 and 6 (Woods Pond) where concentrations range from approximately 15 to 30 mg/kg, with substantially lower concentrations occurring downstream of Woods Pond Dam where average concentrations are generally less than 2 mg/kg. PCB concentrations in vernal pool soil samples are generally higher in Reaches 5A and 5B (~25 to 30 mg/kg) than in Reach 5C (~ 5 mg/kg); only a few samples exist within Reach 6, and no samples were collected downstream of Reach 6. Similar to surface water and sediment PCB data, the median PCB concentrations, especially in the floodplain soil in Reaches 5 and 6, are considerably lower than the averages.
As shown in Figure 2-10, average PCB concentrations in riverbank and floodplain soils in Reaches 5A and 5B are similar, but the average riverbank concentration in Reach 5C is considerably higher than the average floodplain concentration. Median values are higher in riverbank than in floodplain soil in all three of these subreaches. The presence of higher PCB concentrations in the riverbank soils is expected due to the increased contact that riverbanks have with the surface water and sediment. In most reaches, vernal pool PCB concentrations are higher than those in the floodplain and riverbank soils, due to the significantly higher organic carbon content of fine-grained deposits in the vernal pools. However, in Reach 5C, the vernal pool PCB concentrations are much lower than those in the floodplain and riverbank soils.

Floodplain PCB concentrations generally decrease with distance from the River channel due to decreased flood frequency in the more distant portions of the floodplain. For example, average PCB concentrations in the 2- to 10-year floodplain of Reaches 5 and 6 are substantially lower than those in the 2-year floodplain, and the great majority of PCB concentrations beyond the 10-year floodplain in those reaches are at or below 1 mg/kg.

PCB concentrations in the top 2.5 feet of soil in Reach 5 generally show little variation with depth; average PCB concentrations in Reach 6 generally decrease with depth. The limited vernal pool data at depth suggest that PCB concentrations in those areas are highest in the upper 6 inches of soil, and generally decrease with depth.

2.4.3 PCBs in Biota

Rest of River biota investigations have involved sampling of a wide variety of organisms, including fish, invertebrates, reptiles and amphibians, birds, and small mammals, as well as naturally occurring and crop vegetation. The majority of these data were collected between 1998 and 2001 in Reaches 5 and 6. Since several of the IMPGs apply to the concentrations of PCBs in the tissue of fish that may be consumed by humans or wildlife (see Sections 3.2.3.2 and 3.2.4 below), the discussion of nature and extent of PCBs in biota provided below focuses primarily on fish tissue data. Further, fish tissue data provide the most comprehensive data set for evaluating spatial patterns in biota within Massachusetts and Connecticut. A brief summary, including the data sets to be used in the corrective measures evaluation, is provided below.

In the RFI Report, spatial trends in adult fish PCB concentrations in the Massachusetts portion of the Rest of River were evaluated using data from EPA's 1998 sampling effort. These data include multiple species that were collected from Reaches 5, 6 (Woods Pond), and 8 (Rising Pond). White sucker data (whole-body individuals only) collected by EPA from Reach 5 and Woods Pond in 2000 were also included. This data set was supplemented with additional fish data collected by GE in 1998 to provide further data in Rising Pond (Reach 8) and data in a downstream reach (Reach 9) that was not sampled by EPA. In addition, largemouth bass data collected by GE in 2002 were included in the evaluation. In addition to the adult fish tissue PCB data described above, GE has conducted a biennial young of the year (YOY) fish sampling and analysis program since 1994. The GE program targets the young-of-year of three species (largemouth bass, yellow perch, and pumpkinseed or bluegill depending on abundance) from four locations within Reaches 5, 6, 7, and 9. The YOY data represent, for each collection year, a set of exposure conditions during the fishes' first year of life. As such, these data will be one of the first to reflect changes in PCB exposure in response to remediation conducted within the river. The most recent data available from this program are those from 2006. The data sets described above will be used to define current conditions in fish tissue during the CMS.

To evaluate trends in fish PCB concentrations in the Connecticut portion of the River, the RFI Report used fish sampling data collected biennially by the Academy of Natural Sciences of Philadelphia (ANSP) on behalf of GE. The most recent data available from this program are those from 2004; the 2006 data are expected to be available in the summer of 2007. Smallmouth bass data from this data set were used to assess spatial trends since smallmouth bass have consistently been collected from the greatest number of locations and generally have the largest sample sizes in the ANSP program. The ANSP data, and particularly the most recent data, will be used during the CMS to characterize current levels and trends in Connecticut fish tissue PCB concentrations.

Similar to the other media described above, the highest fish tissue PCB concentrations occur in Reach 5 and Reach 6 (Woods Pond). However, within these reaches, there is considerable variability among species, due to variability in tissue lipid content, size differences, and shifts in diet between sediment and water column food sources (BBL and QEA, 2003). In these reaches, average fish tissue concentrations in adult fish fillet samples are generally in the range of 5 to 25 mg/kg (Figure 2-11, upper panel). Average whole-body adult fish tissue concentrations in Reaches 5 and 6 are higher than the fillets, ranging from 35 to 105 mg/kg (Figure 2-11, lower panel). In the reaches between Woods Pond Dam and the Connecticut border, fish tissue PCB concentrations decline, reaching average levels below 10 mg/kg in adult fillets in Reaches 8 and 9 (Figure 2-11, upper panel). Average whole-body adult fish tissue concentrations in Reach 8 are higher than the fillets, ranging from 5 to 50 mg/kg. Similar to the spatial trends in adult fish tissue concentrations, average YOY fish PCB concentrations are generally higher in Reaches 5 and 6 than in Reach 7 and Reach 9. For example, average YOY largemouth bass PCB concentrations above Woods Pond Dam ranged from 15 to 41 mg/kg, but only from 1.3 to 17 mg/kg from locations below the dam to the Connecticut border (GE data, all years).

In the Connecticut reaches of the River, average PCB concentrations in smallmouth bass fillets have been less than approximately 1 mg/kg at each of the four monitoring locations since 1996 (Figure 2-12). Smallmouth bass PCB concentrations decline between the two upstream locations (West Cornwall and Bulls Bridge) and the two downstream locations (Lakes Lillinonah and Zoar), where average values have been approximately 0.5 mg/kg since 1996. The average PCB concentrations in brown trout fillets, which are sampled only at West Cornwall, have ranged from 1.5 to 2.7 mg/kg in the 1994-2004 period.

2.4.4 TEQ Concentrations and Relationship with PCBs

In addition to PCBs, EPA's HHRA and ERA quantified potential risks associated with dioxin Toxicity Equivalency Quotients (TEQs) for certain exposure pathways and receptors. Dioxin TEQs are a measure of the toxicity of different combinations of dioxins and dioxin-like compounds relative to the most potent dioxin congener, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Under the approach used by EPA, total TEQ concentrations are calculated by: (a) multiplying the concentrations of polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran compounds, as well as certain so-called "dioxin-like" PCB congeners, by toxicity equivalency factors (TEFs) developed by the World Health Organization (WHO) to weight the toxicity of each such compound relative to 2,3,7,8-TCDD (van den Berg et al., 1998); and (b) then summing those concentrations.[2] In addition, as discussed in Section 3.2 below, IMPGs have been developed for TEQs in certain media based on the exposure pathways and receptors for which EPA included a quantitative evaluation of TEQ risks in its risk assessments. These media are: fish and waterfowl tissue based on human consumption; fish tissue based on potential risks to the fish themselves; and the prey items of insectivorous birds and piscivorous mammals.

The data sets that characterize PCBs in river sediment, floodplain soils, and fish tissue (described in Sections 2.4.1, 2.4.2, and 2.4.3, respectively) also contain measurements of congener-specific PCBs and dioxins/furans, which support calculation of TEQs, but only for a subset of the samples. Of the samples used to quantify total PCBs, approximately 2% of floodplain soil samples, 5% of river sediment samples, and 90% of fish samples were analyzed for both congener-specific PCBs and dioxins/furans. Thus, the data available to evaluate TEQs are more limited than the total PCB data.

Given this more limited data set, GE has made an assessment of the feasibility of evaluating TEQs in the CMS. The results of this assessment are presented in Appendix A. As discussed in that appendix, there is no direct means to quantitatively assess the ability of remedial alternatives to achieve various TEQ levels, because: (a) the EPA fate, transport, and bioaccumulation model that GE is required to use in the CMS to assess sediment remedial alternatives is limited to PCBs and does not predict TEQ concentrations in any of the media to which the model applies (i.e., water, sediment, and fish tissue); and (b) the data on TEQ concentrations in floodplain soil are too limited to allow an assessment of the impact of floodplain remedial alternatives on TEQ concentrations in the soil.

As further discussed in Appendix A, GE has also evaluated the relationship between total PCB concentrations and total TEQ concentrations to assess the extent to which PCB concentrations could serve as a possible surrogate for TEQ concentrations in the CMS. The results of this evaluation demonstrate that the relationship between PCB concentrations and TEQ concentrations shows a moderate correlation for floodplain soil, a weak correlation for sediments, and a good correlation for fish tissue at higher PCB concentrations, but not at the lower end of the PCB concentration range. Furthermore, the relationships are significantly affected by the treatment of non-detect results. These evaluations indicate qualitatively that implementation of remedial alternatives that would reduce PCB concentrations in these media would likely also reduce TEQ concentrations.

2 In prior submissions to EPA, GE made clear its position that the current scientific evidence does not support the inclusion of PCB congeners in the TEQ approach for assessing human health effects (GE, 2001, 2003; AMEC and BBL Sciences, 2003, 2005).

However, the relationships are not sufficiently robust to allow a reliable quantitative evaluation of TEQs in the CMS.

Moreover, as also discussed in Appendix A, a recent report by the National Research Council of the National Academy of Sciences (NRC, 2006) reviewing EPA's draft Dioxin Reassessment indicates that the method used by EPA to calculate TEQs, at least for human exposure, could produce inaccurate results and is thus unreliable.

With respect to other constituents, while some have been detected in samples of the various media in the Rest of River area, those constituents are generally present at levels that are low relative to background or screening levels, were generally not included in EPA's risk assessments, and were not subject to the development of IMPGs (with EPA approval) (see GE's revised IMPG Proposal, p. 10). As such, other constituents will not be considered further in this CMS Proposal or in the CMS.

For the foregoing reasons, this CMS Proposal focuses on PCBs in discussing the pertinent site information and in identifying and screening potential remedial technologies, and the forthcoming CMS will likewise focus on evaluating alternatives for remediating PCBs in sediments and floodplain soil.

2.5 Conceptual Site Model

The following conceptual site model was developed by GE based on the analysis of the available site data as presented in the RFI Report (BBL and QEA, 2003). This conceptual model is generally consistent with that provided by EPA in the MFD (EPA, 2004b). It should be noted that estimates of water column PCB loading provided in this section were based on the simple weighted averaging approach used in the RFI Report; the values have been updated to reflect the most recent data. In the modeling studies, EPA used alternate approaches to quantify PCB loads: a somewhat more complicated data-based approach was presented in the MFD, and the PCB fate and transport model was used to compute long-term loading estimates over a 26-year period, as presented in the Final Model Documentation Report (FMDR) (EPA, 2006c). Thus, the magnitude of the loads presented in this section differs from those developed using the other methods. Nonetheless, the overall spatial pattern in PCB loadings described below is generally consistent among the various methods.

Historical PCB releases from the GE Pittsfield facility distributed PCBs within the Housatonic River's sediments and floodplain. Historically, PCBs enter the Rest of River at the Confluence, primarily from the East Branch. The completion of the Upper ½-Mile and 1½-Mile Reach Removal Actions will reduce the amount of

PCBs entering the Rest of River from the East Branch. Increases in surface water PCB concentrations across Reach 5 indicate that PCBs contained in the River's sediments and riverbank soils in these reaches move into the water column. Under lower flows, PCBs within the sediment pore waters diffuse up into the overlying water column, causing the PCB loading to increase between the Confluence and Woods Pond (Figure 2-13). At higher flows, erosional processes generally occur within Reach 5A and the upper portion of Reach 5B. PCBs are introduced into the water column when sediments and riverbank soils are resuspended from these areas as a result of shear stress produced by rising current velocities. PCB mass transport during these periods is substantially higher than at lower flows (Figure 2-13). Analyses of solids and PCBs during higher flows indicate that Reach 5C and the adjacent backwaters are generally depositional. Similarly, decreases in solids and PCB fluxes between Reach 5C and Woods Pond Dam indicate that Woods Pond is generally depositional. Deposition of PCBs and solids also occurs within the Reach 5 floodplains when the River experiences overbank flow conditions caused by high flows.

Downstream of Woods Pond Dam, dilution from increased flows causes reductions in PCB concentrations, and other processes (such as deposition and volatilization) result in a further decrease in the mass of PCBs transported within those reaches. "Clean" solids that enter the River in these downstream reaches and are deposited in quiescent areas act to dilute the concentrations of PCBs in the surface sediments.
PCBs in the water column and sediments of the system are taken up by organisms that feed in the River and its floodplains. Analysis of fish data collected from Reaches 5 and 6 indicates that PCB uptake in most fish species derives from a mixture of water column and sediment sources. Data from Rising Pond suggest that PCB uptake of fish in this reach may be more linked to water column sources.

2.6 PCB Mass

The following sections briefly summarize the PCB mass estimates for Housatonic River sediment and floodplain/riverbank soil that were presented in the RFI Report (BBL and QEA, 2003). These mass estimates are highly uncertain due to: 1) the spatial variability of both the physical and chemical characteristics of sediment and soil; 2) the highly variable density and distribution of available data; 3) the inherent need to extrapolate the representativeness of available data over large volumes of sediment and soil; and 4) the compounding effect of combining all these uncertainties in the resulting mass estimates. Given all of these factors, mass estimates provided in the RFI Report were presented as ranges, rather than a single value, for each River reach. A brief summary is provided below.

2.6.1 Sediment

The calculated ranges of PCB mass (in pounds [lbs] of PCBs) in each reach, as set forth in the RFI Report, are shown in Table 2-7 below.

Table 2-7
Estimated Sediment PCB Mass

	PCB Mass Estimate (lbs)
Confluence to Woods Pond	13,000 – 51,000
Backwaters Above Woods Pond	2,000 – 18,000
Woods Pond	3,000 – 29,000
Woods Pond Dam to Rising Pond Dam	3,900 – 14,000
Rising Pond Dam to Connecticut Border	60 – 110
Connecticut Border to Long Island Sound	120 – 5,000
Rounded Total	**22,000 – 117,000**

The large range in these PCB mass estimates highlights the uncertainty inherent in the calculations. However, this evaluation demonstrates that approximately 80% of the sediment PCB mass is contained within the PSA (i.e., Reaches 5 and 6, including backwaters). Approximately 15% of the mass is within the next two downstream reaches (Reaches 7 and 8), while the remaining 5% is downstream of Rising Pond.

2.6.2 Floodplain and Riverbank Soil

The calculated ranges of PCB mass in floodplain soils for each reach, as set forth in the RFI Report, are shown in Table 2-8 below.

Table 2-8
Estimated Floodplain/Riverbank PCB Mass

Reach	PCB Mass Estimate (lbs)
Reach 5A	54,000 – 255,000
Reach 5B	12,300 – 76,000
Reach 5C	14,000 – 105,000
Reach 6 (Woods Pond)	350 – 4,800
Reach 7	5,300 – 15,000
Reach 8 (Rising Pond)	30 – 90
Reach 9	2,400 – 2,800
Rounded Total	**89,000 – 459,000**

Similar to the sediment PCB mass estimates, the great majority of the floodplain PCB mass (approximately 90-95%) is contained upstream of Woods Pond Dam.

3. Remedial Goals

3.1 Preliminary Remedial Action Objectives

This section identifies certain Remedial Action Objectives (RAOs) for the remedial alternatives that will be evaluated in the CMS. The Reissued RCRA Permit does not require that specific RAOs be included in the CMS Proposal or considered in the CMS. However, it does require, as one of the "General Standards" for evaluation of potential corrective measures (Permit Special Condition II.G.1), that GE evaluate how such measures would provide overall protection of human health and the environment. In these circumstances, GE has developed RAOs focused on protecting human health and the environment. These objectives are summarized below and discussed in greater detail in Sections 5.2.4.1 and 5.3.5.1.

For human health protection, the RAO is to achieve a condition in which PCB concentrations in the sediment, floodplain soil, and biota in the Rest of River do not present significant risks of harm (as determined by reference to EPA's cancer risk range of $1x10^{-6}$ to $1x10^{-4}$ and a non-cancer Hazard Index of 1) to the health of individuals who contact the soil or sediment or who consume fish, waterfowl, or agricultural products from the Rest of River area.

For protection of the environment, the RAO includes the goal of achieving a condition in which PCB concentrations in the sediment, floodplain soil, and biota in the Rest of River do not prevent the maintenance of healthy local populations and communities of biota, when evaluated against any adverse environmental impacts of the remedial action. This RAO is consistent with EPA guidance on ecological risk assessment and risk management. EPA guidance makes clear that the general goal for ecologically based response actions is to "reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota" (EPA, 1999a, p. 3).[3] The Agency's guidance indicates further that the goal of overall environmental protection also includes consideration of "the potential impacts of the selected remedy on the environment" (EPA, 1997, p. 8-3) and whether the cleanup would "cause more ecological harm than current site conditions" (EPA, 1999a, p. 6). Thus, EPA (1999a) highlights "the importance of considering both the short-term and long-term effects of the various alternatives . . . in determining which ones 'adequately protect human

[3] For threatened and endangered species, this objective involves evaluation of effects on individual organisms because, given the already stressed nature of the populations of these species, such individual-level effects can adversely impact the local populations.

health and the environment'"; and it states that, "[e]ven though an ecological risk assessment may demonstrate that adverse ecological effects have occurred or are expected to occur, it may not be in the best interest of the overall environment to actively remediate the site" if the remediation would cause more ecological harm than leaving the contamination in place.[4]

In addition to the above RAOs, GE's revised IMPG Proposal (GE, 2006) included, at EPA's direction, a statement regarding the desired outcome of the human health and ecological goals for the Rest of River in terms of designated uses for that portion of the River. That desired outcome is that, for PCBs, the Rest of River portion of the Housatonic River will attain the designated uses defined in the Massachusetts and Connecticut water quality standards – namely: (a) for the Housatonic River from Pittsfield to the Connecticut border, "habitat for fish, other aquatic life, and wildlife," "primary and secondary contact recreation," "irrigation and other agricultural uses," and "compatible industrial cooling and process uses" (314 CMR 4.05(3)(b)); and (b) for the Connecticut portion of the river from the Massachusetts border to Lake Housatonic (Derby) Dam, "habitat for fish and other aquatic life and wildlife; recreation, navigation; and industrial and agricultural water supply" (Connecticut Water Quality Standards). As stated in the EPA-approved IMPG Proposal, these designated uses will not be used as specific comparison criteria in the evaluations of potential corrective measures in the CMS. Rather, the evaluations in the CMS will be based on the criteria specified in the Permit.

3.2 Interim Media Protection Goals

The Permit requires that the IMPGs that have been established for the Rest of River be considered in the CMS Proposal and the CMS. This section describes what IMPGs are and their role in the CMS process. It also describes, in general terms, the IMPGs that have been established for the Rest of River and summarizes the specific IMPGs for human health protection and for protection of ecological receptors.

3.2.1 Definition of IMPGs and Their Role in CMS

Under Special Condition II.C of the Reissued RCRA Permit, IMPGs are to consist of preliminary goals that have been shown to be protective of human health and the environment and that will be used in the CMS in evaluating potential remedial alternatives for the Rest of River. They apply to specific media in the Rest of River area (e.g., sediments, floodplain soils, biota) and must address both human health and ecological receptors. For human health protection, the IMPGs are to consist of numerical concentration-based values for

4 This point is amplified in Section 5.2.4.1 below.

constituents in the relevant media, based on direct contact with such media and consumption of edible biota, and they may also include narrative descriptive goals for such media. For ecological receptors, the IMPGs may consist of either numerical concentration-based goals or narrative descriptive goals, based on an assessment of exposures and risks to such receptors. The IMPGs are required to "take into account" the HHRA and ERA conducted by EPA. As the Permit makes clear, IMPGs are not equivalent to cleanup standards or Performance Standards for the Rest of River remedy, which will be developed in connection with the selection of that remedy.

The Permit also specifies the role of the IMPGs in the CMS. It requires that, in the CMS Report, GE must evaluate alternatives according to two tiers of factors (Special Condition II.G). The first tier consists of the "General Standards." This tier includes overall protection of human health and the environment, control of sources of releases, and compliance with federal and state ARARs (or, when an ARAR would not be met, the basis for a waiver of the ARAR); it does not include attainment of the IMPGs. The second tier consists of "Selection Decision Factors," which must be balanced against one another in evaluating alternatives. These factors include the ability of the alternatives to achieve the IMPGs, along with several other factors – namely, long-term reliability and effectiveness; reduction of toxicity, mobility, or volume of wastes; short-term effectiveness (including impacts to nearby communities, workers, or the environment during implementation); implementability; and cost.

3.2.2 Overview of IMPGs for Rest of River

In accordance with the schedule in the Permit, GE submitted an IMPG Proposal to EPA on September 6, 2005. On December 9, 2005, EPA issued a letter to GE disapproving that IMPG Proposal and directing GE to submit a revised IMPG Proposal that included a number of revisions required by EPA. GE disagreed with a number of EPA's directives for revising the IMPG Proposal and it preserved its position on those issues.[5] Nevertheless, as required by Permit, GE submitted a revised IMPG Proposal on March 9, 2006, which implemented EPA's

[5] Specifically, GE submitted a notice to EPA on January 23, 2006, in which it invoked dispute resolution, pursuant to the Permit, on EPA's disapproval of the September 2005 IMPG Proposal. GE explained that, while it believes that it was not required to take that step in order to preserve its objections for a later review proceeding, it was doing so as a protective measure; and it accompanied its notice letter with a summary Statement of Position outlining GE's main objections. At the same time, GE proposed to stay that dispute resolution proceeding until either (a) the time when GE can seek administrative dispute resolution regarding EPA's notification of its intended decision on the Permit modification to select corrective measures for the Rest of River, or (b) the time of an appeal of that Permit modification pursuant to the Permit and the CD. In a letter dated January 25, 2006, EPA agreed to the stay on the terms proposed by GE.

directives, as set forth in EPA's December 9, 2005 written comments or as modified or clarified by EPA in subsequent discussions between EPA and GE. EPA approved that revised IMPG Proposal on April 3, 2006.

The revised IMPG Proposal (GE, 2006) presented preliminary numerical concentration-based goals for the protection of both human health and ecological receptors. (GE did not include specific narrative descriptive goals in this revised Proposal.) From a human health standpoint, the revised IMPG Proposal addressed direct human contact with sediments and floodplain soil and human consumption of fish, waterfowl, and agricultural products from the Rest of River area. From an ecological standpoint, it addressed several groups of ecological receptors, including benthic invertebrates, amphibians, fish, and certain groups of birds and mammals. It presented concentration values for PCBs – and, in some cases, dioxin TEQs – in sediments, floodplain soil, fish tissue, and/or other biota tissue as relevant to these human and ecological receptors.[6]

To allow for full evaluation of an appropriate array of remedial alternatives in the CMS, the revised IMPG Proposal presented ranges of numerical concentration values (referred to in that document as "Risk-based Media Concentrations" or RMCs), rather than single numbers, for most pathways and/or receptors. For the health-based values, these ranges included values based on different sets of exposure assumptions – namely, EPA's Reasonable Maximum Exposure (RME) assumptions (representing more highly exposed individuals) and its Central Tendency Exposure (CTE) assumptions (representing individuals with average exposure). Further, for each set of assumptions, the ranges included values based on different risk levels within EPA's acceptable cancer risk range (namely, risks of $1x10^{-6}$, $1x10^{-5}$, and $1x10^{-4}$), as well as non-cancer-based values using a Hazard Index (HI) of 1. This use of ranges is consistent with the National Contingency Plan (NCP) under CERCLA, which specifies that, for known or suspected carcinogens, concentration levels will be considered protective if they represent an estimated excess upper-bound lifetime cancer risk to an individual between 10^{-4} and 10^{-6} (40 CFR § 300.430(e)(2)(i)(A)(*2*)). In addition, as directed in EPA's December 9, 2005 comments, the RME-based concentration values associated with a 10^{-6} cancer risk and a non-cancer HI of 1 were identified as "points of departure."

For the ecologically based values, for receptor groups for which EPA identified Maximum Acceptable Threshold Concentrations (MATCs) in the ERA, the ranges included the EPA MATCs, as well as certain other threshold levels which were derived from the ERA. In these cases, as directed by EPA, the values based on the MATCs were identified as "points of departure." For those receptor groups for which EPA did not calculate

6 The IMPG Proposal demonstrated, based on conservative screening-level assessments conducted by EPA, that there was no need to develop IMPG values for surface water or ambient air. Those conclusions were approved by EPA.

MATCs (namely, avian groups for which there are no site-specific effects data), the RMCs included values based on the literature. Specifically, for these groups, the RMCs for PCBs were derived using a calculated effect level of less than 20% from a literature study of the most sensitive avian species identified in the ERA (chickens); as directed by EPA, these RMCs were also identified as "points of departure."[7]

The use of these ranges of numerical values allows for consideration, in the CMS, of the extent to which the potential corrective measures under evaluation will achieve various values within these ranges. Although the values in these ranges were referred to as RMCs in the IMPG Proposal, we have, for ease of reference, referred to these values as IMPGs in the remainder of this CMS Proposal.

As required by EPA's directives, the numerical concentration values presented in the revised IMPG Proposal were calculated based directly on the exposure assumptions, toxicity values, and data interpretations and analyses used or set forth in EPA's HHRA and ERA. GE made clear, however, that the use of this approach in its revised IMPG Proposal did not indicate GE's agreement with or acceptance of those inputs. GE specifically preserved its position, set forth in prior submissions to EPA, that many of the exposure assumptions, toxicity values, and data interpretations in EPA's risk assessments are not supported by the data and substantially overestimate exposures, toxicity, and corresponding risks to humans and ecological receptors in the Rest of River area.

3.2.3 Human Health-Based IMPGs Presented in the IMPG Proposal

EPA's HHRA contained three separate assessments – an assessment of direct human contact with soil or sediment, an assessment of fish and waterfowl consumption, and an assessment of agricultural products consumption. Consistent with those three assessments and with the requirements in the Reissued RCRA Permit, GE developed health-based numerical IMPGs for PCBs in:

- Floodplain soil and sediment based on direct human contact with those media;
- Edible fish and waterfowl tissue based on human consumption of fish and waterfowl; and
- Edible agricultural products based on human consumption of those products.

[7] In addition, for wood ducks, a range of TEQ RMCs was derived based on the TEQ effect threshold range determined from a literature study of wood ducks.

Cancer-based IMPGs were calculated using three cancer risk levels within EPA's target risk range (10^{-6}, 10^{-5}, and 10^{-4}), and non-cancer hazard-based IMPGs were calculated using a target HI of 1.

3.2.3.1 Direct Contact IMPGs

IMPGs were developed for PCBs in floodplain soil and sediments based on direct contact of humans with such media via incidental ingestion and dermal contact.[8] Specific IMPGs, based on each potentially exposed age group of the target population, were developed for each of the following 15 direct contact exposure scenarios:

- Use of Actual/Potential Lawn areas of residential properties (not including riverbanks, areas with steep slopes, and wetland areas) by adults, older children, and young children;[9]
- Use by adults, older children, and young children of those portions of residential properties where the floodplain area consists of riverbanks, steep slopes, or wetlands;[10]
- General recreational use by adults, older children, and young children in high-use recreation areas;
- General recreational use by adults and older children in medium-use recreation areas;
- General recreational use by adults and older children in low-use recreation areas;
- Bank fishing by adults and older children;
- Dirt biking/ATVing by older children;
- Marathon canoeing by adults;
- Recreational canoeing by adults and older children;

[8] IMPGs were not calculated for TEQs based on direct contact because EPA's Direct Contact Assessment in the HHRA discussed TEQs only in its uncertainty analysis and did not include them in the main risk assessment.

[9] As noted in Section 1, the Actual/Potential Lawn areas at current residential properties downstream of the Confluence are not part of the Rest of River under the Reissued RCRA Permit and the CD, but are subject to a separate Removal Action under the CD. For these areas, the CD establishes a Performance Standard of 2 mg/kg for PCBs in soil (CD ¶ 28.b(i)). That Performance Standard was identified as an IMPG for completeness, although it is unlikely to be applied as part of the Rest of River remedy, since the Actual/Potential Lawns at current residential properties will be addressed by the separate Removal Action and it is anticipated that potential future residential uses will be addressed by deed restrictions and Conditional Solutions, as described in Section 4.4.2 below.

[10] For these portions of residential properties, the HHRA used the exposure assumptions for the general recreational use scenario with the exposure frequency considered relevant for the particular area involved – which was generally, but not always, the exposure frequency for high-use general recreational areas (see HHRA, Vol. IIIA, pp. 4-48 to 4-51, 5-23, 5-45). For these portions of residential properties, GE will use the IMPGs calculated for the general recreational scenario for the use category which is most applicable to the area in question (i.e., high-use, medium-use, or low-use).

- Waterfowl hunting by adults and older children;
- Agricultural use by adult farmers;
- Groundskeeping activities by adults in high-use commercial areas;
- Groundskeeping activities by adults in low-use commercial areas;
- Utility work by adults; and
- Sediment contact by adults and older children.

The IMPGs for these scenarios were back-calculated using the same exposure assumptions and toxicity values that were used in the HHRA. The specific exposure parameters, assumptions, absorption factors, and toxicity values used in calculating the IMPGs for each scenario and receptor were detailed in Appendix A of GE's revised IMPG Proposal. The IMPGs were derived based on the assumption that they would be applied as averages, rather than as not-to-exceed values, consistent with the approach used in the Direct Contact Assessment in the HHRA. These values are set forth in Table 3-1.

3.2.3.2 IMPGs for Fish and Waterfowl Tissue Based on Human Consumption

Numerical concentration-based IMPGs were developed for PCBs and TEQs in the edible tissues of fish and waterfowl based on human consumption of fish and waterfowl, using both deterministic and probabilistic approaches. For fish tissues, IMPGs were calculated for bass fillets, trout fillets, and duck breast tissue, based on the assumptions and parameters used in EPA's deterministic Fish and Waterfowl Consumption Risk Assessment (HHRA, Vol. IV). In addition, consistent with EPA's HHRA, IMPGs based on probabilistic techniques were developed using the one-dimensional Monte Carlo (1-D Monte Carlo) model that EPA used in the HHRA. For each type of edible tissue, IMPGs were derived for cancer risks based on combined adult and childhood exposure. Non-cancer IMPGs were separately derived for adults and children.

Six sets of IMPGs, including both deterministic and probabilistic IMPGs, were developed for the fish and waterfowl consumption pathways (with adults and children considered in each). These sets were as follows:

- IMPGs for PCBs based on consumption of bass;
- IMPGs for PCBs based on consumption of trout;
- IMPGs for PCBs based on consumption of waterfowl;

- IMPGs for TEQs based on consumption of bass;
- IMPGs for TEQs based on consumption of trout; and
- IMPGs for TEQs based on consumption of waterfowl.

The specific exposure parameters, assumptions, absorption factors, and toxicity values used in calculating the deterministic IMPGs for each scenario and receptor were detailed in Appendix B of GE's revised IMPG Proposal. The input distributions used in completing the 1-D Monte Carlo analyses were also provided in Appendix B of that document. Due to the lack of a non-cancer Reference Dose for dioxin, the potential non-carcinogenic effects of TEQs were not evaluated in the HHRA. Consistent with that approach, non-cancer IMPGs were not developed for TEQs.

As discussed in the revised IMPG Proposal (GE, 2006), to be consistent with the HHRA methodology, the IMPG values developed for bass consumption are applicable to consumption of largemouth bass, brown bullhead, sunfish, and perch, while the IMPG values for trout consumption are applicable only to the consumption of trout. These values are set forth in Table 3-2.[11]

3.2.3.3 IMPGs for PCBs in Agricultural Products Based on Human Consumption

Numerical concentration-based IMPGs were developed for agricultural biota consumed by humans. These IMPGs were based on human consumption of such products and were derived through back-calculations using the exposure assumptions and toxicity values in EPA's Agricultural Products Consumption Risk Assessment (HHRA, Volume V). Consistent with that assessment, IMPGs were calculated for PCBs in cow milk, beef tissue, poultry meat, and poultry eggs for both commercial and backyard farms.[12] For each type of farm, IMPGs were calculated for cancer risks (for adults and children combined) and for non-cancer impacts (for adults and children separately). In addition, to be consistent with the HHRA, IMPGs were calculated for homegrown produce consumed by humans – specifically, exposed fruit, exposed vegetables, and root vegetables. For these specific farm products, based on discussions with EPA, IMPGs were calculated for children only and were based on non-cancer health effects, using a target HI of 1. In addition, however, EPA summed the HIs for these

[11] For the reasons set forth in Section 2.4.4 above and discussed further in Appendix A, GE does not plan to make a separate quantitative evaluation of the ability of remedial alternatives to achieve the IMPGs for TEQs, due to the lack of a reliable means for doing so.

[12] IMPGs were not calculated for TEQs in agricultural products because EPA's Agricultural Products Consumption Assessment in the HHRA discussed TEQs only in its uncertainty analysis and did not include them in the main risk assessment.

three types of products to produce HIs for total produce. Thus, while it is unlikely that a child would eat all three types of produce grown in the floodplain at the rates assumed in the HHRA for each produce type, particularly the upper bound rates used in the RME analysis, GE also calculated IMPGs for total produce (i.e., all three food groups combined).

The specific exposure parameters, assumptions and toxicity values used in developing these IMPGs were provided in Appendix C of GE's revised IMPG Proposal. The numerical IMPGs for PCBs in edible farm animal and plant tissue based on consumption by humans are set forth in Table 3-3.

3.2.4 Ecologically Based IMPGs Presented in the IMPG Proposal

EPA's ERA evaluated risks to a number of ecological receptor groups, including benthic invertebrates, amphibians, fish, piscivorous birds, insectivorous birds, piscivorous mammals, omnivorous and carnivorous mammals, and threatened and endangered species. As required by the Reissued RCRA Permit, GE then developed ecologically based IMPGs for PCBs (and in some cases TEQs) for each of the ecological receptor groups evaluated in the ERA. For some receptor groups, these IMPGs consist of ranges of numerical values, while for others they consist of single values. For receptors groups for which EPA identified MATCs in the ERA, the IMPGs include the EPA MATCs.

As in the ERA, most of the IMPGs were developed based on the results of studies of specific species (i.e., wood frogs, ospreys, wood ducks, mink, short-tailed shrews, bald eagles) that are considered by EPA to be representative of broader receptor groups (i.e., amphibians, piscivorous birds, insectivorous birds, piscivorous mammals, omnivorous and carnivorous mammals, and threatened and endangered species). Thus, the derivation of the IMPGs reflects studies and life history characteristics specific to the selected receptor species, but the resultant IMPGs are considered to be protective of the range of species within each of the broader receptor groups.

The specific environmental media (e.g., sediment, floodplain soil, tissue) for which IMPGs were calculated varied with receptor group, depending upon the specific exposure medium and exposure pathways that were evaluated in the ERA for a given receptor. Depending upon the receptor group, exposure was evaluated using one of three approaches: (1) based on estimates of direct exposure to sediment or floodplain soil; (2) based on measured tissue concentrations in the receptor of interest; and (3) based on estimates of dietary exposure to prey items. The ecological receptor groups for which IMPGs were developed and the constituents and media to which those IMPGs apply are as follows:

- Benthic invertebrates (represented by the benthic invertebrate community) – PCBs in river sediment;
- Warmwater fish (represented by largemouth bass) – PCBs and TEQs in whole body fish tissue in the Primary Study Area (PSA) (the reach from the Confluence to Woods Pond Dam) and downstream of the PSA;
- Coldwater fish (represented by trout) – PCBs in whole body fish tissue downstream of the PSA;
- Amphibians (represented by wood frogs) – PCBs in floodplain vernal pool sediment;
- Piscivorous birds (represented by osprey) – PCBs in whole body fish tissue;
- Insectivorous birds (represented by wood ducks) – PCBs and TEQs in aquatic and terrestrial invertebrate prey;
- Piscivorous mammals (mink and otters) – PCBs and TEQs in prey items;
- Omnivorous mammals (represented by short-tailed shrews) – PCBs in floodplain soil; and
- Threatened and endangered species (represented by bald eagles) – PCBs in whole body fish tissue.

As recognized in EPA guidance, ecological risk assessment endpoints should be based on potential adverse effects on local populations and communities of biota, rather than individual organisms (EPA, 1999a, pp. 3, 5).[13] Nonetheless, to be consistent with the ERA, many of the IMPGs for the receptors listed above were derived from studies of effects at the organism level, rather than studies at the population or community level. In the ERA, EPA concluded that, where the endpoints from such studies relate to survival and/or reproduction, those endpoints "are expected to be strong indicators of potential local population-level effects," and that "extrapolation from organism-level to population-level effects may be logically achieved based on the predictive nature of the endpoint and/or through the use of process-based models" (ERA, Vol. 1, p. 2-68).

As required by EPA directives, the IMPGs for the above-listed receptor groups were based on EPA's exposure assumptions, toxicity values, and data interpretations and analyses set forth in the ERA. Given the focus of these IMPGs on local populations and communities, which integrate exposure over relatively large areas, the

[13] As noted in Section 3.1 above, for threatened and endangered species, such as the bald eagle, such an assessment can involve consideration of effects on individual organisms due to the potential impact that such effects can have on local populations that are already stressed.

IMPGs were derived based on the assumption that they would be applied as averages, rather than not-to-exceed values.[14] The IMPGs presented in the revised IMPG Proposal and approved by EPA are summarized in Table 3-4.[15]

3.3 Other Target Levels

In some cases, the IMPGs identified in Section 3.2 will need to be converted into values for other media in order to be applied in the CMS. These instances are discussed in this section.

3.3.1 Development of Floodplain Soil Levels from Tissue Concentration IMPGs Based on Agricultural Products Consumption

As indicated in Section 3.2.3, the IMPGs based on consumption of agricultural products by humans apply to PCB concentrations in the agricultural biota themselves – i.e., cow milk, beef tissue, poultry meat, poultry eggs, and homegrown produce (exposed fruit, exposed vegetables, and root vegetables). These IMPGs were developed for such biota at both commercial and backyard farms, using EPA's exposure assumptions and toxicity values in the HHRA.

In order to be used for evaluation in the CMS, these tissue-based IMPGs need to be converted to target PCB concentrations in floodplain soil for comparison to the average floodplain soil concentrations resulting from the remedial scenarios evaluated. For farm animals, this conversion requires that the animal tissue concentrations first be translated into concentrations in the products consumed by those animals (e.g., grass, corn) and then be translated into soil concentrations. For produce, the conversion requires translation from the produce values into soil values. At these target soil concentrations, the tissue burdens of PCBs in the agricultural products grown on, or exposed to, these soils will not exceed the IMPG values presented in Section 3.2.3.

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[14] This is also true for the IMPG for threatened and endangered species represented by the bald eagle given the large foraging range of bald eagles.

[15] As previously discussed in Section 2.4.4 and Appendix A, the CMS will not include a separate quantitative evaluation of the ability of remedial alternatives to achieve the TEQ IMPGs for fish, insectivorous birds, and piscivorous mammals due to the lack of feasible means of doing so. See also Sections 3.3.2.1 and 3.3.2.2 below.

Where necessary to evaluate particular remedial scenarios, the relevant tissue-based IMPGs will be converted into corresponding target soil concentrations using the following equations:[16]

From Ingestion of Dairy Products (milk)

$$C_{soil} = \frac{IMPG_{dairy}}{LC_{milk} * [(BCF_{mammal} * BA_{soil} * D_{soil}) + (BCF_{mammal} * D_{sil} * SCTF) + (BCF_{mammal} * D_{grass} * SGTF)]}$$

Where:

C_{soil} = Target soil concentration (mg/kg)

$IMPG_{dairy}$ = Previously determined IMPG (mg/kg)

LC_{milk} = Lipid content of milk (unitless)

BCF_{mammal} = Mammalian bioconcentration factor (unitless)

BA_{soil} = Bioavailability from soil (unitless)

D_{soil} = Fraction of diet that is soil (unitless)

D_{sil} = Fraction of diet that is silage (unitless)

SCTF = Soil to corn silage transfer factor (unitless)

D_{grass} = Fraction of diet that is grass (unitless)

SGTF = Soil to grass transfer factor (unitless)

From Commercial and Backyard Beef

$$C_{soil} = \frac{IMPG_{beef}}{LC_{beef} * [(BCF_{mammal} * BA_{soil} * D_{soil}) + (BCF_{mammal} * D_{sil} * SCTF) + (BCF_{mammal} * D_{grass} * SGTF)]}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

$IMPG_{beef}$ = Previously determined IMPG (mg/kg)

LC_{beef} = Lipid content of beef (unitless)

BCF_{mammal} = Mammalian bioconcentration factor (unitless)

[16] These equations have been developed to back-calculate target floodplain soil concentrations associated with the IMPGs for farms where the cropland or grazing land is 100% in the floodplain. Procedures for adjusting the resulting concentrations for farms where less than 100% of the cropland or grazing land is in the floodplain are described later in this section.

BA_{soil} = Bioavailability from soil (unitless)

D_{soil} = Fraction of diet that is soil (unitless)

D_{sil} = Fraction of diet that is silage (unitless)

SCTF = Soil to corn silage transfer factor (unitless)

D_{grass} = Fraction of diet that is grass (unitless)

SGTF = Soil to grass transfer factor (unitless)

From Ingestion of Poultry

$$C_{soil} = \frac{IMPG_{poultry}}{LC_{poultry} * (BCF_{poultry} * BA_{soil} * D_{soil})}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

$IMPG_{poultry}$ = Previously determined IMPG (mg/kg)

$LC_{poultry}$ = Lipid content of poultry (unitless)

$BCF_{poultry}$ = Avian bioconcentration factor on a fat basis (unitless)

BA_{soil} = Bioavailability from soil (unitless)

D_{soil} = Fraction of diet that is soil (unitless)

From Ingestion of Eggs

$$C_{soil} = \frac{IMPG_{egg}}{LC_{egg} * (BCF_{egg} * BA_{soil} * D_{soil})}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

$IMPG_{egg}$ = Previously determined IMPG (mg/kg)

LC_{egg} = Lipid content of egg (unitless)

BCF_{egg} = Avian bioconcentration factor on a whole food basis (unitless)

BA_{soil} = Bioavailability from soil (unitless)

D_{soil} = Fraction of diet that is soil (unitless)

From Ingestion of Homegrown Exposed Vegetables

$$C_{soil} = \frac{IMPG_{\exp}}{TF_{\exp}}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

$IMPG_{exp}$ = Previously determined IMPG for exposed vegetables (mg/kg)

TF_{exp} = Transfer factor for exposed vegetables (unitless)

From Ingestion of Homegrown Root Vegetables

$$C_{soil} = \frac{IMPG_{root}}{TF_{root}}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

$IMPG_{root}$ = Previously determined IMPG for root vegetables (mg/kg)

TF_{root} = Transfer factor for root vegetables (unitless)

From Ingestion of Homegrown Fruit

$$C_{soil} = \frac{IMPG_{fruit}}{TF_{fruit}}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

$IMPG_{fruit}$ = Previously determined IMPG for fruit (mg/kg)

TF_{fruit} = Transfer factor for fruit (unitless)

In making these back-calculations of target soil concentrations, GE will, as required, use the same assumptions and exposure variables that EPA used in its Agricultural Product Consumption Assessment (HHRA, Volume V;

see Table 4-11) to convert from soil concentrations to concentrations in the agricultural biota. The RME assumptions will be used in combination with the RME-based IMPGs, and the CTE assumptions will be used in combination with the CTE-based IMPGs. The assumptions and exposure variables to be used in back-calculating target soil concentrations for the commercial farm scenarios (which include those involving consumption of cow milk, beef tissue, poultry eggs, poultry meat, exposed fruit, exposed vegetables, and root vegetables) are listed in Table 3-5. The assumptions and exposure variables to be used for making such back-calculations at backyard farms are provided in Table 3-6. It should be noted that while the equations provided above are general equations for each pathway evaluated, the exposure pathways are not all the same for commercial farms and backyard farms. The differences can be seen by comparing Tables 3-5 and 3-6.[17]

The target floodplain soil levels resulting from these initial calculations would apply to properties where the farmland in question (i.e., the growing or grazing land) is completely contained within the floodplain. However, for areas where the farmland is not entirely contained within the floodplain, these levels will be adjusted to take into account the portion of the farmland that lies within the floodplain. This will be accomplished by dividing the target soil concentration for the appropriate scenario resulting from the above equations (i.e., the concentration derived assuming that 100% of the farmland is within the floodplain) by the fraction of the cropland or grazing land that falls within the floodplain at the particular farm property involved.

By way of example, for a commercial dairy farm, the target soil PCB concentration associated with the IMPG for RME exposure to cow milk at a 10^{-5} cancer risk (0.00026 mg/kg, as shown in Table 3-3) will be calculated as follows for a farm where 100% of the cropland is within the floodplain.[18]

$$C_{soil} = \frac{IMPG_{dairy}}{LC_{milk} * BCF_{mammal} * D_{sil} * SCTF}$$

Where:

C_{soil} = Target concentration in soil (mg/kg)

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[17] For some of the parameters listed in these tables, GE has previously presented its position that the assumptions and values used in the HHRA overstate the actual transfer from soil to plants and/or from those plant materials into the biota consumed by humans, as discussed in GE's prior comments on the HHRA (e.g., AMEC and BBL, 2003, 2005; GE, 2003). These parameters include the soil-to-grass transfer factor, the soil-to-corn transfer factor, and the bioconcentration factor (BCF) for transfer from feed to milk fat in cattle.

[18] For the determination of C_{soil} based on consumption of milk from a commercial dairy farm, only the PCB transfer from soil to silage will be evaluated, consistent with EPA's HHRA. This is due to the fact that dairy cattle are not grazed and thus do not receive exposure through ingestion of floodplain grass or soil.

$IMPG_{dairy}$	=	IMPG of 0.00026 mg/kg for RME exposure at 10^{-5} cancer risk (Table 3-3)
LC_{milk}	=	Lipid content of milk (0.046)
BCF_{mammal}	=	Mammalian bioconcentration factor (3.6)
D_{sil}	=	Fraction of diet that is silage (0.55)
SCTF	=	Soil to corn silage transfer factor (0.0012)

Substitution of the exposure values in this equation results in the following target soil concentration for a commercial dairy farm with 100% of the cropland in the floodplain:

$$C_{soil} = \frac{0.00026}{0.046 * 3.6 * 0.55 * 0.0012} = 2.4 \text{ mg/kg}$$

For a commercial dairy farm where only a portion of the cropland is within the floodplain, this target soil concentration will be adjusted by dividing the initially calculated value by a percentage representing the portion of cropland within the floodplain.

Table 3-7 (below) presents the target floodplain soil PCB concentrations associated with all the RME-based IMPGs for cow milk at a commercial dairy farm, using assumptions that 100%, 75%, 50%, 25%, and 10% of the cropland is within the floodplain:

Table 3-7
Target Floodplain Soil PCB Concentrations Associated with RME IMPGs at Commercial Dairy Farms

Portion of Cropland Within Floodplain	Target Soil Concentrations (in mg/kg) Associated with IMPGs for RME Exposure to Cow Milk at Commercial Dairy Farms (as shown in Table 3-3)				
	Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer – Child	Non-Cancer – Adult
100%	0.24	2.4	24	2.7	12.8
75%	0.32	3.2	32	3.6	17.1
50%	0.48	4.8	48	5.4	25.6
25%	0.96	9.6	96	10.8	51.2
10%	2.4	24	240	27	128

In the CMS, this same approach will be applied to other types of agricultural areas in the floodplain to develop parcel-specific target soil concentrations where necessary to evaluate certain floodplain remedial scenarios.

3.3.2 Development of Sediment and Floodplain Soil Levels from Diet-Based IMPGs for Certain Ecological Receptors

As noted in Table 3-4, the IMPGs for two ecological receptor groups – insectivorous birds and piscivorous mammals – apply generally to concentrations of PCBs (and TEQs) in the prey of those species (rather than a specific type of prey), given the varied and opportunistic feeding habits of these receptors. For insectivorous birds, as represented by the wood duck, these prey items consist of both aquatic and terrestrial invertebrates. For piscivorous mammals (mink and otter), their prey comprises various types of items. For mink, these prey items include fish, small mammals, birds, invertebrates, amphibians, and reptiles; while for otter, their prey is primarily aquatic, mainly fish with a lesser portion of other items such as crayfish (see ERA, Vol. 2, pp. 9-8, 9-11). In these circumstances, the IMPGs specified in Table 3-4 for these receptor groups cannot be directly applied to any specific medium, such as sediment, floodplain soil, or fish tissue.

Given this situation, GE has evaluated methods of converting the IMPGs that apply to the prey of insectivorous birds and piscivorous mammals into target concentrations in specific media that will be evaluated in the CMS – i.e., sediments, floodplain soil, or fish tissue. These evaluations are presented below.

3.3.2.1 Insectivorous Birds

As noted above, the IMPGs for insectivorous birds, which were based on potential risks to wood ducks, apply to concentrations in the tissue of the aquatic and terrestrial invertebrates consumed by these birds. These IMPGs are 4.4 mg/kg for PCBs and 14 to 22 ng/kg for TEQs. To be applied in the CMS, these dietary IMPG values would need to be translated into corresponding concentrations in a medium that will be evaluated in the CMS, such as sediment or floodplain soil. However, this translation is complicated by the fact that the invertebrate portion of the wood duck's diet consists of both aquatic invertebrates, in which contaminant concentrations derive from sediments, and terrestrial invertebrates, in which contaminant concentrations derive from floodplain soil. When calculating sediment and floodplain soil concentrations associated with the IMPG for invertebrate prey, the target concentration in sediment affects the target concentration in floodplain soil, and vice versa. That is, a higher concentration in sediments would require a lower concentration in soil in order to achieve the IMPG, and vice versa. Thus, it is not possible to derive a value corresponding to the IMPG in one medium without knowing the value in the other, and there is an infinite number of combinations of target sediment and floodplain soil concentrations.

In these circumstances, GE has first selected a range of target sediment PCB concentrations that fall within the range of other sediment IMPGs (e.g., based on human direct contract and other ecological receptors). Those selected target PCB concentrations are 1, 3, 5, and 10 mg/kg. GE has then calculated target floodplain soil concentrations associated with achieving the PCB IMPG of 4.4 mg/kg in wood duck prey, assuming that the sediment PCB concentrations are equal to the selected target values.

The equations, assumptions, and results of this analysis are presented in Appendix B. As shown there, to represent the relationship between aquatic invertebrate and sediment PCB concentrations, a site-specific biota-sediment accumulation factor (BSAF) of 1.8 was used, based on the median BSAF derived from an EPA bioaccumulation study on *Lumbriculus variegatus* (an aquatic invertebrate) that was included in the ERA. To represent the relationship between terrestrial invertebrate and soil PCB concentrations, bioaccumulation factors (BAFs) of 0.2 and 0.31 were calculated from an EPA dataset presented in the ERA on the PCB concentrations in co-located litter invertebrates and composite soil samples collected from three stations in the PSA. The BAF of 0.31 reflects the median of the BAFs calculated from all three stations, while the BAF of 0.20 is the median of the BAFs from the two stations with the highest soil PCB concentrations, since the third station had PCB concentrations considerably lower than elsewhere in the floodplain. As shown in Appendix B, the site-specific BSAF used is consistent with both equilibrium partitioning theory and values from the literature, and the site-specific BAFs used are conservative relative to the data in the literature. Based on these factors (along with the other assumptions described in Appendix B), the target floodplain soil PCB concentrations (based on use of BAFs of 0.31 to 0.20) associated with each of four target-sediment concentrations are as follows:

Target Sediment PCB Concentration (mg/kg)	Target Floodplain Soil PCB Concentration (mg/kg)
1	53 to 82
3	49 to 76
5	45 to 70
10	36 to 55

These target floodplain soil concentrations will be used in the CMS in the evaluation of potential floodplain remedial alternatives. Since the pertinent objective is to protect local populations of insectivorous birds that may be present in the floodplain (rather than individual birds), these target floodplain soil concentrations will be applied to the average floodplain soil concentrations within the overall PSA that are estimated to result from various remedial alternatives. In doing so, these ranges of target floodplain soil concentrations will be applied based on specified assumptions about the associated sediment concentrations. For example, if a given floodplain remedial alternative results in an average soil PCB concentration below 36 mg/kg in the floodplain of the PSA, it would be considered to meet the target floodplain soil concentrations for insectivorous birds, provided that the sediment concentration in the PSA is below 10 mg/kg.

For the reasons given in Appendix B, target sediment and floodplain soil concentrations have not been developed for TEQs due to TEQ-related data limitations. In any event, as discussed in Appendix A, there is no reliable way in the CMS to quantitatively evaluate the ability of various remedial alternatives to achieve the IMPGs for TEQs.

3.3.2.2 Piscivorous Mammals

As noted above, the IMPGs for piscivorous mammals (mink and otter) apply to the prey items of these animals. These IMPGs are 0.0984 to 2.43 mg/kg for PCBs and 16.2 to 33 ng/kg for TEQs.

For mink, it is not feasible to calculate specific sediment or floodplain soil levels associated with the IMPG values, because the components of the mink's diet are too diverse and the specific species are unspecified. EPA's ERA assumes that a mink consumes 35% aquatic invertebrates, 23% fish, 15% mammals, 15% amphibians and reptiles, and 11% birds (ERA, Vol. 2, p. 9-11), although the specific species are unspecified. Further, the IMPGs cannot be directly applied to the 23% fish component of the mink's diet because the maximum concentration of PCBs in fish that would be required to meet the IMPG would depend on the concentration in the other components of the mink's diet. Thus, there is no feasible way to convert the IMPGs for mink diet into concentrations in a medium that will be evaluated in the CMS.

For otter, the dietary components are primarily aquatic and less diverse. The ERA assumes that otters consume approximately 80% fish and 20% crayfish (ERA, Vol. 2, p. 9-11). In this case, it is unnecessary to calculate a sediment value, because the IMPG values can roughly be applied directly to fish concentrations.

In these circumstances, GE will use the assumed diet of the otter for application of the IMPGs for piscivorous mammals. Specifically, the IMPGs for PCBs in the diet of these mammals will be compared to the whole-body fish tissue PCB concentrations predicted by the PCB fate, transport, and bioaccumulation model (discussed in Section 5.2.2 below) for the particular remedial scenarios. For TEQs, as discussed in Appendix A, there is no reliable way in the CMS to quantitatively evaluate the ability of various remedial alternatives to achieve the IMPGs for TEQs.

3.4 Assessment of Amphibian Population Protection

As noted in Table 3-4, the IMPGs for amphibians are PCB concentrations of 3.27 to 5.6 mg/kg in vernal pool sediments. In applying these values to vernal pools in the CMS, to be consistent with the objective of protecting local populations, GE will assess the ability of various remedial alternatives to protect the local amphibian population in the floodplain of the PSA. To do so, GE proposes to use EPA's wood frog population model described in the ERA (Vol. 5, Appendix E, Attachment E.4), with minor modifications as well as an extension to vernal pools not specifically included in the model. GE's proposed approach to using that model in these evaluations is summarized in Section 5.3.2.3 below and described in detail in Appendix C. This model will be used to evaluate and compare the effects on the local amphibian population of remedial alternatives that would achieve the amphibian IMPGs to varying degrees (e.g., in a portion of the vernal pools vs. in all of the vernal pools).

4. Identification and Screening of Technologies and Process Options

4.1 General

The Reissued RCRA Permit requires that the CMS Proposal identify the corrective measures that GE proposes to study in the CMS and provide a justification for the selection of those measures. The first step in this process is to identify the general response action types, remedial technologies, and process options that could potentially be applied to address PCBs in the three environmental media subject to remediation in the Rest of River: sediments, riverbanks, and floodplain soils. Response action types are general categories of technology types, which may include one or more technologies that could be applied to the site. Further, as noted in EPA guidance (EPA, 1988a), each technology may include various specific process options. For example, sediment removal is a response action type, which includes the technology of dredging; and that technology includes process options such as mechanical dredging in the wet, mechanical dredging in the dry, and hydraulic dredging.

Thus, for each relevant environmental medium subject to remediation in the Rest of River, GE has identified general response action types, as well as associated remedial technologies and process options. In addition, GE has identified response action types, remedial technologies, and process options that could be applied to manage sediments and soils that are removed during remediation. To limit the corrective measures studied in the CMS to a manageable number, GE has conducted a two-step screening process for each response action type, as described below.

The initial screening generally consisted of an evaluation based on technical implementability to eliminate those technologies that are not appropriate based on site conditions or chemical/physical characteristics of the site media, or that have not been successfully applied on a full-scale basis at other PCB-impacted sites. This screening step was performed by applying general knowledge and experience gained at this and other sites, using both information available in the literature and professional judgment.

For those technology types that were retained after this initial screening, the associated process options were then subject to a secondary screening based on effectiveness and implementability. The overall goal of this secondary screening was to develop a list of the most promising process options, which will subsequently be combined into a manageable set of remedial alternatives (discussed in Section 5) for detailed analysis and comparative evaluation in the CMS. The criteria used in this secondary screening were effectiveness and implementability, as described further below.[19]

Effectiveness – For purposes of the screening presented in this CMS Proposal, the effectiveness of each process option considered under a particular technology was evaluated qualitatively, based on: (a) its general ability to reduce the potential for human and/or ecological exposure to PCBs in sediment or soil (or, for the riverbanks, to prevent or control erosion of riverbank soils into the River); and (b) the extent to which long-term maintenance and/or monitoring is required to ensure effectiveness. For the remedial alternatives evaluated in the CMS, a more detailed evaluation of effectiveness, based on the factors specified in Special Condition II.G.2 of the Reissued RCRA Permit, will be presented in the CMS Report.

Implementability – Implementability includes consideration of both the technical and administrative feasibility of implementing a technology process option, as well as the availability of equipment, materials, and personnel to implement the process option, as recognized in the NCP (40 CFR § 300.430(e)(7)(ii)) and EPA (1988a) guidance. The screening evaluation presented in this CMS Proposal considered these factors for each process option, giving consideration to site conditions and characteristics. For the remedial alternatives evaluated in the CMS, a more detailed evaluation of implementability, based on the factors specified in Special Condition II.G.2.e of the Reissued RCRA Permit, will be presented in the CMS Report.

The following sections describe the identification and two-step screening process conducted for technologies and process options to address PCBs in sediments, riverbanks, and floodplain soils in the Rest of River, as well as those considered to address removed sediments and/or soils. For those technologies that have multiple process options and were subject to secondary screening, a separate subsection is included that presents GE's conclusions as to which process options have been retained for evaluation in the CMS and which have not.

It should be noted that selection of a particular process option for further study does not necessarily eliminate other process options from potential analysis in the CMS if future information or analyses become available indicating that another option may be more effective, implementable, and/or cost-effective. Therefore, GE is retaining a general category of "other options" to cover such process options.

19 These are two of the three criteria (along with cost) specified in the NCP for the screening of remedial alternatives (40 CFR § 300.430(e)(7)). The factors that were considered in applying these criteria for purposes of screening process options, as described below, are more limited than the factors specified for these criteria in the Reissued RCRA Permit (especially for effectiveness). As discussed further in Section 5, the Permit's criteria will be applied in the CMS in the detailed evaluation of remedial alternatives.

4.2 In-River Sediments

To address PCBs in the in-place sediments within the Rest of River area, the following general response actions were considered and screened:

- No action;
- Engineering/institutional controls;
- Monitored natural recovery (MNR);
- Removal;
- *In situ* containment; and
- *In situ* treatment.

Each of these response actions is described briefly below, followed by a discussion of the initial screening and then the secondary screening of the process options within the technologies that were retained after the initial screening. The results of the initial screening are summarized in Table 4-1, and the results of the secondary screening are summarized in Table 4-2. This section and these tables do not separately discuss sediment restoration, which will be considered, as appropriate, in connection with the specific sediment technology or process option.

4.2.1 No Action

The "no action" response action would not include any active or passive remediation. It would take account of changing conditions through the ongoing natural attenuation of PCBs in sediments, but would not include any long-term monitoring or controls. The NCP requires that a no-action alternative be considered at every site (40 CFR 300.430(e)(6)). Thus, this alternative was retained in the initial screening.

The no-action response action was also retained in the secondary screening step. It is clearly appropriate in areas of a site that already meet cleanup goals, and thus can be a component of the selected remedy. In other areas, its effectiveness depends on previously implemented source control measures and the progress of natural processes (e.g., dispersion, silting-over with cleaner sediments) that reduce the potential exposures to PCBs in sediment over time. The no-action response action is implementable and would provide a baseline against which other alternatives can be assessed in the CMS. For these reasons, and in accordance with the NCP, the no-action alternative has been retained for evaluation in the CMS.

4.2.2 Engineering/Institutional Controls

Engineering/institutional controls are physical, legal, and/or administrative controls that would be implemented to limit potential exposure to PCBs in sediment**.** These controls can be used, alone or in combination, to restrict access to portions of the site and/or to initiate and maintain appropriate uses that mitigate the potential for future exposure to PCBs during and after remedy implementation. Engineering/institutional controls to address in-river sediment can include access restrictions (such as fences and signs), activity restrictions on fishing and hunting (such as catch-and release fishing restrictions and/or restrictions on certain types of waterfowl hunting), and information devices (such as biota consumption advisories).

Initial Screening

Engineering/institutional controls can be used at all stages of the remedial process to mitigate the potential for exposure to contaminated sediments. They are often used in conjunction with other response actions (e.g., MNR, sediment removal, *in situ* containment) both during and following remedy implementation. Engineering/institutional controls have been implemented as a component of the removal and capping remedies implemented by GE and EPA on the Housatonic River for both the Upper ½-Mile and 1½-Mile Reaches. At other sites including the Kalamazoo River (MI), Spokane River (WA), the Sheboygan River (WI) and the Ottawa River (OH), catch and release programs and/or fish advisories are in place to help mitigate exposure by humans to PCBs in biota. Thus, engineering/institutional controls were retained for the secondary screening.

Secondary Screening

Several engineering/institutional controls have been considered for the Rest of River as a means of reducing the potential for human exposure to PCBs in sediment. These include physical access restrictions, such as fencing and signs, placed along the River to limit access. They also include fishing and hunting restrictions and biota consumption advisories to warn the public to limit consumption of fish or other aquatic biota from the River.

Effectiveness – Engineering/institutional controls would reduce the potential for human exposure to PCBs in the sediments or biota of the River. Access restrictions, such as fencing and signs, do so by restricting access to portions of the River and could be used during remedy implementation and, potentially in some areas, on a longer-term basis. They would require routine monitoring and maintenance. Fishing and hunting restrictions could include imposition of catch-and-release requirements for fishing and/or restrictions on certain types of waterfowl hunting, and would be implemented through fishing and/or hunting license programs. Biota consumption advisories, which are already in place for fish and/or ducks along certain portions of the River and are commonly used throughout the nation, would be expected to reduce the potential for human exposure to PCBs through ingestion of fish or other biota containing PCBs. Biota consumption advisories would be implemented through preparation and distribution of advisory brochures and posting of signs along the River, with routine monitoring and maintenance of the signs.

Implementability – In general, the engineering/institutional control process options would be technically and administratively implementable, although the implementability of physical access and activity restrictions in certain areas would be dependent on property owner agreement. For physical access restrictions, equipment, materials and personnel are readily available to install any of the traditional fencing options (chain link, mesh), provided the property owner agrees. Implementation of fishing restrictions and/or biota consumption advisories would require coordination with the appropriate agencies and dissemination of information to the general public and surrounding communities.

Since each of the above-described engineering/institutional control process options provides a uniquely different means of helping to reduce the potential for human exposure to PCBs in the River, and each is considered implementable, all of these process options have been retained for evaluation in the CMS as potentially viable components of remedial alternatives.

4.2.3 Monitored Natural Recovery (MNR)

MNR is a response action that relies on ongoing, naturally occurring processes to contain, destroy, or otherwise reduce the bioavailability or toxicity of chemical constituents in sediment, with monitoring to assess the rate of recovery or attenuation. Water bodies have a considerable inherent capacity to recover from either natural or human disturbances. The rate and success of such recovery is typically linked to the effectiveness of upstream source control, which would prevent or minimize the continuing contribution of active sources of contaminants to the water body. The natural processes relied upon for MNR may involve multiple physical, biological, and chemical processes that act together to reduce the mass, toxicity, mobility, concentration, or availability of contaminants in the sediment, as described below.

- **Physical processes** promote natural attenuation in sediments through several mechanisms that may bury, mix, dilute, or transfer contaminants to another medium (EPA, 2005e). One such process is sedimentation, which can eliminate or reduce exposure and risk by containing the contaminants in place through the deposition of cleaner sediments on top of impacted sediments. Those cleaner sediments mix with and effectively reduce constituent concentrations in the upper layer of the sediments, which is the point of exposure for most receptors. Long-term stability provided by sedimentation may be affected by natural events such as floods or ice scouring, and therefore these events must be considered at sites where MNR is a remedial option. Other physical attenuation processes include erosion, dispersion, dilution, bioturbation, advection, and volatilization, which refer to the transfer of PCBs to another medium or to their continued movement within the Rest of River area. These processes may reduce or transfer the risks posed by the PCBs and therefore may be applicable mechanisms for MNR depending on the potential for increased exposure.

- **Biological processes** also depend on site conditions and are therefore highly variable. Although rates of biodegradation are typically driven by nutrient availability, the mechanism of degradation is determined by the oxidation-reduction conditions of the sediment and the nature of the microbiological community (Atlas et al., 1981). With regard to PCBs, EPA has noted that little evidence exists to suggest that dechlorination occurs to a significant extent under anaerobic or anoxic conditions that are typically found in most sediment (EPA, 2005e). Studies carried out with sediments from the upper Housatonic River and Woods Pond have shown that reductive dehalogenation can occur when the microbial community has been primed with brominated biphenyls (Bedard et al., 1998). Although cultures of the bacteria that carry out this reductive dehalogenation have been successfully identified and developed in laboratory settings, thus far a remedial method based on this technology has not been developed (Bedard et al., 2006).

- **Chemical processes,** such as the sorption of PCBs to organic carbon particulates, can control the bioavailability of PCBs and thus affect rates of biodegradation. Levels of organic carbon in the sediment are thus important in assessing potential for natural recovery through chemical processes.

Natural recovery may also be enhanced by certain active remedial actions, such as placing engineered structures in the waterway to slow down surface water velocities and thus improve conditions for sediment deposition (enhanced sedimentation) or placing a thin layer of clean material over contaminated sediments to accelerate the natural recovery process (thin-layer capping).

Initial Screening

Certain MNR and enhanced MNR approaches have been demonstrated at aquatic sites with PCB-containing sediment (EPA, 2004e). These approaches can be and have been applied alone or in combination with other, more active remedial technologies/process options (e.g., removal, *in situ* containment). MNR has been selected as a component of the remedy for contaminated sediment at approximately one dozen Superfund sites (EPA, 2005e). Certain reaches of the Housatonic River are more amenable to MNR than others. These include Woods Pond and Rising Pond, which are depositional in nature and where (as discussed further below) geochronologic analysis of finely sectioned sediment cores indicates a general decline in PCB transport and deposition over time. MNR may also be suitable for reaches, such as those between Woods Pond and Rising Pond and downstream of Rising Pond, where PCB concentrations are already low and which may recover further following upstream remediation. Thus, MNR and enhanced MNR were retained for the secondary screening.

Secondary Screening

An evaluation of MNR, as well as the enhanced MNR techniques of enhanced sedimentation and thin-layer capping, is presented below.

4.2.3.1 MNR

MNR relies on ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. For PCBs, which are generally very stable in the environment, physical processes such as dispersion and natural burial tend to be the predominant natural recovery mechanisms for sediments. The rate and extent to which natural recovery occurs are dependent upon the dynamics of the water body and the extent to which source control measures are completed.

Effectiveness – Through the collection and analysis of finely sectioned cores for PCBs and a number of radioisotopes, natural recovery processes have been previously observed in Rising Pond and portions of Woods Pond, primarily due to deposition of cleaner sediments on the surface of the ponds, estimated to be occurring at average net deposition rates of 0.15 inch/year in Woods Pond and 0.35 inch/year in Rising Pond (RFI Report, BBL and QEA, 2003). Average PCB concentrations in the top 3 feet of sediment in Rising Pond generally increase with depth (from 3 mg/kg at the surface to 12 mg/kg at a depth of 24 to 30 inches), further indicating likely deposition of cleaner sediments over time (*id.*). In addition, natural recovery is likely ongoing elsewhere in the River at varying rates, due to the source control and remediation measures implemented by GE and EPA in and adjacent to the Upper 2-Mile Reach of the River, coupled with ongoing natural sedimentation processes. The burial/replacement of surface sediments containing PCBs with cleaner sediments over time would reduce the potential for exposure to PCBs in sediment by human and ecological receptors. Monitoring would be required, and could be readily implemented, to track the effectiveness and rate of the recovery.

Implementability – MNR is implementable, with the necessary access, equipment, materials and personnel for long-term monitoring readily available. Implementation of MNR would be minimally intrusive and damaging to the ecosystem, with activities limited to periodic river sampling from a boat and/or the shoreline.

4.2.3.2 Enhanced Sedimentation

As seen in impounded areas, the placement of an engineered structure within a waterway can have the effect of slowing down surface water velocities and increasing water depths locally, resulting in conditions more favorable for sediment deposition. For application to the Rest of River, this process option would involve the construction of dams or other engineered structures to alter the rate of sedimentation in portions of the River and increase the rate of natural recovery.

Effectiveness – Enhanced sedimentation would accelerate the rate at which cleaner sediments accumulate on the river bottom, reducing the potential for human and/or ecological exposure to PCBs in sediment over time. The effectiveness of this approach would be dependent upon the localized hydraulic conditions created and the loading rates and quality of the sediment deposited. Enhanced sedimentation would be most effective where low-energy aquatic environments such as impoundments could be created and/or expanded. Long-term maintenance of any engineered structures placed in the River would be required.

Implementability – Enhanced sedimentation would be technically implementable, although placement of engineered structures could alter the local habitat and use of the River by humans. Further, administrative issues would arise due to impacts on surface water elevations and associated flood impacts, which could affect compliance with applicable substantive requirements. Additionally, the potential flooding resulting from installation of a structure(s) may affect community acceptance.

4.2.3.3 Thin-Layer Capping

Thin-layer capping involves placing a thin layer (i.e., a few inches) of clean material over contaminated sediment to provide an immediate reduction of sediment PCB concentrations in the biologically active zone and to accelerate natural recovery. Thin-layer capping is different from isolation capping because it is implemented to support and accelerate an ongoing natural recovery process, rather than being specifically designed to provide long-term isolation by itself. While the thickness of an isolation cap can range up to several feet and the cap components are specified based on the chemical and physical characteristics of the contaminated sediment, a thin-layer cap can consist of as little as a few inches of clean material. Because thin-layer capping typically creates fewer short-term environmental impacts than isolation capping, the benthic population – which is inevitably disturbed during cap placement – can reestablish faster than it would with engineered capping or removal remedies.

Effectiveness – Thin-layer capping could be effective at reducing the potential for human and/or ecological exposure to PCBs in sediment. Its greatest effectiveness has been typically demonstrated in low-energy aquatic environments. Assuming even low rates of natural sedimentation in the future, thin-layer capping can provide a base for sustained long-term reduction in surficial PCB concentrations. Studies have indicated that even very thin layers of new clean material placed on the sediment bed can result in a dramatic reduction in the interaction of sediment-associated contaminants with the overlying water (Talbert et al., 2001). The application of a thin cap can be considered an alternative to construction of a thicker cap over contaminated sediments, which in some circumstances may require dredging prior to placement to maintain adequate water depth. Once constructed, thin-layer caps may require some monitoring to document the future extent of natural recovery in the capped area.

Implementability – Thin-layer capping would be readily implementable. Equipment, materials, and properly trained personnel are considered readily available to implement this option.

4.2.3.4 Results of MNR Secondary Screening

The effectiveness and implementability of MNR, both by itself and as augmented by enhanced sedimentation or thin-layer capping, have been evaluated to select representative MNR process options for use in development of remedial alternatives for the CMS. MNR by itself has been retained for further evaluation in the CMS as a potential remedial component for the sediments due to its likely effectiveness in some areas (as described above) and ease of implementation. Further, recognizing that the rate of natural recovery in the Housatonic River is location-specific (e.g., natural recovery caused by deposition of clean sediments would likely be slower in the backwater areas than in Woods Pond because of the relatively reduced flux of solids to the backwaters), thin-layer capping has also been retained, and may be considered instead of and/or in addition to MNR alone as a remedy component in certain reaches of the River. Enhanced sedimentation has not been retained at this time for further evaluation as a remedial alternative, due to the likely negative impacts that engineered structures could have on the ecology and recreational use of the River and surrounding floodplain and the likely administrative difficulties compared to the other MNR options.

4.2.4 Removal

Removal involves the physical removal of PCB-containing sediments via dredging. Environmental dredging is intended to remove impacted sediment above certain action levels while minimizing the spread of contaminants to the surrounding environment during dredging (National Research Council [NRC], 1997). Dredging may be performed using mechanical techniques, either through mechanical excavation "in the dry" (i.e., after isolating and dewatering the removal area) or mechanical dredging "in the wet" (i.e., through the water column), and/or using hydraulic dredging techniques. The selection of the appropriate technique depends on factors such as accessibility, water depth, hydrology, sediment composition, and the subsequent treatment/disposal options.

Initial Screening

Sediment removal through mechanical and/or hydraulic dredging techniques has been implemented at numerous PCB-impacted sediment sites on a full-scale basis. According to EPA (2005e), sediment removal has been the most frequent sediment remediation method used in the Superfund program, having been selected as a cleanup method for impacted sediment at more than 100 Superfund sites. Accordingly, sediment removal, including mechanical dredging in the wet, mechanical excavation in the dry, and hydraulic dredging, was retained for the secondary screening.

Secondary Screening

A number of different mechanical and hydraulic techniques are available to remove sediment containing PCBs from the Housatonic River. Selection of the proper equipment and technique requires consideration of site conditions in conjunction with an understanding of the technical limitations of each method. While mechanical excavation in the dry may support a more complete removal, water depths, water velocities, and subsurface characteristics may preclude its use in some areas. Similarly, while water depths and sediment type/distribution may support use of a hydraulic dredge in some areas, significant amounts of debris present in the sediment may require mechanical removal as a pre-dredging step, or may preclude use of a hydraulic dredge altogether. Similar to MNR, dredging options can be applied alone or in combination with other remedial options (e.g., MNR, *in situ* containment). An evaluation of mechanical dredging in the wet, mechanical dredging in the dry, and hydraulic dredging as potential remedial components for the Housatonic River is provided below.

4.2.4.1 Mechanical Dredging in the Wet

Mechanical dredging in the wet would involve removing PCB-containing sediment using conventional earthmoving equipment (e.g., clamshell bucket) through the water column. Barge-mounted equipment is typically used, and engineering controls, such as silt curtains and/or temporary sheetpile walls, are used to minimize the migration of sediments beyond the targeted work area. Dredged materials are typically transferred to a container on a barge and transported to a land-based processing facility. Alternatively, mechanical removal can be performed using earth-moving equipment placed on land, if the river is accessible from the adjacent land and permission is granted by the landowner.

Effectiveness – Mechanical dredging in the wet has been used to remove sediments containing PCBs at a number of sites, including the Sheboygan River (WI) and the Grasse River (NY). Dredging in the wet would reduce the long-term potential exposure to human and ecological receptors through removal of PCB-containing sediments. However, it may increase the potential for short-term exposure, as the removal process causes resuspension of sediments, with subsequent downstream transport and/or redeposition, and can also produce releases of dissolved-phase PCBs to the water column (Palermo, 2006). EPA's *Contaminated Sediment Remediation Guidance* (EPA, 2005e, pp. 6-22 - 6-23) reports that: "Although the degree of resuspension will be site-specific, recent analyses of field studies and available predictive models of the mass of sediment resuspended range from generally less than one percent of the mass dredged (Hayes and Wu 2001, Palermo and Averett 2003) to between 0.5 and 9 percent (NRC 2001)." The NRC (2001) document cited by EPA (2005e) indicates that values for silts and clays range from 2.5 to 9 percent for mechanical dredging in the wet. While dredging techniques and containment options are available to reduce resuspension and releases, all dredges suspend sediments and dissolved-phase releases are prone to far-field transport in the water column (Palermo, 2006; EPA, 2005e). In addition, difficulties in consistently achieving low residual PCB concentrations in the surface sediments have been noted with this removal technique, in part due to the resuspension/redeposition of fine-grained sediments on the dredged surface during the removal process (Palermo, 2006; EPA, 2005e). Further, this technique disturbs the upper sediment layer and exposes deeper sediments, which may be more contaminated. In some instances, capping following dredging has been required by the regulatory agencies due to the difficulties in achieving PCB cleanup goals through such dredging alone (White, 1998; Palermo, 2006).

Implementability – The implementability of mechanical dredging in the wet in a given area of the River depends on the characteristics of the River in that area. This option would be technically implementable in areas of the River where access to the sediments is feasible using barge- and/or land-based equipment, although it would have the difficulties described above. It would also be important that the removal area be capable of being adequately contained using silt curtains or another device to contain resuspended solids. The equipment, materials, and personnel qualified to implement mechanical dredging in the wet are available. The necessary access permissions would need to be obtained.

4.2.4.2 Mechanical Dredging in the Dry

Mechanical dredging in the dry would involve removing PCB-containing sediment using conventional earth-moving equipment (e.g., excavator) after dewatering the removal area (e.g., via pump bypass, rechannelization, sheetpiling diversion, etc.). Mechanical removal in the dry can be performed by staging earth-moving equipment along the bank of the River and/or placing such equipment in the dewatered area of the River. Dredged materials may be placed in trucks (for subsequent transfer to a processing facility) or transferred directly to a processing area if it is close enough.

Effectiveness – Mechanical dredging in the dry has been used to remove sediments containing PCBs at a number of sites, including the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River. Since the area to be dredged would be dewatered, this option allows greater precision in excavation than dredging through the water column. Dredging in the dry would reduce the potential exposure to human and ecological receptors through removal of PCB-containing sediments. However, difficulties in consistently achieving low residual PCB concentrations in the surface sediments have been noted in both the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River with this removal technique when complete dewatering of the river bottom is unachievable and/or when NAPL is present in the sediment. For example, coal-tar NAPL was encountered to the bedrock while excavating sediments in the 1½-Mile Reach of the River. Though power washing of the bedrock was conducted to remove any residual NAPL and NAPL-impacted sediment, the bedrock was eventually encapsulated with a grout cement mixture to protect against potential NAPL release from fractures in the bedrock (Weston Solutions, Inc., 2004). With dredging in the dry, there is also a potential for PCB releases during flooding events. In some instances, capping following dredging has been required by the regulatory agencies (White, 1998).

Implementability – The implementability of mechanical dredging in the dry depends on the river characteristics. This technique would be technically implementable in areas of the River that can be contained/dewatered and where access to the sediments is feasible using land-based equipment or equipment placed in the dewatered area of the River. The equipment, materials, and personnel qualified to implement mechanical dredging in the dry are available. The necessary access permissions would need to be obtained.

4.2.4.3 Hydraulic Dredging

Hydraulic dredging uses a hydraulic pump or compressed air to create a vacuum at the dredgehead to remove sediments. Some types of hydraulic dredges include the horizontal auger, cutterhead dredge, PNEUMA pump, etc. The removed sediments are then transported to land in a liquid slurry via pipeline for dewatering and further treatment (i.e., stabilization, solidification) in preparation for disposal. The dredging equipment is most often barge-mounted. Implementation of hydraulic dredging requires that sufficient water depth be available to support the movement and operation of the dredge and appurtenances in the River. The hydraulic process introduces a large amount of water to the removed sediments, with 5% solids content expected for most environmental dredging projects (EPA, 2005e). Because a large amount of water is generated, consideration of the applicability of this approach must include an assessment of whether sufficient space is available near the dredge area to stage sediment dewatering and processing equipment. The site conditions affecting mechanical dredging would also constrain hydraulic dredging; however, the effectiveness and efficiency of hydraulic dredges are impacted to a far greater extent by the presence of debris in the sediment. Similar to mechanical dredging, engineering controls for minimizing suspended sediment transport during dredging would be required.

Effectiveness – Hydraulic dredging has been used to remove PCB-containing sediments at a number of sites, including the St. Lawrence River (NY), the Grasse River (NY), the Fox River (WI), the Sheboygan River (WI), New Bedford Harbor (MA) and Manistique Harbor (MI). Hydraulic dredging would reduce the long-term potential exposure to human and ecological receptors through removal of PCB-containing sediments. However, like mechanical dredging the wet, hydraulic dredging causes resuspension of sediments with subsequent transport and/or redeposition, and can produce dissolved-phase releases to the water (Palermo, 2006). The NRC (2001) document cited by EPA (2005e) indicates that, with hydraulic dredging, resuspension rates for silts and clays range from 0.5 to 4.5 percent of the mass dredged. While hydraulic dredging techniques and containment options are available to reduce resuspension and releases, all hydraulic dredges suspend sediments and dissolved-phase releases can occur during dredging. Further, difficulties in consistently achieving low residual PCB concentrations in the surface sediments have been noted with this removal technique when debris is present and as a result of resuspension/redeposition of fine-grained sediments on the dredged surface during the removal process (Palermo, 2006; EPA, 2005e). Mechanical dredging is sometimes required as a preparation step to remove the debris and improve the efficiency of the hydraulic dredging process. In some instances, capping following dredging has been required by the regulatory agencies due to the difficulties in achieving PCB cleanup goals through such dredging alone (White, 1998).

Implementability – Like the mechanical dredging techniques, the implementability of hydraulic dredging depends on the characteristics of the River. Hydraulic dredging would be technically implementable in areas of the River where access to the sediments is feasible, water depths and velocities are adequate to support dredge movement and use, and a sufficiently large area is available to support sediment storage/dewatering operations, although it would have the difficulties noted above. The appropriate equipment, materials, and personnel are available. The necessary access permissions would need to be obtained.

4.2.4.4 Results of Removal Secondary Screening

The effectiveness and implementability of mechanical dredging in the wet, mechanical dredging in the dry, and hydraulic dredging have been evaluated for potential use as part of the remedial alternatives to be studied in the CMS. All three dredging techniques have been retained for further evaluation as potential remedial components for the Rest of River. However, selection of the proper equipment and technique requires consideration of site conditions in conjunction with an understanding of the technical limitations of each method. For example, while mechanical excavation in the dry may support a more complete removal, its use would be precluded in some areas due to the areal extent of the water, water depths, water velocities, and/or subsurface characteristics.

Similarly, while water depths and sediment type/distribution may support use of a hydraulic dredge in some areas, significant amounts of debris present in the sediment may require mechanical removal as a pre-dredging step or may preclude use of a hydraulic dredge altogether. Given the wide variety of conditions present in the Rest of River, each option has been retained for potential use, where appropriate, in the remedial alternatives involving sediment removal.

4.2.5 *In Situ* Containment

This response action includes the active placement of clean cover materials over the river sediments to mitigate the potential for exposure to human and ecological receptors. *In situ* containment technologies that have been implemented at other sites to mitigate exposure to in-river sediments include capping and river rechannelization. Capping involves placing material (e.g., clean sand, gravel cobbles, sorbents, geofabrics, etc.) over sediment to isolate constituents from biota, mitigate chemical flux, and/or minimize erosion potential. Rechannelization involves the complete backfilling of a portion of the river channel and redirecting the River into a newly constructed channel. Both process options are described in more detail below.

- **Capping** is an active remediation option in which a layer of clean isolating material is placed to contain and stabilize the PCB-containing sediment and to sequester those sediments from the biologically active zone within the sediment bed and from the overlying water column. Caps may be constructed of clean sediment, sand, gravel, and/or amended material, or may, if necessary, involve a more complex design using geotextiles, liners, and sorbent materials. A cap is generally designed to reduce risk through: 1) physical isolation of the impacted sediment sufficient to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the cap surface; 2) stabilization of contaminated sediment and erosion protection of sediment and cap sufficient to reduce resuspension and transport of contaminants into the water column; and/or 3) chemical isolation of contaminated sediment sufficient to reduce exposure from dissolved contaminants that may be transported into the water column (EPA, 2005e).

- **Rechannelization** involves permanently redirecting a waterway into a newly constructed channel and covering/isolating the material in the original channel in place. Ideally, the soil excavated to construct the new channel would be used to backfill the existing reach which is being diverted. Rechannelization could only be implemented in those areas of a river where the adjacent property is available and the local topography supports river reconstruction.

Initial Screening

Capping is an EPA-approved technology for the effective remediation of contaminated sediments. As described by EPA (2005e), it is a viable approach for remediating impacted sediments. *In situ* capping of sediments has been applied in a variety of settings, including rivers, near-shore areas, and estuaries. A variety of capping materials and cap placement techniques are available, and monitoring data collected for a number of projects have indicated that capping can be an effective remedy (Fredette et al. 1992; Brannon and Poindexter-Rollings, 1990; Sumeri et al., 1994). Conventional marine construction equipment and techniques can be used for capping projects, or equipment may be modified for specific applications (as in the case of low-impact placement). While caps have been effectively used as a stand-alone remedy (e.g., Denny Way, WA and Eagle Harbor, WA [Palermo et al., 1998; Bailey et al., 2005]), they have also been incorporated in recent years into multi-component approaches – used in conjunction with removal (part of a site capped, part dredged) or placed over previously dredged areas to provide environmental isolation of residual sediments. Capping was successfully implemented as a remedy component by GE on the Upper ½-Mile Reach of the Housatonic River to cover residual PCBs following sediment removal, and capping is part of the EPA-approved remedy for Silver Lake. Caps have also been constructed and/or are being designed as part of the selected remedy at a number of other sediment sites containing PCBs, including the St. Lawrence River (NY), Onondaga Lake (NY), Eagle Harbor (WA), and Fox River (WI). Capping may likewise be an appropriate remedy or remedy component for certain stretches of the Rest of River. For those reaches similar to the upper 2-Mile Reaches (i.e., shallow water with cobbly bottom and relatively high surface water velocities during high flow events), sediment removal may be required prior to placement of a cap. In other areas (e.g., deeper, lower-energy areas), capping may be employed without prior removal.

River rechannelization has been successfully applied at a number of sediment sites to mitigate the potential for exposure to chemical constituents in sediment by humans and ecological receptors, including the Unnamed Tributary (OH) and the Moss-American Superfund Site (WI). At the Unnamed Tributary site, the sediments were first dredged using mechanical equipment in the dry, and the Tributary was subsequently backfilled with soil generated during construction of a new channel to prevent contact of stormwater or river water with residual PCBs present following dredging (BBL, 2000c). At the Moss-American Superfund site in Milwaukee, WI, rechannelization of approximately 6 miles of the Little Menomonee River was selected as the final remedy to address creosote impacts to the River (EPA, 2006f). There are some reaches of the Housatonic River between the Confluence and Woods Pond where the broad adjoining floodplains and configuration of the River channel could potentially support rechannelization.

Given their successful use full-scale at other PCB-impacted sites, and the presence of site conditions in various reaches of the Housatonic River that are potentially conducive to capping and/or rechannelization, both options were retained for further evaluation in the secondary screening step.

Secondary Screening

As noted previously, there are a number of different *in situ* containment approaches available to sequester PCBs in the sediments of the Housatonic River. Like removal, selection of the proper equipment and technique requires consideration of site conditions in conjunction with an understanding of the technical limitations of each method. Placement of a clean layer of sediment over the river bottom may sufficiently sequester PCBs in the underlying sediment, but placement of an armor layer over the clean sand may be needed in some areas to prevent scour during a high flow event. Placement of a cap over sediments containing PCBs in shallow water may require that some amount of sediment first be removed to reduce the potential for localized flooding due to any changes in bed elevation associated with the cap. To implement rechannelization as a remedy component, nearby property must be available and the topography must be amenable to re-routing of the River. Similar to MNR and removal, *in situ* containment options can be applied alone or in combination with other remedial options (e.g., MNR, removal). An evaluation of capping and rechannelization as potential remedial components for the Rest of River is provided below.

4.2.5.1 Capping

This option consists of placing clean subaqueous cover material over sediments containing PCBs, with a thickness suitable to create a clean bioavailable zone and to isolate the underlying sediments. Where necessary, the cap may contain a sorptive media (e.g., organic carbon, organoclay) and/or physical barrier (e.g., an impermeable geofabric, clay, AquaBlok™) to reduce the flux of PCB to the water column. Implementation in a high-energy environment may require placement of an armor stone layer over the isolation material to reduce the potential for scour, and geotextile placement may be used to help distribute the weight of the cap and prevent mixing, if soft, fine-grained sediments are being capped. In shallower areas, some sediment removal may be required prior to placement of the cap to provide flood storage capacity and/or to support future river uses.

Effectiveness –A cap would reduce the long-term potential exposure to human and ecological receptors by providing a clean cover over the PCB-containing sediments and (where necessary) providing sorptive capacity to sequester PCBs present in groundwater which have the potential to migrate upward through the cap. EPA's

Contaminated Sediment Remediation Guidance (EPA, 2005e, p. 5-3) states that "[a] well-designed and well-placed cap should more quickly reduce the exposure of fish and other biota to contaminated sediment as compared to dredging, as there should be no or very little contaminant residual on the surface of the cap." Design and construction of caps must include an understanding of the conditions in the river reach proposed for capping (e.g., water depths and velocities, groundwater flux, sediment PCB and TOC concentrations, etc.). Post-construction monitoring and maintenance are typically employed to ensure effectiveness.

Implementability – Capping by itself is most readily implementable in deeper, lower-energy reaches of the River. Implementation in shallow, higher-energy environments may require that some sediments be removed prior to capping to address flood storage concerns and support future river uses (as was done in the Upper ½-Mile Reach of the Housatonic River). The equipment, materials, and qualified personnel needed to implement a capping remedy are available. Implementation would require access agreements from the property owners adjacent to the areas of the river to be capped.

4.2.5.2 Rechannelization

With rechannelization, the River would be permanently redirected into a newly constructed channel and material in the original channel would be contained in place (i.e., covered). The covered channel would then be restored to surrounding grade.

Effectiveness – Rechannelization would significantly reduce the potential exposure of human and ecological receptors to PCBs in the sediment through construction of a new channel and backfilling, with several feet of clean fill, of the channel with the sediments containing PCBs. This option would require long-term monitoring and maintenance, as well as deed restrictions related to materials remaining in the original channel.

Implementability – Rechannelization would potentially be technically implementable in a number of river reaches where site conditions are suitable (i.e., where nearby property is available and the topography is amenable to re-routing of the River). This would most likely be limited to certain stretches of the River between the Confluence and Woods Pond where the present river configuration is conducive to rechannelization, such as oxbow areas. The equipment, materials, and personnel qualified to implement a rechannelization option are available. From an administrative standpoint, this option would require that tracts of land be acquired from the adjacent landowners to construct the new channel, and that use restrictions be put in place for those stretches of the River that are backfilled to grade and contain sediments with PCBs at depth, so as to minimize the potential for future human exposure. Given the number of properties along the River, it may be difficult to obtain the necessary tracts of land and property owner agreements to implement rechannelization along large stretches of the Housatonic River.

4.2.5.3 Results of *In Situ* Containment Secondary Screening

The effectiveness and implementability of capping and rechannelization have been evaluated for potential use in the remedial alternatives for the sediments. Based on this evaluation, capping, and, to a much more limited extent, rechannelization have both been retained for further evaluation as potential remedial components for the Rest of River. Due to the successful use of capping at a number of sites containing PCBs and the presence of conditions suitable for capping in portions of the Rest of River, capping has been retained for further evaluation as a potential remedial component. Capping may be used by itself (i.e., placed on top of existing sediments) or in conjunction with sediment removal as part of the remedial alternatives. Rechannelization has not been retained for further evaluation as a large-scale, or site-wide, remedial alternative for the River due to the technical and administrative hurdles anticipated relative to the other *in situ* containment options. However, it has been retained for potential use in certain stretches of the River (e.g., oxbow areas) where it could be more readily implemented.

4.2.6 *In Situ* Treatment

In situ treatment involves using physical, chemical, or biological processes to destroy or degrade contaminants or immobilize the contaminants in place within the sediment. Each of these process options is discussed below.

- ***In situ* physical treatment** involves injecting and/or mixing an immobilization agent into the sediment, to reduce the mobility of PCBs in the sediment. The agent can be coal, coke breeze, activated carbon, Portland cement, fly ash, limestone, or other additive. It is injected/mixed into the sediment to encapsulate the contaminants in a solid matrix and/or chemically alter the contaminants by converting them into a less bioavailable, less mobile, or less toxic form.

- ***In situ* chemical treatment** involves injecting chemical surfactants/solvents or oxidants into the treatment area to remove or destroy PCB constituents. Chemical treatment processes may include common or proprietary solvents and other liquids.

- ***In situ* biological treatment** involves introducing microorganisms and/or nutrients into the treatment zone to increase ongoing biodegradation rates of PCBs in sediments. Biodegradation of PCBs may occur either in the absence of oxygen (anaerobic conditions) in a process termed dechlorination, or with oxygen present (aerobic conditions).

Initial Screening

In situ treatment of sediments is currently under development, with few methods available commercially. EPA has noted that "significant technical limitations currently exist for many of the treatment technologies," especially in terms of their effectiveness (EPA, 2005e). The efficiency for *in situ* treatment is summarized by Renholds (1998) as "almost always less than ex situ treatment." Each of the *in situ* treatment process options is discussed below.

In situ physical treatment was not retained for the secondary screening because the process has not yet been sufficiently developed for sediment *in situ* nor has it been successfully implemented full-scale for PCBs. General disadvantages noted for i*n situ* physical treatment (solidification/stabilization) focus on lack of process controls, particularly with mixing conditions and curing temperatures encountered with in-place sediments (Kita and Kubo, 1983). For example, in an *in situ* demonstration project performed on sediments in the Manitowoc River (WI) containing PAHs and several heavy metals from a former coal gasification plant, good controls could not be established on the mixing of cement/fly ash slurry with the sediment (Renholds, 1998). The lack of adequate process controls has relegated use of this technique to instances when the contaminated sediment can be isolated from the water body (Board on Environmental Studies and Toxicology, 2001). EPA's *Contaminated Sediment Remediation Guidance* (EPA, 2005e) points out that "the lack of an effective delivery system has hindered the application of in situ stabilization systems."

In situ chemical treatment was not retained for the secondary screening because it has not been successfully demonstrated full-scale for PCBs in sediment. *In situ* chemical remediation is often based on addition of an oxidant to the sediment. Studies have shown that the elevated biological oxygen demand exhibited by most sediments requires more oxidant than expected (Murphy et al., 1995). EPA's *Contaminated Sediment Remediation Guidance* (2005e) states that "most techniques for in situ treatment of sediments are in the early stages of development…" Developing an effective i*n situ* delivery and homogenization system for reagents has been problematic. Current studies are underway at the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) for an *in situ* sediment ozonator that may eventually have the potential to remediate PCBs *in situ*, but at this time the project remains in the research stages and has not been applied full-scale (Hong and Hayes, 2006). Dr. Kevin Gardner of the University of New Hampshire is currently carrying out studies on *in situ* dechlorination of PCBs through application of zero-valent iron (ZVI) or magnesium. While laboratory testing on sediments from the Housatonic River has shown promising results (e.g., 84% PCB removal in one day), mass balance analyses have not yet been able to account for all PCBs removed from the sediment (Mikszewski, 2004). As this technology is still in the experimental stage, no information is yet available on performance of a demonstration-scale or full-scale application.

In situ biological treatment also was not retained for the secondary screening because it has not yet been successfully implemented full-scale for PCBs. In order for *in situ* biological remediation to succeed, the key contaminants must be bioavailable to microorganisms and the microorganisms must feed on the target compounds rather than other substrates. To date, these conditions have not been successfully achieved (Renholds, 1998). Further, the effective delivery of reagents to the sediment has not been successfully demonstrated to date.

A field study was performed by GE in the Housatonic River to assess chemical activation of microbial dechlorination on Woods Pond sediments for approximately one year (Bedard et al., 1995, 1998). In this study, two caissons were driven 18 to 24 inches into the sediment, and the sediments in each caisson were mixed for homogenization twice prior to treatment. One cell was treated with 2,6-dibromobiphenyl (2,6-BB) as a microbial primer and the other was left untreated as a control. The preliminary results indicated that dechlorination of highly chlorinated PCB congeners could be performed by native microbial populations with the addition of 2,6-BB, but significant changes in PCB concentration were not noted (Bedard et al., 1995). Further research exhibited positive results for accelerated *in situ* microbial dehalogenation of PCBs through use of brominated biphenyls, but progress was slowed by lack of naturally occurring and effective priming compounds, and again significant changes in PCB concentration were not noted (Bedard et al., 1998).

Reasons that PCBs are resistant to microbial degradation include the following (Renholds, 1998):

- Contaminant toxicity to microorganisms;
- Preferential feeding of microorganisms on other substrates;
- Microorganisms' inability to use a compound as a source of carbon and energy;
- Unfavorable environmental conditions in sediments for propagation of appropriate microorganisms; and
- Poor contaminant bioavailability to microorganisms.

4.2.7 Summary of Retained Technologies/Process Options

The following technologies/process options will be carried forward for further evaluation in the CMS as part of corrective measure alternatives for river sediments:

- No action;
- Engineering/institutional controls;
- MNR (under MNR options);
- Thin-layer capping (under MNR options);
- Mechanical dredging in the wet (under removal);
- Mechanical dredging in the dry (under removal);
- Hydraulic dredging (under removal);
- Capping (under *in situ* containment); and
- Rechannelization (for limited areas) (under *in situ* containment).

These technologies/process options will be used, in various combinations, to develop remedial alternatives for sediments. In addition, if other technologies/process options for addressing the sediments are identified during the CMS, they may also be incorporated into the remedial alternatives presented and evaluated in the CMS Report.

4.3 Erodible Riverbank Soils

This section identifies the general response actions, associated technologies, and process options available to address erodible riverbank soils containing PCBs as they may affect the River via erosion. For purposes of the CMS, the available remedial options for the riverbanks will be considered only insofar as the riverbanks affect the River through the erosion of soil with PCB levels of concern. To the extent that the riverbanks provide an opportunity for direct contact with the soil, the same remedial options discussed below for floodplain soil would apply (combined with any necessary techniques described in this section to address potential erosion of PCB-containing soil). To address erodible riverbank soils, the following general response actions were considered in this screening:

- No action;
- Removal and replacement; and
- Stabilization.

Each of these response actions is described briefly below, followed by a discussion of the initial screening, and then the secondary screening of the process options within the technologies that were retained after the initial screening. The results of the initial screening are summarized in Table 4-3 and the results of the secondary screening are summarized in Table 4-4.

4.3.1 No Action

The "no action" alternative would not include any active remediation of the riverbanks. Given the NCP requirement that a no-action alternative be considered at every site (40 CFR 300.430(e)(6)), this alternative was retained in the initial screening. Further, this alternative was retained in the secondary screening, since active riverbank remediation to address erosion would not be necessary in areas of the banks where erosion is not a significant problem and/or where PCBs are not present in the erodible bank materials. Additionally, the no-action alternative was retained to provide a baseline against which other remedial options for the riverbanks will be assessed.

4.3.2 Removal and Replacement

Removal and replacement would involve the physical excavation of PCB-containing soil from erodible riverbank areas, followed by backfilling/regrading of the bank with clean soil. Depending on the final slope and proximity of the excavated bank to flow (e.g., on the outside or inside bend of the River, along a straight reach), final restoration would include some combination of reseeding, plantings, and/or armoring.

Initial Screening

Bank soil removal and replacement techniques have been demonstrated full scale at a number of aquatic sites, including the Unnamed Tributary (OH), Cedar Creek (WI), Fields Brook Site (OH), and the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River. Removal of the erodible portions of the bank that contain PCBs would eliminate a potential future source of PCBs to the River. Due to its prior use at this and other sites, and the ability to combine removal with other technologies (e.g., bank stabilization) as part of a remedial alternative, this technology has been retained for the secondary screening.

Secondary Screening

Mechanical excavation is a common technique used to remove PCB-containing soil. Material would be removed from the riverbank using conventional earthmoving equipment such as excavators. After removal operations, clean material would be backfilled into select excavated areas of the riverbank. Following backfilling, the riverbank would be stabilized using erosion-resistant measures (e.g., vegetation, geosynthetic composites).

Effectiveness – Mechanical excavation and removal of erodible PCB-containing riverbank soils would reduce the amount of PCB-containing material eroding into the River. Removal has been used at other sites with impacted riverbank soil, and was used previously within the Upper ½-Mile and 1½-Mile Reaches. This option would also entail replacing excavated soil with clean backfill as necessary, and likely would require some form of armoring over portions of the backfill to mitigate the potential for erosion. Following implementation, periodic monitoring and maintenance would be required to ensure long-term bank stability.

Implementability – This option is considered implementable in most riverbank areas, although it may be difficult to implement on steep banks and in forest and wetland areas and remote areas not currently accessible by serviceable roadways. The equipment, materials and personnel required to implement a mechanical excavation approach are readily available.

This option has been retained for further evaluation as a potential alternative for erodible riverbank soils because it could reduce erosion potential and would be implementable in most riverbank areas. In addition to prior use within the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River as well as other sites, excavation operations for the riverbank may be compatible with either mechanical dredging efforts in the River or excavation operations for the floodplain soil, if chosen for implementation.

4.3.3 Bank Stabilization

Bank stabilization is a common practice used in aquatic environments to prevent or control erosion. The design objective for stabilization would be to isolate PCB-impacted riverbank soil and mitigate the potential for erosion of the bank soils into the River. Many engineering techniques are available to control erosion, and typically involve the construction of structures that stop wave energy from reaching the natural riverbank, or absorb and reflect the wave energy. Depending on site conditions, riprap or armor stone, revetment mats, retaining walls, and gabions are commonly employed bank stabilization options.

Initial Screening

Bank stabilization techniques have been demonstrated full scale at a number of aquatic sites, including the Upper ½-Mile and 1½-Mile Reaches of Housatonic River. Through placement of armoring and/or installation of some form of a retaining wall, the riverbank soils would be physically isolated from the River, reducing the potential for erosion and the potential for mobility of PCBs in the riverbank soil. Since this technology has the ability to be combined with other technologies (e.g., bank soil removal) and has been successfully applied at this and other sites with PCB-containing riverbank soil, it has been retained for the secondary screening.

Secondary Screening

Four bank stabilization process options were considered during the secondary screening for the riverbank soils: armor stone, revetment mats, retaining walls, and gabions. All of these options are briefly described below, along with the results of the secondary screening.

4.3.3.1 Armor Stone

An armor stone approach would include using stones placed on the riverbank to create a barrier to destructive flow/wave action. The appropriate size or weight of the armor stone would be determined based on calculated flow, wave, and/or ice forces expected at the location of the bank stabilization structure. This structure would typically extend below the river water line to mitigate the potential for scour at the structure base. The design may also include a geosynthetic separation layer or natural aggregate filter layer between the riverbank soils and armor stone to reduce the potential for erosion of the underlying soils, and prevent intrusion of the riverbank soil into the armor stone during placement. This option may include the installation of temporary structures to either provide a dry environment to conduct work (e.g., sheetpile, port-a-dam) or reduce the potential for dispersing suspended solids from the work area (e.g., silt curtain).

Effectiveness – Placing armor stone on the riverbank could significantly reduce potential erosion through isolation of PCB-containing soils. This technology has been used successfully at other sites for riverbank soil protection, including the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River. Monitoring and maintenance would be required to ensure the long-term effectiveness of this option.

Implementability – This option would be implementable; however, some amount of bank soil removal would likely first be required to accommodate any loss of flood storage capacity related to installation. Armor stone can be quickly installed from either land or water, and is adaptable to a wide variety of shoreline conditions. This approach may require placement of a filter layer of gravel or crushed stone to prevent intermixing of bank soil with the armor layer and reduce the potential for bank erosion through the armor stone. The proper equipment, materials, and personnel would be readily available to implement this option. Potential difficulties that may be encountered during implementation include work within forest and wetland areas as well as possible access issues.

4.3.3.2 Revetment Mats

Revetment mats can consist of double layers of woven fabric forms filled with concrete or grout, reno mattresses (stone-filled wire baskets), or cellular (cabled) concrete mats placed on the slope to be protected. This approach is a standard construction practice for the prevention/control of erosion and has been used successfully at numerous other sites – e.g., Compressor Station 229 (NY), North Avenue Dam Site (WI).

The size or weight of the revetment mats would be designed based on calculated flow, wave, and/or ice forces expected at the location of the bank stabilization structure. Construction is also likely to include an anchoring mechanism to keep the revetment mat in place under dynamic loads imposed by river currents and ice. This structure would typically extend below the river water line to mitigate the potential for scour at the structure base. The design would also include a geosynthetic separation layer or a gravel filter layer between the riverbank soils and revetment mat to reduce the potential for erosion and prevent intrusion of the riverbank soil into the revetment mat. Installation may include the placement of a temporary structure to reduce the potential for dispersing suspended solids from the work area (e.g., silt curtain).

Effectiveness – Placing a revetment mat could significantly reduce potential erosion through isolation of PCB-containing riverbank soils. Construction of stabilization measures would temporarily impact existing vegetation and benthic communities inhabiting these areas. These effects would likely be mitigated over time as aquatic macroinvertebrate and amphibian organisms use spaces within the revetment mats for foraging habitat and cover. Monitoring and maintenance would be required to ensure the long-term effectiveness of this option.

Implementability – This option is readily implementable; however, some amount of bank soil removal would likely first be required to accommodate any loss of flood storage capacity related to installation. Use of revetment mats represents a simple, fast, and potentially cost-effective technique for placement of a barrier layer for slope protection both above and below the water without the need for dewatering. The proper equipment, materials, and personnel would be readily available to implement this option. Potential difficulties include implementation in forest and wetland areas as well as possible access issues.

4.3.3.3 Retaining Walls

A retaining wall approach would involve constructing a retaining wall (e.g., sheetpile, timber, concrete) along the riverbank to stabilize and protect the bank from erosion. The retaining wall would be designed to create a rigid barrier for earth and water while resisting the lateral pressures imposed by the riverbank soils. Typically, retaining wall installation adjacent to the edge of river or within the watercourse involves the installation of a silt curtain to contain suspended solids produced from construction operations. Installation of the wall can be achieved from land or water using standard construction equipment. From a design perspective, retaining wall configurations are adaptable to a wide variety of riparian conditions and can be designed for installation within changing surface and subsurface conditions.

Effectiveness – Retaining walls could significantly reduce potential erosion through isolation of PCB-containing riverbank soils behind the walls. This technology has been used at other sites where PCB impacts exist within riverbank soils, including the Upper ½-Mile Reach of the Housatonic River (steel sheeting). Its greatest effectiveness is for high, steep banks. Monitoring and maintenance would be required to ensure the long-term effectiveness of this option.

Implementability – This option is considered implementable, with proper equipment, materials, and personnel readily available. Bank soil removal in conjunction with retaining wall installation may be required to remove bank soil located on the river side of the wall (i.e., a wedge of bank soil at the toe of the wall which may otherwise be more prone to erosion) and/or to address any associated loss in flood storage capacity related to installation. The loss of bank habitat caused by constructing a retaining wall may require that some form of stable habitat structure (e.g., gravel, clean fill) be placed on the river side of the wall. Other potential difficulties include implementation in forest and wetland areas, access issues in certain areas, the need for potentially significant ongoing maintenance, potential safety issues depending on the height of the wall, and high costs relative to other bank stabilization techniques.

4.3.3.4 Gabions

This option would entail using wire mesh containers that are filled with crushed stone to form flexible structures such as retaining walls, seawalls, and channel linings. These structures would then be placed on the riverbank to help control, or even prevent erosion of the soil. The design would also include a geosynthetic or gravel separation layer between the riverbank soils and gabions to reduce the potential for erosion and prevent intrusion of the riverbank soil into the gabions. Installation may include the placement of temporary structures to either provide a dry environment to conduct construction work (e.g., sheetpile, port-a-dam) or reduce the potential for dispersing suspended solids from the work area (e.g., silt curtain). Gabions are suitable where the retained material is likely to be saturated and where the bearing quality of the soil is poor.

Effectiveness – Using gabions for bank stabilization could significantly reduce the potential for erosion through isolation of PCB-containing riverbank soils. This technology has been used at other sites where PCB impacts exist within riverbank soils, including the 1½-Mile Reach of the Housatonic River. Its greatest effectiveness is for low, steep banks. Long-term monitoring and maintenance would be required to ensure the long-term effectiveness of this option.

Implementability – This option would be implementable, with proper equipment, materials, and personnel readily available. However, some amount of bank soil removal would likely first be required to accommodate any loss of flood storage capacity related to installation. Other potential difficulties include implementation in forest and wetland areas and possible access issues in certain areas.

4.3.3.5 Results of Bank Stabilization Secondary Screening

The effectiveness and implementability of armor stone, revetment mats, retaining walls, and gabions have been evaluated to select representative bank stabilization process options for use in the remedial alternatives for erodible riverbanks. Each of these bank stabilization methods has been shown to be effective in controlling erosion. Armor stone and revetment mats have been retained as representative options for bank stabilization due to their use in the Upper ½-Mile and 1½ Mile Reaches of the Housatonic River along banks similar in height and grade to those present in Reaches 5 and 6, their availability, and their wider applicability over varying river and bank conditions. Retaining walls and gabions have not been retained as process options for remediating erodible banks containing PCBs due to the availability of other process options with wider applicability and lower costs.

4.3.4 Summary of Retained Technologies/Process Options

The following process options will be carried forward for further evaluation in the CMS as potential means of addressing erodible riverbank soils containing PCBs:

- No action;
- Mechanical excavation (under removal and replacement);
- Armor stone (under stabilization); and
- Revetment mats (under stabilization).

As noted in Section 5, these technologies/process options for addressing erodible riverbanks will be evaluated together with those for addressing sediments, since both affect the River. In addition, if other technologies/process options for addressing erodible riverbanks are identified during the CMS, they may also be used in the sediment remedial alternatives presented and evaluated in the CMS Report.

4.4 In-Place Floodplain Soils

To address the PCBs present in floodplain soils, the following general response actions were considered and screened:

- No action;
- Engineering/institutional controls;
- MNR;
- Removal and replacement;

- *In situ* containment; and
- *In situ* treatment.

Each of these response actions is described briefly below, followed by a discussion of the initial screening, and then a description of the secondary screening of the process options within the technologies that were retained after the initial screening. The results of the initial screening are summarized in Table 4-5 and the results of the secondary screening are summarized in Table 4-6.

4.4.1 No Action

The "no action" response action for floodplain soil would not include any active or passive remediation. As noted above, the NCP requires that a no-action alternative be considered at every site (40 CFR 300.430(e)(6)). Thus, this alternative was retained in the initial screening.

The no-action response action was also retained in the secondary screening step. It is technically implementable, is appropriate in areas of a site that already meet cleanup goals, and has been a remedy component for floodplain areas adjacent to the Upper ½-Mile and 1½-Mile Reaches of the River where PCB concentrations are below the applicable soil-related performance standards. In addition, this alternative may be appropriate for floodplain areas where potential human exposure is not reasonably anticipated (e.g., due to the steep slopes or wet nature of the areas) and in areas where the damages anticipated due to remediation (e.g., in ecologically sensitive habitat areas) outweigh the potential benefits. There are no technical or administrative conditions that would preclude implementation of no action as a remedy component. Further, the no-action alternative can provide a baseline against which other floodplain corrective measures can be assessed in the CMS. For these reasons, and in accordance with the NCP, the no-action alternative has been retained for evaluation in the CMS.

4.4.2 Engineering/Institutional Controls

Engineering/institutional controls are physical, legal, and/or administrative controls that are implemented to limit potential exposure to PCBs in floodplain soils by humans and/or ecological receptors. Such controls can be used to restrict access to and use of the site, and can be implemented to maintain appropriate uses that mitigate the potential for future human and, to some extent, ecological exposure to PCB-containing soil. Engineering/institutional controls for floodplain areas may include, but are not limited to, physical access restrictions (such as fences and signs), activity and use restrictions (including deed restrictions), and information devices (such as biota consumption advisories). For the Rest of River, this category would also include, as necessary, the use of Conditional Solutions, as defined in the Consent Decree.

Initial Screening

Engineering/institutional controls can be used to mitigate the potential for exposure to PCBs in floodplain soils. They are frequently a necessary component of a comprehensive remedial alternative and can be used alone (in certain areas) or in conjunction with other technologies/process options (e.g., removal and replacement, *in situ* containment) when the concentrations of PCBs that remain in place exceed those that are deemed protective for unrestricted uses. Engineering/institutional controls have already been successfully implemented at certain floodplain properties along the Housatonic River, as well as at other sites having PCB impacts in floodplain soils. Because of these circumstances, they were retained for the secondary screening.

Secondary Screening

Potential engineering/institutional controls for the floodplain include access restrictions, land use restrictions, Conditional Solutions, and consumption advisories, as further discussed below.

4.4.2.1 Access Restrictions

Access restrictions would include physical constraints, such as fencing and signs, placed around a floodplain area containing PCBs. They could be used during implementation of remedial actions and, in some instances, on a longer-term basis.

Effectiveness – Access restrictions would limit access by humans and, to a limited degree, ecological receptors and thereby reduce the potential for exposure to PCBs in soils within the floodplain area. To ensure ongoing protection, limited monitoring and maintenance activities would be required.

Implementability – Access restrictions are both technically and administratively implementable. However, agreement by property owners would be required and could hinder the implementation of these measures.

4.4.2.2 Land Use/Deed Restrictions

Land use restrictions include legal deed restrictions on uses or activities at properties to reduce the potential for human exposure to PCBs in floodplain soil. They include Grants of Environmental Restrictions and Easements (EREs), such as described in the CD for other portions of the GE-Pittsfield/Housatonic River Site. These restrictions may prohibit future changes to different types of land use (e.g., from commercial or recreational use to residential use) and/or impose specific restrictions on certain future activities (e.g., excavation). This option can be implemented alone (e.g., where properties meet the applicable standards for current uses but not for anticipated future uses) or in combination with other technologies/process options.

Effectiveness – Land use restrictions reduce potential human exposure to PCBs contained in floodplain soils by placing limits on future uses and/or activities performed on the property. They have been used at other sites, including the non-Rest of River portions of the GE-Pittsfield/Housatonic River Site. Long-term monitoring and maintenance would be required to ensure the long-term effectiveness of this option.

Implementability – Land use restrictions are both technically and administratively implementable provided that the owners of the subject properties agree to them. The majority of the land within the floodplain in the PSA is owned by the Commonwealth of Massachusetts or the City of Pittsfield. The Commonwealth of Massachusetts has agreed in the CD (Paragraph 62.b) that, for any Commonwealth-owned property for which GE is required to seek an ERE under the CD, it will "not unreasonably withhold consent" to the placement of an ERE. In addition, the City of Pittsfield has agreed in the CD (Paragraph 66) to impose EREs on any City-owned properties where EREs are warranted. For private properties, the placement of land use restrictions would require the property owners' agreement.

4.4.2.3 Conditional Solutions

For areas of the GE-Pittsfield/Housatonic River Site other than the Rest of River, the CD provides for the use of Conditional Solutions (see Paragraph 34). For non-residential properties in such areas that are not remediated to the applicable standards for unrestricted use and where an ERE is not recorded to address future activities and uses, GE is required to implement a Conditional Solution. A Conditional Solution requires GE to conduct remediation necessary to achieve the applicable standards for the property's current use and to agree to conduct additional remediation in the future, under certain conditions, to address actual changes in the property's use that would require such remediation. To change a property use so as to trigger that obligation, the owner must obtain necessary governmental approvals and permits for the future use and also provide documented evidence of his/her commitment to that use. This same Conditional Solution approach could be used for non-residential floodplain properties in the Rest of River.

Effectiveness – A Conditional Solution would effectively protect human health because it would involve cleanup to the standards that are protective for the property's current uses, and a legal commitment by GE to conduct further cleanup in the future as necessary to be protective of any legally permissible actual future use. Such future uses may include a change to a less restrictive use (e.g., from commercial or recreational use to residential use) or an expansion or renovation of existing buildings. This approach has been effectively used at the non-Rest of River portions of the GE-Pittsfield/Housatonic River Site. Monitoring (visual inspections) would be performed to ensure the long-term effectiveness of this option.

Implementability – The use of Conditional Solutions would be both technically and administratively implementable, as evidenced by the fact that they have been implemented at the non-Rest of River portions of the GE-Pittsfield/Housatonic River Site.

4.4.2.4 Consumption Advisories

Consumption advisories warn the public to limit consumption of certain biota found in, or certain agricultural products grown in, portions of the floodplain. Such advisories are already in place for frogs, turtles, and/or ducks along certain portions of the Housatonic River floodplain, and are commonly used throughout the nation. Such advisories are and/or can be publicized through posting of signs and/or distribution of brochures. This option can be implemented alone (for certain areas) or combined with other technologies/process options.

Effectiveness – Consumption advisories reduce potential human exposure to PCBs in biota derived from floodplain soils by placing restrictions on the uptake of certain biota and agricultural products from the floodplain area. To be effective, the advisories would need to be adequately publicized via posting of signs, distribution of brochures, etc.

Implementability – Consumption advisories would be readily implementable; require minimal activities, personnel, and equipment; and continue over the long term. Implementation of consumption advisories would require coordination with the appropriate agencies and dissemination of information on the advisories to the general public and surrounding communities.

4.4.2.5 Results of Engineering/Institutional Controls Secondary Screening

The effectiveness and implementability of access restrictions, land use restrictions, the Conditional Solution approach, and consumption advisories have been evaluated for potential use in the remedial alternatives for the floodplain. Due to their use at other sites and at other portions of the GE-Pittsfield/Housatonic River Site, and recognizing the unique aspects and potential applicability of each option to some portion of the Rest of River floodplain, all engineering/institutional control options – access restrictions, land use restrictions, Conditional Solutions, and consumption advisories – have been retained for further evaluation in the CMS as potential components of an overall remedy for the floodplain.

4.4.3 MNR

MNR is a response action that relies on ongoing, naturally occurring processes to contain, destroy, or otherwise reduce the bioavailability or toxicity of chemical constituents in soils, with long-term monitoring to assess the rate of recovery or attenuation. For the floodplain soils, physical processes such as natural burial via deposition with cleaner material (e.g., cleaner sediments during floods) would likely be the predominant natural recovery mechanism. The rate and extent to which natural recovery occurs are dependent upon the dynamics of and interaction between the River and the floodplain soils.

Initial Screening

PCBs are present in the floodplain soils downstream of the Confluence due to historical and ongoing deposition of PCB-containing sediment which occurs when the surface waters of the Housatonic rise and inundate the floodplains. As noted in the RFI Report (BBL and QEA, 2003), the highest floodplain soil PCB concentrations are generally observed adjacent to the River, where surface water inundation is most frequent and the physical conditions are most conducive to sediment deposition (i.e., where gradients and vegetation types are most prone to slow down/pool the flow of surface water over the floodplain). As measures are implemented which reduce the concentration of PCBs on the solids being transported to and deposited on the Housatonic River floodplains, natural recovery of the surface soils (i.e., reduced soil PCB concentrations) should occur over time, with recovery occurring more quickly in those areas with the greatest deposition rates. Given the potential for natural recovery through depositional processes to occur, and the variable range of PCB concentrations across the Housatonic River floodplain, MNR was retained for secondary screening as a potentially viable floodplain remedial component.

Secondary Screening

As noted above, for PCBs in floodplain soils, physical processes such as natural burial are the predominant natural recovery mechanism. In areas of the floodplain that contain PCB concentrations that are slightly above the cleanup objectives, and/or in areas of the floodplain that are fairly inaccessible and/or support unique or sensitive habitat, MNR, while potentially slow, may offer certain advantages over more destructive removal or containment alternatives.

Effectiveness – MNR could be effective at reducing potential exposure to human and ecological receptors over time, through reduction in floodplain PCB concentrations due to natural recovery processes. Under this approach, monitoring the natural recovery of soils in the floodplain area would be performed to assess the extent to which ongoing natural attenuation processes are effectively achieving remedial goals. Such long-term monitoring data can be used to evaluate trends and make predictions regarding future conditions. Periodic monitoring would cause minimal disruption to the environment, particularly within sensitive areas.

Implementability – MNR would be readily implementable. The activities associated with implementing MNR would be primarily associated with monitoring. Personnel and equipment necessary for conducting monitoring activities and assessing the corresponding results are readily available and the work could be performed with minimal intrusive activity at affected properties.

MNR has been retained for further evaluation as a potential remedial component for the floodplain soils, as it is minimally intrusive, easily implemented, and may be effective in certain portions of the site when coupled with measures that would reduce the PCB concentrations on the solids transported to and deposited on the floodplain.

4.4.4 Removal and Replacement

This general response action involves the physical removal of PCB-containing soil from the floodplain with replacement of material by backfilling, as necessary, with clean soils. This process typically employs readily available earthmoving equipment, such as backhoes and bulldozers.

Initial Screening

Soil removal and replacement has been performed at a number of floodplain properties adjacent to the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River and at other sites where PCBs were present in the floodplain to mitigate the potential for human and ecological exposure. Accordingly, this technology/process option has been retained for the secondary screening.

Secondary Screening

Removal and replacement would involve excavating unsaturated and/or saturated soil using conventional earthmoving equipment such as excavators, and then backfilling the excavated areas with clean material. With this option, dewatering may be required in some locations, depending upon the depth of the groundwater table and location of the River relative to the area subject to soil removal and replacement. This option can be implemented alone or combined with other technologies/process options.

Effectiveness – Mechanical excavation would significantly reduce the potential exposure to human and ecological receptors through removal of PCB-containing soils. Removal has been used at other sites with impacted floodplain soil, and has been used within the floodplain adjacent to the Upper ½-Mile and 1½-Mile Reaches. This option would also entail replacing excavated soil with clean backfill as necessary, and revegetation/restoration of the excavation area. If residual PCBs remain in the floodplain soils following removal, institutional controls may be required to ensure remedy effectiveness.

Implementability – Removal and replacement are likely implementable in most floodplain areas. The equipment, materials, and personnel qualified to implement this option are available. However, it may be difficult to implement in forest and wetland areas and in remote areas not currently accessible by serviceable roadways. In addition, this option would require access permission from property owners.

Soil removal and replacement has been retained for further evaluation as a potential remedial alternative for the floodplain soil due to its proven effectiveness and implementability.

4.4.5 *In Situ* Containment

This response action would involve the placement of some type of physical barrier over the PCB-containing floodplain soils to mitigate the potential for exposure to human and ecological receptors. There are various types of barriers that could be used for this purpose. These include: (a) placement of a simple soil cover over the existing soils, which would provide a clean surface and minimize the potential contact with the underlying soil, while not restricting the movement of water from precipitation into and through the soil cover; (b) adding pavement or enhancing the current pavement over the underlying soils to provide a barrier to contact; and (c) placement of an engineered barrier, which can be either vegetated or paved and typically involves several layers (including an impermeable layer), to isolate the underlying soil, minimize erosion of that soil, and minimize infiltration of precipitation that could result in potential migration of contaminants. *In situ* containment options are sometimes implemented following removal, and are typically implemented in conjunction with activity and use restrictions, which prohibit or restrict interference with the barrier and thus provide further assurance that the potential for exposure is minimized.

Initial Screening

In situ containment options, including soil covers, enhanced pavement, and engineered barriers, are specified in the CD for certain applications in the areas outside the Rest of River, including properties within the floodplain adjacent to the Upper ½-Mile Reach of the River. They have also been implemented at numerous other sites with PCBs to mitigate the potential for human and ecological exposure. *In situ* containment options can be used as a stand-alone remedy or combined with other technologies/process options (e.g., institutional controls, MNR, and removal and replacement) to create a multi-component approach. For these reasons, *in situ* containment has been retained for the secondary screening.

Secondary Screening

For the secondary screening, soil and pavement covers will be considered together under the general category of covers, followed by an evaluation of engineered barriers.

4.4.5.1 Covers

The cover option would include the placement of soil fill and topsoil or pavement over the PCB-containing floodplain soil to provide a barrier to contact. Clearing, grubbing, and site grading may be required prior to cover placement. This option can be implemented alone or may need to be combined with other technologies/process options (e.g., removal may first be required prior to cover placement to maintain flood storage capacity in the area).

Effectiveness – A cover could significantly reduce potential exposure to human and ecological receptors by isolating the PCB-containing floodplain soils, mitigating direct exposures, and reducing the potential for migration of PCB-impacted soils. Institutional controls and a long-term monitoring and maintenance plan would be required to ensure remedy effectiveness following implementation.

Implementability – This option is likely implementable in most floodplain areas. Soil removal may be required prior to placement of the cover to maintain adequate flood storage capacity. The appropriate equipment, materials, and personnel are available to install a cover. From an administrative standpoint, it would be necessary to obtain permission from the property owner for access to install such a cover.

4.4.5.2 Engineered Barriers

An engineered barrier is a permanent cover, which can be paved or unpaved, designed to isolate and contain underlying soils, prevent direct contact with those soils, and minimize the potential for PCB migration from those soils via erosion or infiltration of precipitation water. Implementation of such a barrier typically includes placement of multiple layers of cover material over the underlying soil, which generally include an impermeable layer and may include a combination of sand, gravel, clay, geosynthetics, asphalt and/or topsoil with vegetation planted on the top. Clearing, grubbing, and site grading may be required prior to barrier placement. This option can be implemented alone or may need to be combined with other technologies/process options (e.g., removal may first be required prior to barrier placement to maintain flood storage capacity in the area).

Effectiveness – Installing an engineered barrier can result in a significant reduction in the potential exposure to human and ecological receptors by isolating the underlying PCB-containing floodplain soils. Institutional controls and a long-term monitoring and maintenance plan would be required to ensure remedy effectiveness following remedy implementation.

Implementability – This option is likely implementable in most floodplain areas. Soil removal may be required prior to placement of the barrier to maintain existing flood storage, and venting mechanisms may be necessary to prevent gas buildup if covering over decaying vegetation. The appropriate equipment, materials, and personnel are readily available to implement this option. From an administrative standpoint, it would be necessary to obtain permission from the property owner for access to install such a barrier.

4.4.5.3 Results of *In Situ* Containment Secondary Screening

The effectiveness and implementability of covers and engineered barriers have been evaluated for potential use in the remedial alternatives for the floodplain. Due to their proven effectiveness and implementability, both of these options have been retained for potential use as part of a remedial scenario for floodplain soil.

4.4.6 *In Situ* Treatment

In situ treatment involves the use of physical, biological, chemical, or thermal processes to destroy, degrade, or immobilize the contaminants within the soil. Each of these process options is discussed below.

- ***In situ* physical immobilization** would involve mixing an immobilization agent into the floodplain soil to reduce the potential mobility of PCBs in the soil. The agent can be coal, coke breeze, activated carbon, Portland cement, fly ash, limestone, or other additives. It is injected/mixed into the soil to encapsulate the contaminants in a solid matrix and/or chemically alter the contaminants by converting them into a less bioavailable, less mobile, or less toxic form.

- ***In situ* biological treatment** would involve introducing microorganisms and/or nutrients into the treatment zone to increase ongoing biodegradation rates of PCBs in floodplain soils. Biodegradation of PCBs may occur either aerobically or anaerobically.

- ***In situ* chemical treatment** would involve injecting chemical surfactants/solvents or oxidants into the treatment area to remove or destroy PCB constituents in the floodplain soils. Chemical treatment processes may include use of common or proprietary solvents and other liquids.

- ***In situ* thermal treatment** would involve heating the PCB-containing soil to high enough temperatures to remove and/or destroy PCBs in the floodplain soils. It could include the use of steam or direct heat (via heat elements) and thermal conductivity to heat soils and vaporize contaminants for collection and treatment/disposal. In addition, resistance heating could be employed, which uses electromagnetic waves to heat targeted soils in an effort to enhance contaminant removal. *In situ* vitrification, a higher energy form of thermal treatment, uses temperatures high enough to vitrify the soil (i.e., turn it into a stable glass-like material), destroying or immobilizing contaminants that are present. The success of this response action is highly dependent on soil heterogeneity, subsurface conditions, and the effectiveness of the delivery system.

Initial Screening

No sites have been identified where *in situ* biological, chemical, or thermal treatment was successfully demonstrated full scale to address PCBs in soil. While aerobic and anaerobic biodegradation of PCBs are known to occur both naturally and through enrichment (e.g., through addition of nutrients and/or microbes which are know to degrade PCBs), no processes or sites were identified in the literature where significant reductions in PCB concentrations have been documented. With specific regard to both *in situ* biological and chemical treatment studies performed by others, problems have been noted with design of an effective nutrient/chemical delivery and containment system for materials injected or mixed into the soils to promote degradation (Renholds, 1998). Further, land disposal restrictions and underground injection-related regulations may limit the viability of using chemical treatment (EPA, 2006d). EPA has noted that while injecting chemical surfactants/solvents to treat soils is common in oil field applications, “it has found limited application in the environmental arena” (EPA, 2006d). When using oxidants for *in situ* chemical treatment, the effectiveness can be greatly affected by site stratigraphy, soil oxidant demand, and pH. Chemical oxidation usually requires multiple applications, and some unreacted oxidants may remain in the subsurface (EPA, 2006d). Thermal treatment would require installation of numerous electrodes and/or injection/extraction wells to allow for sufficient coverage. If thermal treatment were applied to the floodplain soils at temperatures sufficient to volatilize or destroy the PCBs, the soils would need to be amended with nutrients or removed/covered with new soil (if vitrified) following treatment to support vegetative growth. Thus, the *in situ* biological, chemical, or thermal treatment technologies have been eliminated from further consideration in the CMS.

Physical immobilization was evaluated in 1988 under EPA’s SITE program at a GE service shop in Hialeah, FL. Contaminants of concern included PCBs, as well as VOCs and metals. The demonstration process involved deep soil mixing using Geo-Con equipment and International Waste Technologies (IWT) HWT-20 cementitious additive. The conclusions drawn were that: (a) immobilization of PCBs appeared likely (although this could not be confirmed due to low PCB concentrations in both the untreated soil and leachate for the treated and untreated soils); (b) a small volume increase can be expected; (c) the solidified material showed satisfactory physical properties (e.g., unconfined compressive strengths, permeability, and integrity) but unsatisfactory integrity for the freeze/thaw samples; and (d) a dense, low-porosity, homogeneous mass was produced, indicating potential for long-term durability (EPA, 1990).

In situ stabilization was also implemented as a final remedial component to address in-place soils at the Caldwell Trucking site (NJ) (EPA, 2006E). Other than PCBs, the constituents of concern at this site were metals (primarily lead) and VOCs. Although no specific data were found, review of a five-year review report by EPA indicated the stabilization of contaminated soil was "intact and in good repair" and that it "has greatly reduced the potential for exposure and mobility of site related contaminants" (EPA, 2002).

Based on these prior uses, physical immobilization has been retained for the secondary screening.

Secondary Screening

Physical immobilization was carried forward into the secondary screening. This option would involve mixing the floodplain soils *in situ* with Portland cement or some other stabilization agent to reduce the bioavailability of PCBs in the soils. Clearing, grubbing, and site grading may be required prior to implementation. This option can be implemented alone or may need to be combined with other technologies/process options. For example, to maintain flood storage capacity in the area, soil removal may be required prior to soil stabilization so as to accommodate the increased volume that would be caused by the addition of the stabilization agent and/or to accommodate a soil cover which may need to be placed over the stabilized soils to support vegetative growth.

Effectiveness – Physical immobilization could reduce the bioavailability of PCBs in floodplain soils, thereby reducing the potential for human or ecological exposure. Treatability studies would have to be conducted to determine site-specific effectiveness, which could vary with different types of stabilizing agents, different mixing/injection processes, and different physical characteristics of the soil within various reaches of the floodplain. Problems/challenges noted with the Hialeah site, which would also need to be considered for the Housatonic River floodplain soils, include volume increase and freeze/thaw integrity issues. In addition, if an immobilization agent were utilized that solidified the soils following mixing/injection, a soil cover would likely need to be placed over the treated material to sustain vegetation and provide habitat for floodplain organisms. A long-term monitoring and maintenance plan would be required following installation to monitor and maintain remedy effectiveness.

Implementability – This option would be technically implementable. The equipment, materials, and operating personnel are readily available. However, there could be some technical and administrative issues, such as incompatibility with future uses of floodplain soils and restoration options (i.e., may not be able to support vegetative growth), flood storage issues due to volume expansion during implementation of this option, and potential difficulty obtaining permission from property owners to carry out the immobilization on their properties. Also, this option is best suited for deeper applications within a relatively small footprint, rather than a large, shallow-depth application such as the floodplain soils of the Housatonic River. Finally, this option would be costly to implement given the relatively shallow vertical distribution of PCBs in the floodplain soil (which would make this an expensive remedy per unit area applied) and the likely need to remove material prior to or following implementation to accommodate flood storage needs.

Due to potential effectiveness and implementation issues noted above and the relatively high implementation costs compared to other more proven and effective floodplain soil remedial options, physical immobilization has not been retained for further evaluation as a floodplain soil remedial option at this time. Of primary concern are the compatibility of this technology/process option with future land use and the unknown effectiveness of the option.

4.4.7 Summary of Retained Technologies/Process Options

The following technologies/process options will be carried forward for further evaluation in the CMS as part of remedial alternatives for the floodplain soils:

- No action;
- Access restrictions (under engineering/institutional controls);
- Activity and use restrictions (under engineering/institutional controls);
- Conditional Solutions (under engineering/institutional controls);
- Consumption advisories (under engineering/institutional controls);
- MNR (under MNR);
- Mechanical excavation and replacement (under removal and replacement);
- Soil covers (under *in situ* containment); and
- Engineered barriers (under *in situ* containment).

In addition, if other technologies/process options for addressing floodplain soils are identified during the CMS, they may also be incorporated into the remedial alternatives presented and evaluated in the CMS Report.

4.5 Management of Removed Sediment and Soil

This section describes the general response actions, associated technologies, and process options considered to address PCBs in removed sediment, riverbank soil, and floodplain soil, and the process by which they were screened. *Ex situ* treatment/management of any type first requires that the sediment or soil be removed, and therefore the technologies/process options are subject to the considerations discussed previously for removal of sediments and riverbank and floodplain soils. Once the material is removed from the designated area(s), the resulting impacts and benefits to the removal area remains the same, regardless of how the material is managed.

To manage the removed material, the following general response actions were considered in this screening:

- Solids dewatering;
- *Ex situ* treatment (physical, biological, chemical, and thermal);
- Local disposal;
- Off-site treatment/disposal; and
- Beneficial reuse.

Each of these response actions is described briefly below, followed by a discussion of the initial screening and then a description of the secondary screening of the process options within the technologies that were retained after the initial screening. The results of the initial screening are summarized in Table 4-7 and the results of the secondary screening are summarized in Table 4-8. In most instances, the technologies/process options within these response actions could not be used alone, but would need to be combined with technologies/process options within other response actions. For example, for removed sediments, the dewatering and *ex situ* treatment technologies would need to be combined with one or more of the options for disposal or reuse of the dewatered or treated material.

4.5.1 Solids Dewatering

Solids dewatering would likely be needed to remove excess water from removed sediments and saturated soils to facilitate their handling and treatment/disposal. Dewatering is typically performed using some combination of mechanical and/or gravity-assisted techniques, briefly described below.

- **Mechanical dewatering** is accomplished when slurry from the removed material is pumped or fed through a filtration device or subjected to centrifugal forces. Examples of mechanical dewatering equipment include the belt filter press, plate and frame filter press, solid-bowl (centrifuge) equipment, and the evaporator. These dewatering process options are usually required for sediments that are hydraulically dredged, and sometimes used for mechanically dredged sediments.

- **Gravity dewatering** involves allowing the removed sediment and soil to settle and consolidate on a lined, bermed pad and/or in a tank, basin, or other device. Depending on sediment type and the area/container being used to gravity dewater, flocking agents can be added to enhance the dewatering process.

Initial Screening

Mechanical and/or gravity dewatering techniques have been successfully applied at a number of sediment sites where PCB-containing sediments were removed for processing/disposal, including the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River, the Fox River (WI), the St. Lawrence River (NY), Manistique Harbor (MI), and New Bedford Harbor (MA). Depending on the material characteristics and the removal methods used, some form of solids dewatering is currently anticipated for those remedial alternatives that include sediment removal as a remedy component. Given their use at other sites and their potential applicability for processing wet sediments and/or soils removed from the Housatonic River, both mechanical and gravity dewatering have been retained for the secondary screening.

Secondary Screening

Various mechanical and gravity dewatering options were evaluated during the secondary screening, as described below.

4.5.1.1 Mechanical Dewatering

Various methods are available for mechanical dewatering of removed sediments and wet riverbank soil, including the belt filter press, plate and frame filter press, solid-bowl (centrifuge), and evaporator. These process options were assessed during the secondary screening to examine their potential applicability for the River. A description of each option is provided below, along with the results of the secondary screening.

- The **belt filter press** operation would involve feeding gravity-dewatered materials between two continuous belts, one above the other. Pressure is applied to the belts to dewater the solids, yielding an aqueous filtrate. The dewatered solids are continuously removed from the belt by a scraper. Effluent from the process may require treatment prior to discharge to surface water. Following treatment, solids would be subject to a disposal option.

- A **plate and frame filter press operation** consists of a series of plates and frames held together using a hydraulic ram. Dredged material (which can be chemically conditioned to enhance filterability) is pumped into the space between the plates within the frames. Water is forced through filter media on the plates and out the plate outlets, which yields a dilute aqueous filtrate. The dewatered solids are then removed by separating the plates and frames. An optional membrane filled with compressed air can be used to effect further dewatering. Effluent from the process may require treatment prior to discharge to surface water. Following treatment, solids would be subject to a disposal option.

- The **solid bowl (centrifuge)** process option is widely used in industry to separate liquids of different density, thicken slurries, or remove solids. Chemicals may be added to removed solids for conditioning prior to centrifuge operation. With this technology, solids would be fed at a constant flow rate into the rotating bowl where they would separate into a dense cake containing the solids and a dilute aqueous stream called “centrate” that may require further treatment. The solids cake would be discharged from the bowl by a screw feeder. Upon discharge from the bowl, the solids cake would be subject to a disposal option. Effluent from the process may require treatment prior to discharge to surface water.

- The **evaporator** process option employs an evaporation unit into which the dredged solids would be placed. The solids would be subject to increased heat and pressure to vaporize water, which would be collected separately. The solids would be removed and disposed of as appropriate. Collected water may require treatment prior to being discharged to surface water. Due to the addition of heat, this process is highly energy-intensive.

Effectiveness – The belt filter press and plate and frame filter press have proven reliable at other sites – e.g., New Bedford Harbor (MA), St. Lawrence River (NY), and Grasse River, (NY). Pretreatment steps may be required to support/enhance the dewatering step. Generally, plate and frame presses achieve lower water contents in solids cake than belt filter presses (USACE, 2004).

Historically, the solid bowl (centrifuge) process option has required frequent maintenance and often experienced operational difficulties. Cake solids are typically lower than those attained by filter presses (USACE, 1988).

No long-term operation and maintenance would be required for any of these process options.

Implementability – The belt filter and plate and frame filter presses would be readily implementable. The equipment, materials, and operating personnel are available to implement these options. Specific treatment requirements, such as pretreatment measures and specialized equipment, would be determined through treatability testing using site sediment and soil prior to implementation. Depending on the rate at which sediments/soils are generated and the percent solids of the material to be dewatered, a large tract of land may be required to support the dewatering activities.

The solid bowl (centrifuge) option would be implementable for sediments present in the Housatonic River. However, centrifuges do not operate efficiently when the feed composition is variable. Thus, this process would be difficult to control where the sediments and soils removed from the River and floodplain have a variable composition (e.g., large changes in grain size distribution). The equipment, materials, and operating personnel would be available to implement this option.

The evaporator option is potentially implementable, but is not likely practical. The evaporation process often produces drier cake than is required, and is not typically employed for sediments. In addition, this option would have a higher cost to implement than the other mechanical dewatering methods.

Results of Mechanical Dewatering Secondary Screening

The effectiveness and implementability of the belt filter press, plate and frame filter press, centrifuge, and evaporator have been evaluated to select a representative mechanical dewatering process option for use in the remedial alternatives to be studied in the CMS. Based on this evaluation, the plate and frame filter press has been retained for further evaluation in the CMS as the representative mechanical dewatering option. This option was retained due its effectiveness at achieving lower water content than other dewatering options. The achievement of lower water contents lowers the weight of material being shipped, which allows more volume to be shipped per load, thus reducing transportation and disposal costs.

The belt filter press was not retained for further evaluation as a dewatering option because other process options, notably the plate and frame filter press, are regarded as superior and potentially more suitable for the project requirements. The belt filter press does not offer the efficiency of other options, resulting in increased cost and time to adequately treat the removed sediment and soil. The centrifuge was likewise not retained for further evaluation because the variability of sediment/soil composition would make this process difficult to control. The plate and frame filter press provides a higher level of efficiency, and would therefore be preferable. Finally, the evaporator option was not retained for further evaluation due to its high energy requirement and high cost compared to other dewatering options.

4.5.1.2 Gravity Settling

Various methods are available that employ gravity dewatering techniques to increase the solids content of wet sediments and soils, including stockpiling, use of a thickener, placing material in a settling basin, and using geotubes. These process options were assessed during the secondary screening to examine their applicability for the River. A description of each option is provided below, along with the results of the secondary screening.

- A **stockpile** approach would involve placing the removed sediment and soil in an on-site stockpile, where free liquids would be allowed to gravity drain. The liquids would be collected within a sump for proper treatment/disposal. The stockpile area would be lined and bermed to contain solids and liquids. Materials placed within the stockpile would remain until the moisture content was sufficiently low to allow for further processing/treatment or transport and disposal. Stockpiling was used to dewater sediment prior to landfill disposal during remediation of the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River.

- A **thickener** approach would involve dewatering the removed sediment and soils by allowing solids to settle by gravity within a circular tank, where the sediment would consolidate at the bottom. Pretreatment with chemical additions, such as flocculants, may be used to enhance the settleability of the slurry and expedite the thickening process. Water from the top of the circular tank can be removed and treated, if necessary, prior to discharge to surface water. The settled solids would most likely require additional treatment to be sufficiently dewatered to allow off-site transportation. Additional treatment would typically be performed using another technology/process option.

- With a **settling basin**, wet sediment or soil would be placed in a basin, where the solids would be allowed to settle, drain, and consolidate in the bottom of the basin. Pretreatment with chemical additions such as flocculants may be used to enhance the settleability of the slurry and expedite the consolidation process. Basins may consist of prefabricated tanks, or structures constructed at the work site using portable equipment, creating a temporary, lined structure capable of containing a shallow liquid/solids pool. Clarified water would be either treated or discharged directly to surface water. Settled solids would likely require further treatment to reduce moisture content. Additional treatment would most likely involve an additional technology/process option.

- A **geotube option** would involve pumping the sediment slurry into fabric tubes, which would help to consolidate the slurry as liquids are forced out through the fabric matrix. Upon being forced out of the geotube, liquids would be collected for proper treatment/disposal, followed by discharge to surface water. Consolidated solids would be removed from the geotube for subsequent management.

Effectiveness – The stockpile option would be effective, especially for sediments and soils composed of sands and gravels. Stockpiling has already been implemented in the upstream reaches of the River and proven to be reliable in dewatering those removed sediments.

The thickener and settling basin options may be effective when used as a pre-treatment step in conjunction with other dewatering technologies. However, a site-specific study would be required prior to implementation to verify effectiveness.

The geotube option could be used for hydraulically dredged sediments, since hydraulic dredging already uses a pump system, which can then be used to pump the dredged sediment into the geotubes for dewatering. While a geotube system has been used to dewater hydraulically dredged sediments with PCBs from the Fox River (WI) and Grasse River (NY), some issues have been noted – e.g., less bearing capacity of dewatered sediment for landfilling, geotube failures, longer dewatering times than originally estimated, and potentially more space required than for mechanical dewatering (Hahnenberg, 2007). A site-specific study would be required to verify the effectiveness of using geotubes for material from the Rest of River.

No long-term operation and maintenance would be required for these options.

Implementability – All the gravity dewatering process options would be implementable. The equipment, materials, and operating personnel are readily available. Each would require adequate space to create dewatering structures, which would require landowner agreement in the vicinity of the remedial construction activities.

Results of Gravity Dewatering Secondary Screening

The effectiveness and implementability of the stockpile, thickener, settling basin, and geotube options have been evaluated to select a representative gravity dewatering process option for use in the remedial alternatives to be studied in the CMS. Based on this evaluation, stockpiling has been retained for further evaluation in the CMS as the representative gravity dewatering option. This option was retained because it was used effectively during the Upper ½-Mile and 1½-Mile Reach Removal Actions, requires the least amount of space to operate, and is less expensive than the thickener, settling basin, and geotube options (which may require additional treatment steps to be effective). Stockpiling (which would provide for effective dewatering of the more gravely solids) along with the plate and frame filter press (the mechanical dewatering option retained for the wetter, finer materials) would be expected to provide the best mix of options for the varying material types and potential removal techniques to be considered for the Rest of River. While the thickener and settling basin options were not retained for further evaluation as a dedicated dewatering step, these process options may be incorporated into another dewatering process as a pretreatment operation.

4.5.2 *Ex Situ* Physical Treatment

Ex situ physical treatment involves physically stabilizing the removed materials by mixing immobilization agents, and/or segregating PCB-containing solids via particle separation. An example of *ex situ* physical treatment includes physical mixing of cement-based and/or pozzolanic reagents with sediment and soil to form a stabilized mass that binds PCBs and sediment and soil particles. Another example is the separation of fine particles (i.e., silt- and clay-size particles) from the coarse fraction (i.e., sand- and gravel-sized particles), which may be worth considering in order to reduce disposal costs if the PCBs in the removed material are preferentially bound to a particular material size fraction.

Initial Screening

Ex situ physical treatment has been successfully applied at a number of sediment sites where PCB-containing sediments were removed for processing/disposal, including the Unnamed Tributary (OH), where a cement-based product was added to the sediments prior to disposal (BBL, 2000c), and Manistique Harbor (MI), where particle separation was used to separate dredged sediments from wood chips which contained high concentrations of PCBs (Committee on Contaminated Marine Sediments, 1997). Given its use at other sites and its potential applicability for stabilizing/treating wet sediments and/or soils removed from the Housatonic River site, *ex situ* physical treatment was retained for the secondary screening.

Secondary Screening

In screening the available *ex situ* physical treatment process options, *ex situ* stabilization/solidification and particle separation were evaluated as potentially viable options for managing the removed sediment and soil. Both process options are specifically described below, along with the results of the secondary screening.

4.5.2.1 *Ex Situ* Stabilization/Solidification

Ex situ stabilization/solidification involves mixing the removed materials *ex situ* with Portland cement, fly ash, lime, kiln dust, or some other stabilization agent. This process option may be used for dewatering only (e.g., to facilitate the vehicular transport of materials), to reduce the leachability (i.e., mobility) of the chemical constituents, or to modify the material's structural properties (compressive strength) to make it more compatible with disposal or beneficial reuse. The process option may be combined with a disposal option that requires a stabilized material having low moisture content. Depending upon the stabilizing agent, mixing can occur within a lined work area, in a container (such as a mix box), or in dedicated processing equipment that agitates or rotates the sediment/soil and treatment material. Control of dust is an important element of the stabilization process, as stabilizing agents tend to be fine-grained materials that are susceptible to airborne dispersion. For dewatering, stabilization is typically performed to a level where the material passes the Paint Filter Liquids Test (SW-846 Method 9095B).

Effectiveness – Implementation of this option would reduce the toxicity and mobility of PCBs, but at the same time, it would increase disposal volume due to the addition and mixing of stabilization agents with impacted sediment and soil. *Ex situ* stabilization/solidification is commonly used to reduce free moisture for disposal purposes, and can also be applied to reduce chemical constituent toxicity and mobility (if required or desired to allow further treatment of the materials) prior to disposal. This option would not require operation and maintenance over the long term, as satisfactory treatment of sediment and soil would not require reapplication of treatment processes at a later time.

Implementability – This process option would be technically implementable, as the necessary equipment, materials, and personnel are available to implement this option. This process option would require sufficient space to conduct the treatment activities, which would require locating a suitable area and reaching an access agreement with the property owner.

4.5.2.2 Particle Separation

During the process of particle separation, finer grained PCB-containing particulates are physically separated, for subsequent management and treatment, through particle size separation techniques. The most commonly used technique for particle size separation is soil washing.

During soil washing, sediment and soil would be passed through screens/sieves, mixing blades, and water sprays. Hydrocyclones and/or gravity separation could also be used. This process would wash silt and clay from the larger-grained soil, separating these materials. The wash water would be collected and treated in an on-site treatment system for reuse in the scrubbing process.

The fine particles, which typically contain proportionally higher PCB concentrations, are retained for further treatment or disposal. The coarse fraction may possibly be reused (e.g., as backfill) following confirmation that applicable standards are achieved. The coarse fraction may also be rewashed in an effort to allow reuse. Overall, soil washing could provide a mechanism for reducing the quantity of PCB-impacted sediment and/or soil requiring disposal, or potentially reducing the cost for disposal by segregating the material into fractions with PCBs $\geq$ 50 mg/kg and < 50 mg/kg, which may allow approval for the latter to be disposed of at a non-TSCA facility. Further, for sediments with variable grain size, separating out the sands/gravels from the finer grained materials can also be used as a dewatering pretreatment step to help save time and money if a plate and frame or belt press is being used to dewater the sediments.

Effectiveness – The effectiveness of particle separation would depend on the association between PCBs and grain size. This process option could reduce the volume of material requiring treatment/disposal. Particle separation is less likely to be effective when oil is present. This technology has been proven to be effective at other sites; however, not all sediment and soil types are amenable to treatment using this technique. A particle size fractionation study was previously conducted on a subset of samples collected by EPA in Reaches 5 and 6 of the Housatonic River to provide data for use in the modeling study. Samples were separated into three different size classes prior to being analyzed for PCBs. Results indicated that the highest PCB concentrations were generally associated with the smallest size class (BBL and QEA, 2003). However, given the current uncertainties associated with full-scale application for the Rest of River sediments/soils, performance of additional treatability tests using sediments from various reaches of the Housatonic River would be necessary to properly evaluate the effectiveness of particle separation as part of the remedy. While short-term operation and maintenance would be required to operate the treatment equipment, no long-term operation and maintenance would be required for treated soil.

Implementability – This process option would be implementable; however, specialized equipment and materials would be needed to perform the treatment operations. Personnel are available with the knowledge and experience to construct and reliably operate a particle separation process. This process option would require sufficient space to conduct the treatment activities, which would require locating a suitable area and reaching an access agreement with the property owner.

4.5.2.3 Results of *Ex Situ* Physical Treatment Secondary Screening

The effectiveness and implementability of *ex situ* stabilization/solidification and particle separation have been evaluated to select a representative *ex-situ* physical treatment process option for use in the remedial alternatives to be studied in the CMS. Based on this evaluation, *ex situ* stabilization/solidification has been retained for further evaluation as a potential alternative for sediment and soil handling due to its proven effectiveness for other projects and ease of implementation. Particle separation has not been retained at this time due to its uncertain effectiveness and implementability for full-scale application to the Rest of River. However, it could be considered at a later date for potential use as part of the remedy, subject to treatability testing, in an effort to reduce the volume of material requiring disposal and/or disposal costs.

4.5.3 *Ex Situ* Biological Treatment

Ex situ biological treatment involves landfarming or amending the removed sediment and soil to enhance the biodegradation of PCBs using microorganisms and nutrients in an aerobic or anaerobic environment. Available *ex situ* biological treatment technologies include the addition of oxygen and minerals, possibly combined with cultured microorganisms to increase the level of microbially mediated degradation reactions occurring in sediment and soil.

Initial Screening

Ex situ biological treatment approaches to reduce the concentration/toxicity of PCBs in sediments and soil have been field tested quite extensively by GE and others (Pointing, 2001; Ruiz-Aguilar et al., 2002; Kamei et al., 2006). Although certain microbes have been identified which are capable of PCB biodegradation and dechlorination, no processes have been identified which have successfully demonstrated significant reductions in PCBs, nor was any full-scale application of *ex situ* biological treatment to remediate PCBs in sediment or soil noted. In general, *ex situ* biodegradation is a slow and labor-intensive process, and full-scale implementation would require the use of large tracts of land for set-up and operation. For these reasons, *ex situ* biological treatment was not retained for the secondary screening.

4.5.4 *Ex Situ* Chemical Treatment

Ex situ chemical treatment involves mixing chemical surfactants, solvents, or other liquids with excavated PCB-containing sediment and soil to remove or destroy PCBs. Removed PCBs and the surfactant, solvent, or other liquid would require further treatment and/or disposal. Chemical treatment processes may include common or proprietary solvents and other liquids.

Initial Screening

Ex situ chemical treatment was successfully applied at the Sparrevohn Long Range Radar Station Site (AK), where solvent extraction was used to reduce average PCB concentrations from 80 mg/kg in the untreated soils to 3.27 mg/kg in the treated soil (EPA, 1998b). The treatment vendor was Terra Kleen Response Group. A total of 288 cy of stockpiled soil were treated in 85-cy batches using solvent extraction in lined treatment cells. The solvent was reclaimed and burned on site (EPA, 1998b). The final disposition/management method for the treated soil could not be verified based on a review of available information. Full-scale demonstration of chemical extraction using BioGenesis℠ is currently underway using sediment from NY/NJ Harbor and the Lower Passaic River (EPA, 1999b, 2006b), although that project involves sediments with relatively low PCB concentrations and thus may not evaluate the ability of BioGenesis℠ to extract PCBs from sediments with higher concentrations. Full-scale demonstration of chemical extraction using B.E.S.T. Solvent Technology for sludge impacted with PCBs was also conducted at the General Refining, Inc. Superfund site (EPA. 1993). The PCB concentrations in the sludge were reportedly reduced by approximately 99%; however, the initial concentrations in the untreated sludge ranged up to only approximately 14 mg/kg. The Springfield Township Superfund Site reportedly successfully remediated more than 12,000 tons of PCB-impacted soil with concentrations greater than 50 mg/kg by implementing a chemical extraction treatment (vendor ART International, Inc.) (EPA, 2004c). The final cleanup goal for the site was 1 mg/kg PCBs in soil; however, treated soils containing residual levels up to 5 mg/kg of PCBs were backfilled into the excavation areas and covered with a 1-foot thick layer of clean soil and revegetated (EPA, 2004c).

Given its use at other sites and its potential applicability for stabilizing/treating sediments and/or soils removed from the Rest of River, *ex situ* chemical treatment was retained for the secondary screening.

Secondary Screening

In screening the available *ex situ* chemical treatment process options, chemical extraction and chemical destruction were evaluated as potentially viable options for managing the removed sediment and soil. Both process options are specifically described below, along with the results of the secondary screening.

4.5.4.1 Chemical Extraction

During the chemical extraction process, an extraction fluid/solvent is mixed with the removed sediment and soil, and PCBs are removed from the solid media into the extracting fluid. The extraction fluid/solvent is used to desorb solid-phase PCBs from the solids matrix. Extraction fluids used in this process may consist of common chemicals or proprietary products. Extraction fluids that have been used for PCB treatment include acetone, kerosene, liquefied carbon dioxide, propane and other hydrocarbons, and methanol.

Once removed from the River, riverbank, or floodplain, the material would be sifted to remove rocks and debris. The extraction fluid/solvent would then be added in an extractor, where mixing occurs to promote the dissolution of PCBs in the extraction fluid/solvent. If extraction fluid/solvent remains within the treated sediment and soil, the sediment and soil may be heated and the volatilized liquid would be collected. Once the extraction fluid/solvent dissolves the sorbed PCBs, a separator is typically used to remove PCBs and recycle the extraction fluid/solvent for additional treatment processing. Depending on the effectiveness of the treatment process, chemical extraction could potentially be used, with EPA approval, to reduce the volume of material subject to TSCA disposal, or if constituent concentrations are low enough, to prepare the material for reuse as backfill or some other reuse product.

Effectiveness – *Ex situ* treatment by chemical extraction could be applied to dredged sediments and/or soils to reduce the potential toxicity, mobility, and volume of PCBs prior to disposal. As discussed above, this process has been, or is being, used at a number of other sites to reduce PCB concentrations in soils or sediments to varying degrees. Depending on the final residual PCB concentrations, use of this process may allow more cost-effective disposal options. In addition, if the treatment process could achieve sufficiently low residual PCB concentrations and could accommodate sufficient quantities of sediment/soil to do so in a timely and cost-effective manner, reuse of the treated materials as backfill could also be considered (provided that chemical additives are not present in the treated soil that would preclude its reuse).

The selection of a particular extraction fluid is site-specific, and the material may require pretreatment prior to implementation. Factors that can impact the effectiveness of a given chemical extraction technique include sediment/soil type, grain size, water content, organic content, and physical-chemical properties of the chemicals present. As a result, performance of treatability tests, using sediments/soils from representative reaches of the River, would probably be warranted, at least prior to implementation, to select the most effective technique. GE is currently evaluating the need for such treatability tests at this time.

While short-term operation and maintenance would be required to operate the treatment equipment, no long-term operation and maintenance would be required.

Implementability – This process option would be implementable; however, it would require specialized equipment, materials, and operating personnel. Concentrated PCBs in the extract would require proper disposal. Traces of chemical/solvent remaining in the treated solids may need to be addressed, depending on the end use of the treated materials. This process option would require sufficient space to conduct the treatment and processing activities, which would require locating a suitable area and reaching an access agreement with the property owner.

4.5.4.2 Chemical Destruction

During the chemical destruction process, reagents are added to the removed sediment and soil to break down PCBs. The destruction process can be achieved through several processes, including base-catalyzed dechlorination, gas-phased reduction, and sodium-based degradation. Each of these processes provides a different mechanism to destroy PCB molecules. At this time, these processes have been investigated primarily at the bench scale. No full-scale applications that have successfully destroyed PCBs at concentrations similar to the Housatonic River site sediments and soils were identified in the remediation databases provided on the US EPA Technology Innovation Program Hazardous Waste Clean-up Information (Clu-In) Website (http.//clu-in.org/databases) (EPA, 2007), which includes numerous other databases. Although this process option has been reportedly shown to treat PCB concentrations up to 45,000 mg/kg, chemical destruction is considered to be most cost-effective for small-scale applications (FRTR, 2002).

Effectiveness – The chemical destruction methods identified above have not been proven effective on a full-scale basis at sites with PCB-containing sediments and soils similar to those at the Rest of River. Moreover, the variability of sediment/soil composition and PCB content at this site could make this process difficult to control. While short-term operation and maintenance would be required to operate the treatment equipment, no long-term operation and maintenance would be required.

Implementability – As noted above, no full-scale applications of this process option were identified that have successfully destroyed PCBs at concentrations similar to the Rest of River sediments and soils. Thus, the implementability of this process option is questionable. It would require specialized equipment, materials, and operating personnel. In addition, this process option would require sufficient space to conduct the treatment and processing activities, which would require locating a suitable area and reaching an access agreement with the property owner.

4.5.4.3 Results of *Ex Situ* Chemical Treatment Secondary Screening

The effectiveness and implementability of chemical extraction and chemical destruction have been evaluated to select a representative *ex situ* chemical treatment process option for use in the remedial alternatives to be studied in the CMS. Based on this evaluation, chemical extraction has been retained as the representative chemical treatment option for further evaluation in the CMS due to its use full-scale at other PCB sites and its potential to reduce PCB concentrations and associated disposal costs. Chemical destruction has not been retained for further evaluation as a potential alternative because this process option has not been proven effective full-scale for materials similar to those in the Rest of River.

4.5.5 *Ex Situ* Thermal Treatment

Ex situ thermal treatment involves heating the PCB-containing sediment and soil to high enough temperatures to remove and/or destroy PCBs. This includes relatively low-temperature extraction that involves carrier gases to remove volatilized PCBs (which are then treated or destroyed), as well as high-temperature destruction, where excessive heat destroys the PCBs in the removed material.

Initial Screening

Ex situ thermal treatment (desorption) was applied at the Outboard Marine Corporation Superfund Site (IL), where a rotary kiln was used to reportedly achieve 99.98% PCB removal efficiency on 12,755 tons of soil/sediment with initial PCB concentrations ranging from 2,400 to 23,000 mg/kg (EPA, 1995). Cleanup goals at that site were reached, with concentrations in treated soils and sediments ranging from 0.4 to 8.9 mg/kg. Most concentrations after treatment were below 2 mg/kg (EPA, 1995). The treated soil and sediment were placed in containment cells on-site. In addition to treated solids, the end products of the thermal treatment included vapor and flue gas. The vapor was recovered from two locations in the treatment system and resulted in condensed water and approximately 50,000 gallons of oil containing PCBs. The condensed water was treated in an onsite wastewater treatment system and discharged to a sanitary sewer. The oil was collected and disposed of off-site. The flue gas was treated and released to the atmosphere. The fines recovered during the flue gas treatment were mixed with treated solids (EPA, 1995).

Ex-situ thermal treatment (low-temperature thermal desorption) was also applied at the Re-Solve, Inc. Superfund Site (MA), where a rotary kiln was used to reportedly achieve the cleanup goal of 25 mg/kg for PCBs on approximately 37,500 cubic yards of soil and sediment (EPA, 2003). The 1987 ROD indicated that PCB levels of the untreated soil/sediment ranged upwards of 500 mg/kg (EPA, 1987). The treated soil and sediment were backfilled in a designated waste disposal area on-site after treatment and capped with 18 inches of gravel. The initial remedy selected included plans for dechlorination following thermal treatment; however, after completing the pilot tests, the dechlorination system was eliminated from the full-scale design due to the larger than anticipated volume of dechlorination residuals predicted by the pilot study. Instead, the PCB-contaminated oil generated by the thermal treatment system was disposed of at an off-site TSCA-permitted incinerator (Halliburton NUS Environmental Corporation and Badger Engineers, Inc., 1993).

Thermal destruction, another *ex situ* thermal treatment process, has been demonstrated on full-scale applications at sites with PCB-containing media (EPA, 1998a). Full-scale applications at Superfund sites generally exceeded 99.99% destruction for PCBs and produced off-gases and combustion residuals (ash), which required treatment (EPA, 2004a). Combustion residuals generated from on-site incineration would likely not be suitable as fill without the addition of amendments (i.e., organics), and as such would likely be disposed of in a landfill after pretreatment. Flue gases from incineration units need to be cooled quickly to minimize the possibility of organics like dioxins forming in the stack emissions. High moisture content and low thermal content (low BTU value) of sediments would require additional fuel for drying and sustaining the incineration process.

Given its use at other sites and its potential applicability for stabilizing/treating sediments and/or soils removed from the Rest of River, *ex situ* thermal treatment was retained for the secondary screening.

Secondary Screening

In screening the available *ex situ* thermal treatment process options, thermal desorption and thermal destruction were evaluated as options for managing the removed sediment and soil. Both process options are specifically described below, along with the results of the secondary screening.

4.5.5.1 Thermal Desorption

Thermal desorption physically separates the PCBs from the sediment/soil by adding heat to the material to volatilize the PCBs, which are subsequently condensed/collected as a liquid, captured on activated carbon, and/or destroyed in an afterburner. Heating is typically accomplished by indirectly fired rotary kilns, a series of externally heated distillation chambers, heated screw conveyors, or fluidized beds (EPA, 1991). The boiling points for PCBs generally range from 644 to 707 degrees Fahrenheit (°F); therefore, the thermal desorption treatment reaches temperatures greater than this range in order to effectively volatilize PCBs. Removed liquid PCBs would require treatment/disposal. Soils/sediments treated with temperatures greater than 600°F usually do not contain any free organic material, which makes them suitable for backfill. However, these treated solids may not be able to support microbial life, which may limit potential application.

Effectiveness - Thermal desorption would reduce the potential toxicity, mobility, and volume of PCBs in the removed solids via treatment and proper management and/or disposal of treatment residuals. Appropriate environmental and process controls (e.g., process treatment units) would be used during treatment. Depending on the final residual PCB concentrations, use of this process may allow more cost-effective disposal options. In addition, if the treatment process could achieve sufficiently low residual PCB concentrations and could accommodate sufficient quantities of sediment/soil to do so in a timely and cost-effective manner, reuse of the treated materials as backfill could also be considered. However, the treated solids usually do not contain any free organic material and thus may not support microbial life without amendment. This would limit potential applications of this process option and/or increase the cost for reuse of the treated solids.

Performance of treatability tests using sediments/soils from representative reaches of the Rest of River may be warranted to evaluate the degree of effectiveness of the technology for this site and the reuse potential of the treated solids. GE is currently evaluating the need for a treatability study for this technology.

While short-term operation and maintenance would be required to operate the treatment equipment, no long-term operation and maintenance would be required.

Implementability – Thermal desorption is generally considered to be an implementable process option for sediment and soil. While specialized equipment, materials, and operating personnel would be required, commercial vendors are available. Very wet sediments would require stabilization and/or dewatering before treatment. An additional step would be needed to destroy the removed chemicals, since thermal desorption extracts but typically does not destroy the target chemicals unless the system contains an afterburner (similar to an incineration unit) at the end of the process. This process option would require sufficient space to conduct the treatment and processing activities, which would require locating a suitable area and reaching an access agreement with the property owner. This could pose a challenge. Construction and operation of thermal treatment units at other sites have often been met with community resistance – e.g., at the New Bedford Harbor (MA) site (Davila et al., 1993, and EPA, 2005d).

4.5.5.2 Thermal Destruction

Thermal destruction, or incineration, generally destroys organic chemicals by subjecting the media to temperatures typically greater than 1,000°F in the presence of oxygen and a flame. During thermal destruction, volatilization and combustion convert the organic constituents (e.g., PCBs) to carbon dioxide, water, hydrogen chloride, and sulfur oxides. The incinerator off-gas requires treatment by an air pollution control (APC) system to remove particulates and neutralize and remove acid gases. This technology may generate three residual streams that must be properly managed: solids from the incinerator and APC system; water from the APC system; and air emissions from the APC system.

Effectiveness – Thermal destruction would reduce the potential toxicity, mobility, and volume of PCBs in the removed solids via destruction of the PCBs, with subsequent disposal of treatment residuals. Appropriate environmental and process controls would be used during treatment. While short-term operation and maintenance would be required to operate the treatment equipment, no long-term operation and maintenance would be required.

Implementability – Thermal destruction might be performed on-site with a transportable incineration unit; specialized equipment, materials, and operating personnel would be required. Very wet sediments would require stabilization and/or dewatering before treatment. This process option would require sufficient space to conduct the treatment and processing activities, which would require locating a suitable area and reaching an access agreement with the property owner. Thermal destruction has encountered strong community opposition at other sites, including New Bedford Harbor, MA (Davila et al., 1993, and EPA, 2005d);[20] and there are likely to be significant administrative constraints in securing necessary access agreements and meeting the substantive requirements of applicable regulations. Finally, thermal destruction would be more costly than thermal desorption, in part due to the high moisture content anticipated for much of the removed material.

4.5.5.3 Results of *Ex Situ* Thermal Treatment Secondary Screening

The effectiveness and implementability of thermal desorption and thermal destruction have been evaluated to select a representative *ex situ* thermal treatment process option for use in the remedial alternatives to be studied in the CMS. Based on this evaluation, thermal desorption has been retained for further evaluation as a potential alternative for sediment and soil handling due to its reported use and effectiveness for other projects, its potential implementability, and its potential to reduce PCB concentrations and associated disposal costs. Thermal destruction has not been retained for further evaluation due to: (a) likely issues of community

[20] The ROD approved for Operable Unit 2 at the New Bedford Harbor site included the on-site incineration of the dewatered dredged sediments; however, the initial public support for the on-site incinerator was reversed at the time the incinerator was to be mobilized due to concerns over air quality impacts. EPA halted the remedy and began investigating other remedial alternatives (EPA, 2005d).

acceptance; (b) administrative and regulatory constraints; and (c) the higher costs and lack of additional benefits of incineration compared to thermal desorption.

4.5.6 Local Disposal

Local disposal may be a viable option for managing the removed material, by placement either in a confined disposal facility (CDF) constructed within the water in the Rest of River area or in a nearby, newly constructed upland disposal facility, as described below:

- **Disposal in a CDF** would involve the placement of sediment and/or soil in a disposal facility constructed within a water body at the site.

- **Upland disposal** would involve the placement of PCB-containing sediment and soil in an upland disposal facility constructed in close proximity to the site (following dewatering).

Initial Screening

Both local disposal options being considered for removed materials – CDF and upland disposal – have been implemented at a number of sediment sites where PCB-containing sediments were removed for processing/disposal. For example, the Removal Actions for the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River utilized, in part, upland local disposal at the OPCAs, and other sites such as the Ashtabula River and Harbor Site (OH) and the Waukeegan Harbor Site (IL) have also used upland local disposal. Additionally, in-water CDFs have been used to dispose of sediments containing PCBs at sites including New Bedford (MA) and U.S. Steel (IN). Implementation would require approval to obtain and use a nearby parcel of property to construct the CDF or upland disposal facility. Given their use at other sites and their potential applicability for disposition of sediments and/or soils removed from the Rest of River, both the CDF and the upland disposal facility options have been retained for the secondary screening.

Secondary Screening

Two local disposal options were assessed during the secondary screening – placing removed materials in a CDF or in an upland disposal facility. Both of these options are briefly described below, along with the results of the secondary screening.

4.5.6.1 Confined Disposal Facility (CDF)

Under this process option, a CDF(s) would be constructed within the water to accommodate removed sediment and soil, so as to permanently isolate PCB-containing material from the environment. This facility would be constructed within the river basin at a location(s) selected to receive materials from as wide a segment of the River as needed, while transporting the material over as short a distance as practical. Construction of a CDF may include installation of steel sheetpiling to create cells into which sediment is placed.

CDFs are designed to allow removed solids to gravitationally separate, settle, and consolidate. CDFs may be required to operate over an extended length of time, depending on the period required for sediment removal. After operation, the CDFs would likely be capped, graded, and seeded. CDFs have been used for other sites with PCB-impacted sediment and floodplain soils, as noted previously.

Effectiveness – A CDF could effectively manage PCB-containing sediment removed from the River. However, construction of such a facility may result in loss of aquatic habitat due to the location of the CDF within or adjacent to the River. This option would require long-term monitoring and maintenance.

Implementability – This option is implementable so long as a suitable in-water location is identified where a CDF could be constructed and transport for disposal of sediments is feasible and which would meet applicable substantive regulatory requirements (or where a waiver of such requirements could be obtained). The personnel, equipment, and materials are available to construct, monitor, and maintain the CDF.

4.5.6.2 Upland Disposal Facility

This option would involve placing the PCB-containing sediment and soil, following dewatering where necessary, in an upland disposal facility, which is assumed to be constructed in close proximity to the River. Upland disposal facilities typically include liners, barrier layers, and leachate collection and detection systems. An upland disposal facility would need to be situated in a location where transport of sediment and soil from the River would be feasible.

Effectiveness – An upland disposal facility could effectively manage PCB-containing sediment and soil removed from the River, riverbank, and floodplain, thereby preventing future exposure by human and ecological receptors to the removed material. These types of facilities have been used for the final disposition of PCB-containing materials removed from several aquatic sites. Disposal in close proximity to the River would preclude the need to transport large volumes of sediment over long distances to an off-site disposal facility(ies), thereby reducing or eliminating the potential for accidents and spills during off-site transport. Depending on the location of the facility, construction could potentially result in the loss of habitat. The upland disposal facility would require long-term operation, monitoring, and maintenance.

Implementability – This option is implementable so long as a suitable location is identified for this facility that would meet applicable substantive regulatory requirements (or where a waiver of such requirements could be obtained). The personnel, equipment, and materials are available to construct, monitor, and maintain an upland disposal facility.

4.5.6.3 Results of Local Disposal Secondary Screening

The effectiveness and implementability of an in-water CDF and an upland disposal facility have been evaluated for potential use in the remedial alternatives to be studied in the CMS. Based on this evaluation, given the potential volume of material that may be considered for disposal in the CMS, the differences between the two disposal options, and their proven use and effectiveness for other PCB-contaminated sediment/soil remediation projects, both options have been retained for further consideration in the CMS.

4.5.7 Off-Site Disposal

In addition to local disposal options, existing, permitted off-site facilities could be used for disposing of sediment and soil removed from the River, riverbanks, and floodplain (following dewatering where necessary). Under this option, PCB-containing sediment and soil would be transported to an off-site permitted facility for disposal.

Initial Screening

Disposing of the removed material at an existing off-site disposal facility is a viable option for the sediment and soil removed from the River, riverbanks, and floodplain. Off-site disposal is one of the most commonly used methods for final disposition of removed sediment and soil from remediation projects throughout the country. It has been employed at a multitude of sites after full-scale sediment and soil removal operations, and was used for a portion of the sediments removed from the Upper ½-Mile and 1½-Mile Reaches of the Housatonic River. Thus, off-site disposal has been retained for the secondary screening.

Secondary Screening

Under this process option, excavated sediments and soils would be transported for disposal at an appropriate off-site disposal facility. Such materials with PCB concentrations $\geq$ 50 mg/kg would require disposal at a TSCA-regulated landfill, while materials with PCB concentrations < 50 mg/kg may be transported for disposal at a solid waste landfill permitted to accept such wastes. Inclusion of a stabilization or dewatering process option would likely be necessary for sediments prior to off-site transport/disposal. This is necessary both for transport of sediment/soil by truck, per United States Department of Transportation requirements, and for satisfying acceptance criteria at the disposal facility.

Effectiveness – Off-site disposal would be effective for the permanent disposition of removed materials from the River, riverbanks, and floodplain. These materials would be confined within an engineered structure, eliminating the potential for future exposure to human and wildlife receptors. There are, however, some potential risks of exposure and transportation accidents associated with hauling the removed material to an off-site location. A large number of trucks or train cars may be needed to accomplish the transportation component of the disposal operation, representing a potential risk due to accidental spills or other releases. While long-term operation and maintenance would be required for the off-site facility, responsibility for such measures would be undertaken by the facility operator.

Implementability – This option is implementable so long as an appropriate off-site facility(ies) is identified with the necessary availability and capacity and an adequate means of transport is available. Administratively, the availability and capacity of existing off-site disposal facilities would be critical factors in determining implementability. For transport of materials from the site, trucks would be the most efficient means or transportation; however, local road conditions may require improvement to make this option implementable. If rail is used for materials transport, local tracks would need to be constructed and/or upgraded, and it is likely that intermodal transportation methods would be required to transport materials to the rail loading and off-loading locations.

Disposal at an off-site facility has been retained for further evaluation as a component of the overall remedy due to its use for other sediment and soil remediation projects.

4.5.8 Beneficial Reuse

The beneficial reuse option would involve treating the removed material and then using it in beneficial ways such as cover material for solid waste landfills or converting it into useable products such as cement, light weight aggregate, and glass tile.

Initial Screening

For the beneficial reuse option to be effective, the removed material would require additional treatment to meet beneficial reuse standards. The type and level of treatment would be dependent upon the future beneficial use of the material, physical characteristics of the sediment/soil, and PCB concentrations. For uses such as cover material for solid waste landfills or conversion into useable products, the removed materials would require treatment to meet applicable reuse standards. Following treatment, a sampling, analysis, and verification process would be required to demonstrate that applicable remedial standards have been achieved. Soil would then be transported from the treatment location to the location where the beneficial use would take place.

It is unlikely that a significant portion of the treated site materials would have PCB content low enough to be candidates for beneficial reuse. In addition, if the material requires treatment for other constituents, the treatment process may become increasingly complicated. Furthermore, the cost associated with implementation of this option would be high since the cost associated with the additional required treatment would be excessive relative to the cost for disposal within a local or off-site disposal facility.

To date, few dredged sediment sites have used beneficial reuse, mainly due to the lack of available cost-effective uses (EPA, 2005e). A full-scale demonstration project is currently underway for sediments dredged from the NY/NJ Harbor Federal Navigation Channel to assess the usability of treated sediments as a manufactured soil, architectural tile and a cement additive (EPA, 2005e). While the thermal treatment and chemical treatment technologies being tested are apparently capable of treating PCBs, the typical range of PCB concentrations reported in the NY/NJ Harbor sediments is 0.05 - 3.32 mg/kg (MWH, 2005), which is significantly lower than the range of concentrations in the Rest of River sediments and soils. No sites have been identified where a beneficial reuse technology was successfully applied full-scale to treat sediments or soils with PCBs with concentrations comparable to those in the sediments/soils of the Housatonic River.

Beneficial reuse has not been retained for the secondary screening due to the lack of any successful full-scale projects with sediments/soils containing PCB concentrations similar to those of the Rest of River and because of the likely high cost associated with the requirement that the material meet restrictive beneficial reuse standards.

4.5.9 Summary of Retained Technologies/Process Options

The following technologies/process options will be carried forward as options for handling sediment and soil removed from the River, riverbank, and floodplain:

- Plate and frame filter press (under mechanical dewatering);
- Stockpiling (under gravity dewatering);
- *Ex situ* stabilization/solidification (under physical treatment);
- Chemical extraction (under chemical treatment);
- Thermal desorption (under thermal treatment);
- Disposal at an in-water CDF (under local disposal);
- Disposal at an upland disposal facility (under local disposal); and
- Disposal at off-site permitted landfill facility(ies) (under off-site disposal).

In addition to these options, some of the process options that were not carried forward (e.g., thickener, settling basin, particle separation) may be incorporated as a component of other processes (e.g., pretreatment in a dewatering process, processing prior to transport for disposal). Further, if other technologies/process options for managing removing sediments and soils are identified during the CMS, they may also be incorporated into the remedial alternatives presented and evaluated in the CMS Report.

5. Methodology for Evaluation

This Section of the CMS Proposal describes the methodology that will be used in the CMS to evaluate potential corrective measures for the Rest of River. Section 5.1 presents the general methodology for the identification of remedial alternatives, including how they will take account of the IMPGs. Section 5.2 presents the methods for evaluation of sediment/riverbank remedial alternatives and includes a description of:

- specific remediation alternatives for in-river sediments and erodible bank soils, based on the retained technologies and process options described in Sections 4.2 and 4.3, for evaluation during the CMS;
- the application of EPA's PCB fate, transport, and bioaccumulation model for simulating how these alternatives will affect future sediment, water, and fish tissue PCB concentrations in the Massachusetts portion of the River (as well as a proposed procedure for predicting such concentrations in the Connecticut portion of the River);
- descriptions of specific remedial alternative components for managing removed sediments and soils, based on the retained technologies and process options described in Sections 4.5, for evaluation in the CMS; and
- the application of the criteria specified in the Reissued RCRA Permit for evaluating the sediment/riverbank remediation alternatives.

Section 5.3 presents the methodology for evaluating potential corrective measures for floodplain soil and includes a description of:

- specific floodplain soil remediation alternatives, based on the retained technologies and process options described in Sections 4.4, for evaluation during the CMS;
- the methodology to be used to determine the areal extent and volume of soil requiring remediation under each alternative;
- specific remedial alternatives for managing removed material, based on the retained technologies and process options described in Sections 4.5, for evaluation in the CMS; and
- the application of the criteria specified in the Reissued RCRA Permit for evaluating the floodplain soil remediation alternatives.

5.1 General

Specific remedial alternatives for addressing sediment/riverbanks and floodplain soil (i.e., specific combinations of the remedial technologies and process options that have been retained for evaluation, as discussed in Section 4) have been developed to represent a range of alternatives, from no action to extensive removal of sediment and soil. In addition to the alternatives described in this section, the evaluations and analyses conducted during the CMS may identify other alternatives (e.g., other combinations of the retained technologies/process options) that warrant detailed evaluation under the RCRA Permit criteria. Accordingly, while the remedial alternatives identified in this Proposal will be evaluated in the CMS, other alternatives may also be identified and evaluated in the CMS Report.

The Reissued RCRA Permit requires that the CMS Proposal consider the ability of the various alternatives to achieve IMPGs. For the IMPGs applicable to in-river sediment remediation alternatives (i.e., the IMPGs for sediments and fish tissue), this proposal considers the ability of the alternatives to meet those goals in a general manner. However, the expected reductions in sediment and fish tissue concentrations under a given remedial alternative cannot be quantified until the PCB fate, transport, and bioaccumulation model is applied to simulate that alternative, which is a time-intensive process that will be performed as part of the CMS (see Section 5.2.2). The model will be used to assess the extent to which a given sediment remediation alternative can be expected to achieve sediment and fish tissue concentrations within the ranges of the relevant IMPGs, and those results will be discussed in the CMS Report.

For floodplain soils, several of the alternatives identified in this section will include a determination of the extent of soil remediation necessary to reduce average concentrations over various areas (e.g., human direct contact exposure areas) to be within the range of IMPGs associated with those areas' relevant exposure scenarios. As such, these alternatives directly account for the ability to attain IMPGs.

In developing these remedial alternatives and considering their ability to achieve the IMPGs, GE has focused on remedial alternatives for addressing PCBs and on the IMPGs for PCBs, since PCBs are the primary constituent of concern in the Rest of River, as discussed in Section 2.4 above. Similarly, in evaluating the remedial alternatives, the CMS will assess the effectiveness of the alternatives to address PCBs and their ability to achieve PCB concentrations within the ranges of the IMPGs for PCBs in the EPA-approved IMPG Proposal.[21]

5.2 Methodology for Evaluating Potential Corrective Measures for Sediments/Riverbanks

This section identifies the remedial alternatives that have been developed for sediments and erodible bank soils and describes the methodology that will be used in the CMS to evaluate those alternatives.

5.2.1 Development and Identification of Corrective Measure Alternatives for In-River Sediments and Erodible Riverbank Soils

Based on review of the technologies and process options retained for in-river sediments and erodible riverbanks, as discussed in Section 4, several potential corrective measure alternatives for addressing the sediments and riverbanks in the various reaches of the River have been developed for evaluation in the CMS. In developing these alternatives, the retained technologies/process options for addressing sediments (listed in Section 4.2.7) and riverbanks (listed in Section 4.3.4) have been combined, because the riverbank technologies and process options have been identified and will be considered in the CMS only in relation to their effects on the River via erosion of PCB-containing soil. (For the alternatives that involve sediment/bank soil removal, several alternatives have also been developed for managing the removed sediments/soils; these are described in Section 5.2.3 below.)

The development of alternatives for addressing sediments and erodible riverbanks has been based on consideration of several objectives and factors. First, the alternatives have been selected to provide a broad range of alternatives using the retained technologies and process options. As such, the alternatives encompass a range from no action to extensive removal of river sediments, and include various combinations using different technologies for different reaches. They also utilize different approaches to remediation, including MNR, specified combinations of sediment removal, capping (including both engineered capping and thin-layer capping), in different reaches, and removal of all sediments in specific reaches to a given depth or PCB concentration. Each of the alternatives that includes sediment removal also includes removal and stabilization

[21] As described above (Sections 3.2.3.2 and 3.2.4), IMPGs have also been developed for dioxin TEQs in certain media – namely, fish and waterfowl tissue based on human consumption, fish tissue based on potential risks to fish, and prey items of insectivorous birds and piscivorous mammals. However, for the reasons given in Section 2.4.4 above and explained in more detail in Appendix A, GE proposes not to make a separate quantitative evaluation of the ability of the remedial alternatives under study to achieve the TEQ IMPGs.

of erodible riverbank soils containing PCBs in Reaches 5A and 5B (no erodible banks have been identified by EPA in the further downstream reaches of the PSA).

Second, the active remediation alternatives focus primarily on the river reaches where the highest PCB concentrations are present in sediments, as discussed in Section 2.4.1.1 – namely, Reaches 5 and 6. Additionally, some alternatives address sediments in Reaches 7 and/or 8. Average PCB concentrations downstream of Reach 8 are markedly lower than those in upstream sediments (Figure 2-8).

Third, the alternatives have taken into account the suitability of the various remedial technologies/process options for different river conditions. For example, for removal technologies, mechanical dredging in the dry is more feasible for shallower areas where dewatering is more readily implementable, while hydraulic dredging is generally more implementable in wider, deeper portions of the River. As another example, engineered capping without prior sediment removal is more suitable in deeper water areas of the River. In such areas, capping may provide isolation of the PCB-containing sediments in a shorter timeframe and with less disruption than removal. In some areas, where river conditions are not suitable for placement of a cap on top of the existing sediments, removal of the upper portion of the sediments will generally be necessary before a cap is placed so as to address flood storage concerns and maintain river uses. Further as previously discussed, thin-layer capping, as an enhancement to MNR, would be most effective for low-energy depositional areas.

Based on consideration of these objectives and factors, eight sediment/riverbank remediation alternatives have been developed at this time for detailed evaluation and comparison in the CMS. These alternatives are described below and summarized in Table 5-1 on a reach-specific basis. In addition, for all alternatives that involve active remediation in the River between the Confluence and Woods Pond, consideration will be given to rechannelization of the River in stretches where it would be a viable option. Further, as explained above, other alternatives may be developed and evaluated during preparation of the CMS Report.

Sediment Alternative 1 (SED 1) – No Action in All Reaches

SED 1 (no action) will be evaluated for potential applicability for all reaches of the River, as required by the NCP and to provide a baseline against which other alternatives can be assessed in the CMS. SED 1 would not include any active or passive sediment remediation, and no monitoring efforts would be implemented. In addition, no action would be taken to mitigate erodible riverbank areas along the River containing PCBs.

Sediment Alternative 2 (SED 2) – Monitored Natural Recovery (MNR) with Institutional Controls in All Reaches

SED 2 (MNR with institutional controls) will be evaluated for all reaches of the River in the CMS. With SED 2, reductions in the concentration of PCBs in the surficial sediments of the Housatonic River through natural processes would be monitored over time, and institutional controls would be implemented concurrently with the monitoring program to reduce the potential for human exposure to PCBs. Natural recovery processes have been previously documented in Rising Pond and portions of Woods Pond (BBL and QEA, 2003) and are likely ongoing throughout the River at varying rates, due in part to the source control and remediation measures implemented by GE and EPA in and adjacent to the Upper 2-Mile Reach, coupled with ongoing natural sedimentation processes. Monitoring of natural recovery (including long-term sediment sampling) would be implemented to track the effectiveness of the combined natural physical, biological, and chemical mechanisms working to reduce the bioavailability of PCBs in sediments.

In addition to the MNR component, SED 2 would involve continuation and maintenance of biota consumption advisories and/or implementation of fishing restrictions so as to limit the public's consumption of fish and other biota from the River.

Sediment Alternative 3 (SED 3) – Sediment Removal/ Capping in Reach 5A, Thin-Layer Capping and MNR to Woods Pond Dam

SED 3 includes a combination of sediment removal, capping, and MNR for portions of the Housatonic River from the Confluence to Woods Pond Dam. Specifically, this alternative includes the following elements:

- In Reach 5A, removal of all sediments to a depth of 2 feet, followed by replacement with an engineered cap;
- In Reaches 5A and 5B, removal and stabilization of erodible banks containing PCBs;
- In portions of Reach 5C and for all of Woods Pond, thin-layer capping;
- MNR in the remainder of the Housatonic River system; and
- Continued maintenance of biota consumption advisories and/or implementation of fishing restrictions to limit the public's consumption of fish and other biota from the River.

Under SED 3, sediments would likely be removed from Reach 5A via mechanical dredging in the dry where River access is feasible using land- and/or barge-based equipment and where dewatering (e.g., pump bypass, sheetpiling diversion) could be implemented. The depth of sediment removal was determined based on the estimated thickness of an engineered replacement cap considering the water velocities in this reach. Following removal, the excavated areas would be covered with an engineered cap where necessary to isolate the underlying PCB-containing sediments. The cap would be designed to limit the potential for upward migration of the PCBs in the underlying sediments to the bioavailable zone and to limit the potential for cap scour/movement. The cap design would take into account USEPA and USACE guidance (Palermo et al, 1998). Cap materials would be transferred into the river using conventional earth-moving equipment. It will be assumed, for purposes of evaluation, that engineered caps would be composed of at least 12 inches of isolation layer material (e.g., sand with organic material), followed by an appropriate thickness of armor stone (designed to be stable based on river hydraulic conditions).

Under SED 3, erodible banks containing PCBs in Reaches 5A and 5B would be subject to soil removal and stabilization with revetment mats or armor stone. It is assumed that revetment mats would be used where bank elevations/slopes are greatest. Selection of the most appropriate removal/stabilization option(s) would ultimately be made considering the physical features of the bank area in conjunction with the adjacent sediment and/or floodplain soil remedial activities at each bank erosion area.[22]

This alternative would involve implementation of thin-layer capping in the downstream portions of Reach 5C and in Woods Pond to provide an immediate reduction of sediment PCB concentrations in the biologically active zone and to accelerate the natural recovery processes in these areas. This thin-layer cap would be a few inches thick and the capping material for these caps would likely be slurried and then transferred via pipeline for hydraulic placement in these areas.

Staging/handling and dewatering areas would be constructed to allow for management of the excavated sediments. Where land-based operations are employed, access roads would need to be constructed along the River to facilitate access to the River (provided access permission is obtained). Remediation activities would proceed from upstream to downstream.

[22] This discussion in this paragraph also applies to the remaining sediment remediation alternatives described below, all of which include removal and stabilization of erodible banks containing PCBs in Reaches 5A and 5B.

Under SED 3, MNR would be implemented for the remainder of the Rest of River, where surface sediment PCB concentrations would be monitored to track the reductions due to the removal and capping activities. In addition, this alternative would include the maintenance of biota consumption advisories and/or implementation of fishing restrictions.

Sediment Alternative 4 (SED 4) – Combination of Sediment Removal and Capping to Woods Pond Dam

SED 4 includes a combination of sediment removal and capping for portions of the Housatonic River from the Confluence to Woods Pond Dam. This alternative includes the same elements as SED 3 with the addition of some sediment removal in Reach 5B and Woods Pond and more extensive capping in Reach 5C. Specifically, this alternative includes the following elements:

- In Reach 5A, removal of all sediments to a depth of 2 feet, followed by replacement with an engineered cap;
- In Reach 5B, a combination of: (a) thin-layer capping in depositional areas or where the water is shallow and surface water velocities are low; and (b) removal of sediments to a depth of 2 feet, followed by replacement with an engineered cap, in other areas, based on the depth necessary to limit flow-induced scour of the underlying sediments after replacement;
- For the banks in Reaches 5A and 5B, removal and stabilization of erodible banks containing PCBs;
- In Reach 5C, combination of: (a) thin-layer capping in depositional areas or where the water is shallow and surface water velocities are low; and (b) engineered capping (without prior sediment removal) in areas with deeper water depths;
- In the Reach 5 backwaters, thin-layer capping of certain backwaters based on PCB concentration;
- In Woods Pond, combination of: (a) sediment removal to a depth of 1.5 feet in the shallower areas followed by placement of an engineered cap; and (b) placement of a thin-layer cap in the deep area of the Pond;
- MNR in the remainder of the Housatonic River system; and
- Continued maintenance of biota consumption advisories and/or implementation of fishing restrictions to limit the public's consumption of fish and other biota from the River.

Under SED 4, sediment would likely be removed via mechanical dredging in Reaches 5A and 5B. It is assumed that mechanical dredging in the dry would be implemented in areas where dewatering (e.g., pump bypass, rechannelization, sheetpiling diversion) is feasible and practicable, and that mechanical dredging in the wet would be implemented in areas where it is feasible and safe to do so and where adequate containment could be provided with silt curtains or another resuspension control device. It is also assumed that hydraulic dredging or mechanical dredging in the wet would be implemented to accomplish the sediment removal in the shallower areas of Wood Pond. Following removal (or in some cases without prior sediment removal), the area would be restored with an engineered cap (as described in SED 3) to isolate the underlying sediments.

SED 4 would include implementation of thin-layer capping in the portions of Reaches 5B and 5C not subject to removal or engineered capping, in portions of the Reach 5 backwaters, and in the deep area of Woods Pond, so as to provide an immediate reduction of sediment PCB concentrations in the biologically active zone and to accelerate the natural recovery processes in these areas.

Staging/handling and dewatering areas would be constructed to allow for management of the excavated sediments. Where land-based operations are employed, access roads would need to be constructed along the River to facilitate access to the River (provided access permission is obtained). Remediation activities would proceed from upstream to downstream.

Sediment Alternative 5 (SED 5) – Combination of Additional Sediment Removal and Capping to Woods Pond Dam and Thin-Layer Capping in Rising Pond

SED 5 includes a combination of sediment removal and capping for the Housatonic River from the Confluence to Woods Pond Dam and thin-layer capping in Rising Pond. This alternative includes the same elements as SED 4 with additional sediment removal in Reaches 5B and 5C, engineered capping in a portion of Woods Pond, and thin-layer capping in Rising Pond. Specifically, this alternative includes the following elements:

- In Reach 5A, removal of all sediments to a depth of 2 feet, followed by replacement with an engineered cap;
- In Reach 5B, removal of all sediments to a depth of 1.5 to 2 feet, followed by replacement with an engineered cap;
- For the banks in Reaches 5A and 5B, removal and stabilization of erodible banks containing PCBs;

- In Reach 5C, a combination of: (a) sediment removal to a depth of 1.5 to 2 feet, followed by replacement with an engineered cap, where the water is shallow; and (b) engineered capping (without prior sediment removal) in areas with deeper water depths;
- In the Reach 5 backwaters, thin-layer capping of certain backwaters based on PCB concentration;
- In Woods Pond, a combination of: (a) sediment removal to a depth of 1.5 feet in the shallower areas, followed by replacement with an engineered cap; and (b) placement of an engineered cap (without prior sediment removal) in the deep area of the Pond;
- Thin-layer capping in Rising Pond;
- MNR in the remainder of the Housatonic River system; and
- Continued maintenance of biota consumption advisories and/or implementation of fishing restrictions to limit the public's consumption of fish and other biota from the River.

Under SED 5, sediment removal would likely be carried out via a combination of mechanical dredging in the wet, mechanical dredging in the dry, and hydraulic dredging, depending on river conditions. Under this alternative, mechanical removal has been assumed for those areas requiring removal between the Confluence and New Lenox Road. Hydraulic dredging could potentially be implemented in accessible areas where water depths and velocities are adequate to support dredge movement and use, such as the River from New Lenox Road to Woods Pond Dam. Following removal, all excavated areas would be restored with an engineered cap (as described in SED 3).

SED 5 would include installation of engineered caps (without prior sediment removal) in portions of Reach 5C and in the deep area of Woods Pond to isolate the underlying sediments. These caps would be designed and implemented as described in SED 3. Further, SED 5 would utilize thin-layer capping (as described above) for portions of the backwaters above Woods Pond and for Rising Pond.

Staging/handling and dewatering areas would be constructed to allow for management of the excavated sediments. Where land-based operations are employed, access roads would need to be constructed along the River to facilitate access, as described for the prior alternatives. Remediation activities would proceed from upstream to downstream.

Sediment Alternative 6 (SED 6) – Sediment Removal to Woods Pond Dam, Capping Below Woods Pond

SED 6 includes a combination of sediment removal and capping for the entire Housatonic River from the Confluence to Woods Pond Dam, and a combination of thin-layer capping and engineered capping for impounded areas below Woods Pond Dam. This alternative includes the same elements as SED 5 with additional removal in Reach 5C and the backwaters and more extensive use of thin-layer and engineered capping in the impoundments downstream of Woods Pond. Specifically, this alternative includes the following elements:

- In Reach 5A, removal of all sediments to a depth of 2 feet, followed by replacement with an engineered cap;
- In Reach 5B, removal of all sediments to a depth of 1.5 to 2 feet, followed by replacement with an engineered cap;
- For the banks in Reaches 5A and 5B, removal and stabilization of erodible banks containing PCBs;
- In Reach 5C, removal of all sediments to a depth of 1.5 to 2 feet, followed by replacement with an engineered cap;
- In the Reach 5 backwaters, a combination of: (a) removal of sediments with PCB concentrations at or above 50 mg/kg in the top foot, followed by replacement with backfill/engineered cap; and (b) thin-layer capping in the remaining areas with PCBs exceeding 1 mg/kg;
- In Woods Pond, a combination of: (a) sediment removal to a depth of 1.5 feet in the shallower areas; followed by placement of an engineered cap; and (b) placement of an engineered cap (without prior sediment removal) in the deep area of the Pond;
- In the Reach 7 impoundments (i.e., the impoundments behind the Columbia Mill, Glendale, and Willow Mill Dams), thin-layer capping;
- In Rising Pond, a combination of: (a) placement of an engineered cap (without removal) in the deeper portion; and (b) thin-layer capping in the shallow portions;
- MNR in the remainder of the Housatonic River system; and
- Continued maintenance of biota consumption advisories and/or implementation of fishing restrictions to limit the public's consumption of fish and other biota from the River.

For this alternative, the sediment removal techniques would be the same as described for SED 5, and the engineered and thin-layer capping techniques would be the same as described for SED 3 (although they would be applied to different areas).

Staging/handling and dewatering areas would be constructed to allow for management of the excavated sediments. Where land-based operations are employed, access roads would need to be constructed along the River to facilitate access, as described for the prior alternatives. Remediation activities would proceed from upstream to downstream.

Sediment Alternative 7 (SED 7) – Sediment Removal and Capping to Rising Pond

SED 7 includes a combination of sediment removal with capping or backfill for the entire Housatonic River from the Confluence to Woods Pond Dam, and a combination of removal, engineered capping/backfill, and thin-layer capping for the impoundments between Woods Pond Dam and Rising Pond Dam. This alternative includes the same elements as SED 6 with additional sediment removal in all reaches. Specifically, this alternative includes the following elements:

- In Reach 5A, removal of all sediments to a depth of 3 to 3.5 feet, followed by replacement with stable backfill;
- In Reach 5B, removal of all sediments to a depth of 2.5 feet, followed by replacement with stable backfill;
- For the banks in Reaches 5A and 5B, removal and stabilization of erodible banks containing PCBs;
- In Reach 5C, removal of all sediments to a depth of 2 feet, followed by replacement with an engineered cap;
- In the Reach 5 backwaters, a combination of: (a) removal of sediments with PCB concentrations at or above 10 mg/kg in the top foot, followed by replacement with an engineered cap or backfill; and (b) thin-layer capping in the remaining areas with PCBs exceeding 1 mg/kg;
- In Woods Pond, a combination of: (a) sediment removal to a depth of 2.5 feet in the shallower areas followed by replacement with an engineered cap; and (b) placement of an engineered cap (without prior sediment removal) in the deep area of the Pond;

- In the Reach 7 impoundments, a combination of: (a) removal of sediments containing higher PCB concentrations (defined for evaluation purposes as those containing PCB concentrations greater than 5 mg/kg) in the top 1.5 feet, followed by replacement with an engineered cap or backfill; and (b) thin-layer capping in the remaining areas with PCBs exceeding 1 mg/kg;
- In Rising Pond, a combination of: (a) removal of sediments containing higher PCB concentrations (defined for evaluation purposes as those containing PCB concentrations greater than 5 mg/kg) in the top 1.5 feet of the shallower portions, followed by replacement with an engineered cap or backfill; (b) thin-layer capping in the remaining shallower areas with PCBs exceeding 1 mg/kg; and (c) placement of an engineered cap (without removal) in the deeper portion;
- MNR in the remainder of the Housatonic River system; and
- Continued maintenance of biota consumption advisories and/or implementation of fishing restrictions to limit the public's consumption of fish and other biota from the River.

For this alternative, the sediment removal techniques would be the same as described for SED 5, and the engineered and thin-layer capping techniques would be the same as described for SED 3 (although they would be applied to different areas).

Staging/handling and dewatering areas would be constructed to allow for management of the excavated sediments. Where land-based operations are employed, access roads would need to be constructed along the River to facilitate access, as described for the prior alternatives. Remediation activities would proceed from upstream to downstream.

Sediment Alternative 8 (SED 8) – Removal of Sediments to 1 mg/kg Depth Horizon in Reaches 5, 6, 7 (impoundments), and 8

SED 8 would involve removing all sediments from the main channel and backwaters of the River between the Confluence and Wood Pond Dam, from the three impoundments between Woods Pond and Rising Pond, and from Rising Pond – with the depth of removal set as the depth to which PCBs have been detected above 1 mg/kg (referred to as the "1 mg/kg depth horizon"), determined on a reach-average basis. SED 8 would also include removal and stabilization of erodible banks containing PCBs in Reaches 5A and 5B (as described for SED 3). Under this alternative, MNR would be implemented for the Reach 7 channel and downstream of Rising Pond Dam.

Under SED 8, material would likely be removed via a combination of mechanical dredging in the wet, mechanical dredging in the dry, and hydraulic dredging, based on consideration of the area-specific conditions (e.g., water area and depth, water velocities, sediment type/extent, accessibility, etc.). Following removal, the excavated areas would be backfilled with clean fill that is similar in composition to the removed material.

As with the other active remediation alternatives, roads would need to be constructed along the River to provide access where necessary; staging/handling and dewatering areas would be constructed to allow for management of the excavated sediments; and remediation activities would proceed from upstream to downstream.

Finally, as with each of the prior alternatives, SED-8 would include the continuation and maintenance of biota consumption advisories and/or implementation of fishing restrictions to limit the public's consumption of fish and other biota from the River.

5.2.2 Use of PCB Fate, Transport, and Bioaccumulation Model

To evaluate the in-river sediment/riverbank remedial alternatives described in Section 5.2.1 (and any other such alternatives developed during the CMS), GE will use the model that was developed by EPA under the Consent Decree to simulate the fate, transport, and bioaccumulation of PCBs in the Housatonic River between the Confluence and Rising Pond Dam. In April 2004, EPA issued its Model Framework Design (MFD) report that summarized both the approach to and objectives of the modeling study (EPA, 2004b). Subsequently, EPA issued a Model Calibration Report (MCR) in December 2004 (EPA, 2004f) and a Model Validation Report (MVR) in March 2006 (EPA, 2006a). These three reports were peer reviewed. Peer reviewers were critical of key aspects of the model. EPA issued Responsiveness Summaries for each report to provide its responses to the peer reviewers' comments. A Final Model Documentation Report (FMDR) was issued by EPA in November 2006 that summarizes the documents described above, includes several supporting analyses, and discusses input from the Model Working Group (composed of representatives from EPA, GE, and their consultants) and peer reviews (EPA, 2006c).

As required by the Reissued RCRA Permit, the EPA model will be used during the CMS to evaluate the sediment/riverbank remedial alternatives. Specifically, the PCB fate and transport (EFDC) and bioaccumulation

(FCM) submodels developed by EPA will be used to predict future sediment, surface water, and fish tissue PCB concentrations resulting from those alternatives.[23]

This section includes a description of:

- the temporal and spatial scales over which future simulations will be conducted;
- the development of model inputs necessary for future projections (i.e., boundary conditions and initial conditions);
- how the sediment remedial actions identified for evaluation will be represented in the model (e.g., production rates, post-remediation PCB concentrations, etc.);
- metrics that will be used as the basis for comparison of model predictions among alternatives; and
- certain proposed modifications to the EFDC model code.

5.2.2.1 Temporal Scale

EPA's model calibration and validation efforts were conducted over decadal timescales. Specifically, EPA's model validation (i.e., continuous simulation conducted with no modification of model parameters) simulated the 26-year period between 1979 and 2004. As part of the CMS, the model will be used to conduct long-term future simulations of the various sediment and riverbank remedial alternatives, so as to predict what future sediment, water, and fish PCB concentrations may result from their implementation. Remedial scenario simulations in the CMS will be conducted over a 52-year period that consists of two cycles of the 26-year validation period, as discussed further below. These simulations will include a representation of the time required to implement remedial actions (see Section 5.2.2.3). Further, depending on the estimated duration of the simulated remediation, the length of certain simulations will be extended so as to provide a minimum of 30 years following completion of the simulated remedy. This period should be sufficient for the model to achieve, for a particular remedial alternative, an approximate "steady state" condition in sediment and fish tissue PCB concentrations under a given set of inputs.

[23] GE does not currently plan to use the model to evaluate the impacts that remedial measures conducted in the floodplain have on in-river PCB concentrations. This is because an initial review of the EPA model predictions indicate that such impacts would be minimal (i.e., the primary interaction between the river and floodplain is the deposition of in-river suspended sediments onto the floodplain during overbank conditions). The methodology for evaluating potential corrective measures for floodplain soils is described in Section 5.3. However, as discussed in Section 5.2.2.3, the model will include an input of PCBs from direct drainage, representing washoff from the floodplain.

5.2.2.2 Spatial Scale

Spatial Domain

Massachusetts Portion of the River

The spatial domain for EPA's model extends from the Confluence to Rising Pond Dam and is simulated by two separate models. The "PSA Model" extends from the Confluence to Woods Pond Dam and includes the main River channel, backwaters, and associated 10-year floodplain over this reach. The "Downstream Model" extends from Woods Pond Dam to Rising Pond Dam and includes the main River channel and associated 10-year floodplain. These two models are coupled at the Woods Pond Dam boundary and together will be used to predict water, sediment, and fish tissue PCB concentrations over the simulated stretch of river (i.e., Reaches 5 to 8).

Connecticut Portion of the River

Since the EPA model extends only to Rising Pond Dam, it cannot be used to predict the response of the River below that impoundment, including the Connecticut portion of the River, to the sediment remedial alternatives evaluated during the CMS. Indeed, the existing data would not support a modeling effort for the Connecticut portion of the River similar to that undertaken by EPA for the upstream reaches, due to the paucity of certain types of data (e.g., suspended sediment loadings) as well as the low PCB concentrations in Connecticut (BBL and QEA, 2003). Thus, to evaluate the impacts of the remedial alternatives on the Connecticut portion of the River, GE proposes to develop, in the CMS, a semi-quantitative framework that incorporates the available data from the Connecticut section of the River as well as predictions from the EPA Downstream Model. This framework, referred to hereafter as the "CT 1-D Analysis," will be used to develop estimates of future changes in PCB concentrations in the Connecticut portion of the River. The CT 1-D Analysis will focus on the Bulls Bridge Dam impoundment, since that location contains high-resolution (i.e., finely segmented) sediment cores with radionuclide dating and is one of the routine fish sampling sites (BBL and QEA, 2003). The CT 1-D Analysis will simulate the response of surface sediment and fish tissue PCB concentrations at the Bulls Bridge Dam impoundment to changes in PCB loads passing over Rising Pond Dam based on the following approach:

- Predictions from the Downstream Model of annual flow-weighted average particulate-phase PCB concentrations passing over Rising Pond Dam will be used in conjunction with an attenuation factor[24] to estimate the particulate-phase PCB concentrations of sediments depositing in the Bulls Bridge Dam impoundment in the future. Similarity in high-resolution core profiles collected from Bulls Bridge and Rising Pond in 1998 (BBL and QEA, 2003, Figure 4-23) suggests that future changes in PCB concentrations in Bulls Bridge can be approximated based on changes in PCB loads from Rising Pond.[25]

- These computed particulate-phase PCB concentrations will be used in conjunction with the data-based deposition rate for Bulls Bridge Dam (i.e., 1 to 1.5 cm/yr, as noted in the RFI Report, p. 4-31) as input for a one-dimensional (1-D) model of the sediment column that simulates the top 1 foot of sediments in that impoundment. This model, which is similar in structure to the bed component of the model developed by EPA, is based on the principle of mass balance, and will require the following inputs:
    - Vertically variable initial PCB concentrations and sediment properties (bulk density, TOC, and porosity), which will be based on the 1998 high-resolution cores and 1998-2000 EPA data from the Bulls Bridge Dam impoundment (BBL and QEA, 2003);
    - Sediment PCB diffusion coefficients, mixing rates, and mass transfer coefficients, which will be based on values developed by the EPA for the Agency's model of Woods Pond or Rising Pond; and
    - PCB partitioning coefficients, which will be the same as those in the EPA model.

- The 1-D model will perform a time-variable mass balance calculation to predict future changes in Bulls Bridge surface sediment PCB concentrations (e.g., within the bioavailable zone, such as top 3-6") based on future changes in PCB deposition (i.e., reductions in PCB loads passing Rising Pond Dam). This 1-

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[24] The attenuation factor will be developed based on available flow and sediment data. For example, surface sediment PCB data suggest that average concentrations change from about 3 mg/kg in Rising Pond to less than 1 mg/kg in Bulls Bridge Dam impoundment, a reduction of threefold or more (RFI Report, Section 4). This reduction is consistent with the approximate threefold increase in flow between these two locations. Specifically, the average flow at Great Barrington is 522 cfs (Section 2.2.2.2) and the average flow at Bulls Bridge is approximately 1400 cfs, estimated based on the flow at Gaylordsville (1692 cfs; Section 2.2.2.2) subtracting out the average flow of the Tenmile River (306 cfs, as reported by USGS Gage # CT01200000).

[25] High-resolution sediment core data collected in 1998 from the Bulls Bridge Dam impoundment indicate an average deposition rate on the order of 1 to 1.5 cm/year, which is consistent with estimates from similar cores in Rising Pond (BBL and QEA, 2003, p. 4-31). The location of the PCB peak relative to the Cs-137 peak is similar for these cores as well (i.e., PCBs peaked near the 1960s date horizon), which suggests that the PCB loading history in Bulls Bridge was similar to that in Rising Pond.

D approach has been used to develop future predictions of sediment concentrations at other sites (e.g., for cap design at the Grasse River, NY; Alcoa, 2003).

- For fish, a representative biota sediment accumulation factor (BSAF) will be developed for smallmouth bass (the species for which the best temporal and spatial data are available in Connecticut; see Section 2.4.3) based on carbon-normalized sediment PCB concentration data and lipid-normalized fish PCB concentration data from Bulls Bridge. Future sediment PCB concentrations predicted by the 1-D model will be multiplied by that BSAF to estimate future changes in Bulls Bridge smallmouth bass PCB concentrations.

To provide an estimate of PCB concentrations at other impoundments within the Connecticut portion of the River, specifically, Lake Lillinonah and Lake Zoar, attenuation factors will be used for each of those impoundments, relative to the Bulls Bridge Dam impoundment, based on the weight of evidence from the available data (i.e., flow, sediment PCBs, and fish PCBs).[26] These attenuation factors will be multiplied by future predictions of PCB concentrations in Bulls Bridge Dam impoundment to estimate future sediment and fish PCB concentrations for those two impoundments.

The development and application of the CT 1-D Analysis, including a discussion of its limitations, will be fully documented in the CMS Report.

Spatial Resolution

The model's future predictions of water column PCBs will be evaluated at the same locations as those used by EPA during calibration. These include: Holmes Road, New Lenox Road, Woods Pond Headwaters, and Woods Pond Outlet for the PSA Model; and Rising Pond Outlet for the Downstream Model.

Future predictions of sediment and fish tissue PCB concentrations will be generated on a subreach-averaged basis for both the PSA and Downstream Models. These subreaches are the same as those defined in Section 2.2.2.1 (i.e., Reaches 5A through 5C, 6, 7A through 7G, and 8), and are consistent with the reaches used by EPA during validation of both the PSA and Downstream Models.

[26] For example, the attenuation factor for Lake Zoar will be approximately two, since average smallmouth bass concentrations (1994-2004 data) decrease from Bulls Bridge to Lake Zoar by a factor of about two (from 1.1 to 0.5 mg/kg; Figure 2-12), which matches closely with the approximate two-fold increase in flow between these two locations (approximately 1400 cfs at Bulls Bridge to 2662 cfs at Stevenson; see Section 2.2.2.2).

Additionally, sediment PCB concentrations will be evaluated at a scale finer than subreaches. Simulation of sediment remediation within the main channel of the PSA will be considered over the approximately ¼- to ½-mile reaches referred to by EPA as "spatial bins." These spatial bins formed the basis for the sediment PCB data averaging scheme used by EPA to develop model initial conditions and were the reaches over which the model predictions of sediment PCB concentrations were calibrated. As such, the spatial bins represent the finest scale at which the model can be used to evaluate sediment processes and, consequently, the smallest remedial units reasonably simulated by the model. Thus, the finest scale at which sediment concentrations will be evaluated during the CMS will be averages over the spatial bins.

5.2.2.3 Model Inputs

Application of the model to forecast natural recovery and active sediment/riverbank remediation scenarios requires specification of future hydrologic conditions, as well as future solids and PCB loadings to the system, for each model boundary (i.e., boundary conditions). Additionally, specification of starting sediment PCB concentrations (i.e., initial conditions) is required for the simulations. The remaining model input parameters required for the model projections will be consistent with those developed by EPA during model validation.

Flow Boundary Conditions

The 26-year hydrograph for the model validation period (i.e., 1979-2004) provides a good statistical representation of the historical hydrograph, and repeating it for projections provides an efficient means of generating future flow conditions. Thus, specification of future hydrologic conditions in the model will be achieved by repeating the 26-year validation period hydrograph twice, to develop a 52-year hydrograph for the CMS simulations.[27] The 26-year validation period hydrograph includes the time-series of flows for the East Branch, West Branch, tributaries, and direct drainage generated using the watershed submodel (HSPF) developed and calibrated by EPA. As described in the FMDR, the HSPF-simulated direct drainage (nonpoint) flows conveyed by the runoff from the local drainage areas are added directly to the river channel by uniformly distributing the flows/loads to the river channel cells within each local drainage area (EPA, 2006c). The HSPF-simulated time series of flows from the tributaries are represented as direct inputs to the river channel cells located at the confluence of each tributary with the river.

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[27] As discussed in Section 5.2.2.1, simulations will be extended if necessary to provide a minimum of 30 years post-remedy. In the event that such an extension is needed for a particular alternative, the 26-year hydrograph will be cycled again for the necessary number of years.

To represent the potential impact of an extreme hydrologic event on future projections, the hydrograph from an extreme event that occurred in March 1936 will be inserted into the 52-year CMS simulation hydrograph within year 26 of the projection. EPA has synthesized an hourly hydrograph for this event, and following review and discussion by the Model Working Group, the estimated flow rates will be used by GE in the CMS model projections. The methodology used to develop the hydrograph for the extreme event will be documented in an interim deliverable, the Model Input Addendum, which will be provided to EPA for review and approval by April 15, 2007.

Suspended Solids Boundary Conditions

Similar to the approach for specifying future hydrologic conditions, future solids loadings from the East Branch, West Branch, tributaries, and direct drainage will be specified by repeating the 26-year validation period solids loadings to develop a 52-year (or longer 30-year post remedy) time series. As described in the FMDR, EPA derived these solids loadings using equations developed from relationships between TSS mass fluxes and river flow rate (EPA, 2006c) for the East and West Branch boundaries; HSPF was used to predict solids loadings for the tributaries and direct drainage. Moreover, a model of a short section of the East Branch was used to specify the sediment grain size distribution, including bed load at the PSA model boundary. As with the flow rates, repeating the 26-year validation period solids loading time-series provides an efficient means of generating future solids loading conditions for the CMS simulations.

Solids loadings during the simulated extreme event (based on the March 1936 storm) will be computed based upon relationships between TSS and river flow rate. For the tributary and direct drainage boundaries, relationships between TSS and flows will be developed from the HSPF-simulated storm events captured during the 26-year validation period. These relationships will then be used to compute solids loads for the extreme event based on the estimated flows. Solids loadings for the East Branch and West Branch boundaries during the simulated extreme event will be computed based on the hourly flow rates developed for that event and the relationships between TSS load and flow described in the FMDR (EPA, 2006c, Appendix B.2).

Bank erosion represents an additional input of solids in the model (EPA, 2006c). Similar to the water column TSS loads from the flow boundaries, the bank erosion loads specified for the 26-year validation period will be repeated for the 52-year CMS simulation period.[28] Bank erosion during the simulated extreme event will be

[28] If an extension is necessary to provide a minimum of 30 years post-remedy, the 26-year bank erosion rate time-series will be cycled again for the necessary number of years.

specified based upon the empirical functions used by EPA to compute bank erosion rates over the 26-year validation (EPA, 2006c).

PCB Boundary Conditions

Under current conditions within the Rest of River, internal PCB sources (sediment diffusion, sediment erosion, and bank erosion) control water column and sediment PCB dynamics and, consequently, PCB exposure concentrations. As these internal sources are controlled through active remediation, external source loadings attributable to diffuse background and watershed sources, as well as sediment PCB concentrations remaining following remediation, will exert a greater influence on long-term sediment PCB exposure concentrations downstream. Therefore, it is important to develop realistic approximations of future upstream and tributary PCB boundary conditions for the remedial projections.

<u>East and West Branch PCBs</u>

Upstream (East Branch and West Branch) PCB loads were specified by EPA during model calibration and validation using data-based approaches described in Appendix B.2 of the FMDR (EPA, 2006c). These approaches specified East Branch and West Branch PCB boundary conditions during periods when data were not available based on loading equations developed from relationships between particulate-phase PCB concentrations and river flow rate (EPA, 2006c). These analyses, while appropriate for specifying PCB loads during the model calibration and validation periods, cannot be used directly during the simulation of future conditions in the Rest of River since they do not account for reductions in PCB loading that might result from the various remedial measures conducted by GE and EPA within, and adjacent to, the upper two miles of the River (see Section 2.3).

The development of PCB boundary conditions for use in simulations of future conditions during the CMS is complicated by a lack of sufficient monitoring data in the East Branch following completion of both the Upper ½ Mile Reach and 1½ Mile Reach Removal Actions, the latter of which was completed in November 2006. Results from GE's monthly water column monitoring program samples collected in 2005 and 2006 at locations within the East Branch upstream of EPA's 1½ Mile Reach work activities have been largely non-detect, but at a Method Detection Limit (MDL) of 22 ng/L. Additionally, PCBs have been detected in a number of samples from Newell and Lyman Street Bridges at concentrations of 30 to 270 ng/L. With respect to the West Branch, it is expected that the major identified source of sediment contamination (i.e., the sediments and the lower riverbanks adjacent to Dorothy Amos Park) will be remediated in the near future, as the Remedial Action Work

Plan for that work is anticipated to be submitted in April 2007 (see Section 2.3.7). However, given that this remedial action has yet to take place, there are no post-remediation data to use as the basis for developing a future West Branch PCB boundary condition.

Considering all of the above, future East Branch and West Branch water column PCB loadings in the CMS simulations will be developed using a method similar to that employed by EPA for the model calibration/validation, whereby an effective particulate-phase PCB concentration will be applied to the water column solids load and a dissolved-phase component will be estimated based on three-phase partitioning (see FMDR Appendix B.2). For the CMS model projections, the water column PCB boundary condition time-series at the East and West Branches will be developed by applying assumed initial effective particulate-phase PCB concentrations for the solids entering the model (to represent conditions at the start of the 52-year CMS projections), and specifying a timeframe over which these initial concentrations will decline linearly during the simulation period:

- The initial particulate-phase PCB concentrations to be used as the starting point in the development of the PCB boundary conditions will be chosen to reflect current conditions within the East and West Branches. As described above, there are insufficient data to characterize the current particulate-phase PCB concentrations in the East Branch. Thus, estimates of current particulate-phase PCB concentrations in the East Branch will be developed based upon an assessment of the various sources of PCBs to this reach of the river. This assessment may be refined during the CMS by data collection efforts focused on quantifying post-remediation surface sediment PCB concentrations within the ½ Mile Reach of the River.[29] With regard to the West Branch, the assumed initial particulate-phase PCB concentration will reflect the current pre-remediation sediment concentrations in the West Branch based on the data collected by GE, EPA, and MDEP (see Section 2.3.7).

- The future particulate-phase concentration (to which the initial value will linearly decline to over a specified timeframe) will be chosen to reflect potential future conditions following completion of planned additional remediation activities at or near the GE facility on the East Branch, as well as at the Dorothy Amos Park area on the West Branch.

[29] In November 2000, EPA collected ten post-remediation surface sediment samples from within the ½ Mile Reach; PCB concentrations ranged from 0.065 to 1.9 mg/kg with an arithmetic mean of 0.5 mg/kg. Additional sediment PCB data from this reach could provide information to help refine the estimate of current particulate-phase PCB concentrations within the East Branch.

Based on these approaches, GE will develop reasonable estimates of initial and future particulate-phase PCB concentrations to be used in developing the model boundary conditions for the East and West Branches. As described above, dissolved-phase concentrations will be estimated from the particulate-phase concentrations based on the three-phase partitioning approach from the model. The values selected for use in the CMS will be documented in the Model Input Addendum discussed above.

Tributary PCBs

EPA noted in the MCR that there are no known sources of PCBs within the watersheds of the tributaries that enter the PSA downstream of the Confluence (EPA, 2004f), and thus it did not specify PCB loads from the tributaries for model calibration and validation. However, it is reasonable to assume that some amount of PCBs will be transported to the River via the tributaries due to diffuse watershed sources. Therefore, the simulation of remedial alternatives in the CMS will include estimates of non-zero tributary PCB inputs to represent these contributions to the River.

In general, the majority of the drainage area associated with each of the Housatonic River tributaries is located outside of the 1 mg/kg isopleth. For example, more than 99% of the drainage area for the three main tributaries in Reach 5 (Sackett, Roaring, and Yokun Brooks) is contained outside the 1 mg/kg isopleth. Therefore, tributary PCB boundary conditions used in the model projections will be developed to reflect atmospheric PCB sources based upon a review of the relevant literature. More specifically, the tributary PCB concentrations will be estimated based on literature studies that document monitoring results for PCB concentrations in remote, un-impacted streams for which atmospheric inputs represent the only source of PCBs (e.g., Rawn et al., 1998; VanRy et al., 2002; Glaser et al., 2006) as well as measurements of PCBs in rainwater and atmospheric PCB fluxes (e.g., Totten et al., 2004; Glaser et al., 2006). As with the East and West Branch boundary conditions, the values chosen for tributary PCB concentrations will be documented in the Model Input Addendum.

Direct Drainage PCBs

Similar to the tributaries, EPA did not specify PCB loads from direct drainage for model calibration and validation. However, it is again reasonable to assume that some amount of PCBs will be transported to the River via direct runoff due to localized soil washoff from the floodplain within the 1 mg/kg isopleth. Therefore, the simulation of remedial alternatives in the CMS will include estimates of non-zero direct drainage PCB inputs to represent these contributions to the River.

In a manner similar to the East Branch and West Branch boundary conditions, direct drainage PCB loadings will be derived from an estimated effective particulate-phase PCB concentration on solids entering the river. The particulate-phase water column PCB concentrations will be estimated using average floodplain soil PCB concentrations, weighted by the fraction of the drainage area within the 1 mg/kg PCB isopleth. Given that this contribution is from direct runoff, it will be assumed that all PCBs entering the river from direct drainage are on the particulate phase. Development of the direct drainage PCB boundary condition will be documented in the Model Input Addendum.

Sediment Initial Conditions

The sediment initial conditions (i.e., horizontal and vertical distribution of grain size and PCB concentrations) required for simulation of future conditions will be set equal to the results predicted by the model at the end of the validation period (i.e., 2004).

5.2.2.4 Simulation of Remedial Actions

The remedial technologies that comprise the alternatives discussed in Section 5.2.1 can be classified into two groups: 1) "passive" technologies, which include no action and MNR; and 2) "active" technologies, which contain some form of active remediation by removal and/or capping. Model simulation of the passive technologies requires no change to the model framework since the processes that govern these technologies are implicitly accounted for in the model (e.g., sediment deposition). However, simulation of active remedial alternatives requires representation within the model framework and specification of:

- schedule and production rates for the various remedial alternatives;
- post-remediation PCB concentrations in sediments;
- concentration reduction efficiency for backfill and cap materials;
- PCB releases during sediment dredging; and
- sediment properties (e.g., grain size distribution, bulk density, organic carbon content) for capping and backfill materials.

Specification of values for each of these parameters is highly site-specific and subject to uncertainty. However, reasonable assumptions will be made in order to reflect a degree of realism in the model simulations of sediment remediation during the CMS. For example, sediment remediation will be simulated in the model at a rate that is consistent with rates from other remediation projects (i.e., it will not be assumed that remediation occurs instantaneously). As described below, the model assumptions often differ based on the remedial technology being utilized in a given sediment alternative (e.g., thin-layer capping progresses at a faster rate than mechanical dredging of sediments); therefore, the assumptions made for each of these components are discussed with respect to the retained "active" technologies described in Section 4.2.7.

Timing and Production Rates

Model simulation of remedial alternatives during the CMS requires specification of a start date for remediation. As stated in Section 5.2.2.1 above, remedial scenario simulations in the CMS will be conducted over a 52-year period that consists of two cycles of the 26-year validation hydrograph (or a minimum of 30 years following completion of the simulated remedy, whichever is longer). For all alternatives (except no action/MNR), the start of simulated remediation in the model forecast will be assumed to begin in the first year of the 52-year projection period.

The timing and production rate of each active remedial action simulated with the model will be consistent with those experienced in the Upper ½ Mile and 1½ Mile Reach Removal Actions and at other sites. That is, for each alternative that includes "active" remedial technologies, a schedule of the remedial action will be developed for the model projections. For simplicity, it will be assumed that remediation is laterally uniform, and generally progresses from upstream to downstream. The time in which remediation is completed within each model grid cell will be calculated based on an assumed areal production rate (e.g., square meters per day) and the area of the particular grid cell.

Estimates of areal production rates to be used in the model simulations have been developed using technology-specific production rate information (e.g., mechanical/hydraulic dredging, mechanical dredging in the dry) from several sources, including: 1) production rate data from other comparable contaminated sediment sites where remedial action has been completed; and 2) production rate information obtained during removal of contaminated sediments from the upper two miles of the Housatonic River. Table 5-2 below contains a summary of the areal production rates (by retained active remediation technology) that will be used in the CMS model simulations, and an estimated equivalent volumetric production rate for comparison. The rates presented in Table 5-2 are based on average annual production rates converted to a daily rate for application in the model.

Table 5-2
Production Rates to be used in CMS Model Simulations

Technology	Areal Production Rate (m^2/d) [used in model]	Equivalent Volumetric Production Rate (cy/d)
Mechanical/Hydraulic Dredging in the Wet (≤ 2-ft removal)[1]	180	70 - 140
Mechanical/Hydraulic Dredging in the Wet (> 2-ft removal)[1]	90	110 - 220
Mechanical Dredging in the Dry (≤ 2-ft removal)[1]	140	60 - 110
Mechanical Dredging in the Dry (> 2-ft removal)[1]	70	80 - 170
Thin-layer Capping	600	60 - 120
Engineered Capping	300	120 - 240

Note:
[1] Assumes placement of an engineered cap or backfill after removal consistent with scenario descriptions provided in Section 5.2.1.

Post-Remediation Sediment PCB Concentration Assumptions

The active remedial alternatives for in-river sediments will include some amount of sediment removal and/or capping. Sediment removal/capping generally will be simulated in the model by changing the bed PCB concentrations in the appropriate model grid cells from the current predicted value to a lower (non-zero) value. Therefore, simulation of these scenarios requires making estimates of the post-remediation sediment PCB concentrations to be used in the model. Such assumptions will be made separately, depending on the specified remedial technology (e.g., removal in the dry versus hydraulic dredging), for cap/backfill material placed in the river, post-removal residual sediment PCB concentrations, and the percent reduction in concentration achieved by placement of cap/backfill materials.

Cap/Backfill Concentrations for Mechanical Dredging in the Dry and Thin-Layer Capping

Sampling of backfill source material used at the GE-Pittsfield/Housatonic River Site indicates that PCB levels in that material are less than the MDL. Therefore, in conducting remediation evaluations for areas outside the River under the CD, GE generally uses an assumed PCB concentration of 0.021 mg/kg for the backfill, which represents one-half of the average detection limit from actual sampling of backfill sources. Thus, model simulations of mechanical dredging in the dry (with subsequent addition of cap or backfill material) and thin-layer capping will use an assumed concentration of 0.021 mg/kg for the cap/backfill materials. The use of this value assumes that removal in the dry will avoid significant mixing of remaining native sediments with the replacement cap or backfill material. Further, the use of this value for the thin-layer capping represents a starting concentration for this material in the model; mixing processes that occur in the bioavailable zone in the model will serve to subsequently mix the thin-layer cap material with the native sediments.

Cap/Backfill Concentrations for Dredging in the Wet and Engineered Capping Without Dredging

Simulation of hydraulic or mechanical dredging in the wet (with subsequent addition of cap or backfill material) and engineered capping alone (without removal) will also include specification of a starting PCB concentration for the post-placement cap/backfill material in the model. This starting concentration will likely be somewhat higher than that of the source material to reflect the likelihood of mixing, during wet dredging and subsequent cap/backfill placement or during cap placement by itself, between the disturbed native sediment and the cap/backfill material.

For wet dredging followed by placement of a cap of backfill material, the starting concentration for the placed cap/backfill material will be based upon estimated values for the post-dredging residual sediment PCB concentration and the reduction efficiency for cap/backfill placement, as described below:

- Residual contamination, by definition, represents PCBs remaining in sediments after removal has been completed. Sediment residual concentrations are dependent on site conditions (e.g., amount of debris), equipment used, and the vertical distribution of contaminants. While there is no commonly accepted method to predict the amount of residual contamination likely to result from specific actions (EPA, 2005e), information compiled from several dredging sites in the U.S. suggests that the residual concentration on sediments left behind following wet dredging is consistent with the vertically averaged concentration of the sediments removed (Patmont and Palermo, 2007). Thus, the vertical average PCB concentration of the sediments dredged will be used to specify the residual PCB concentration for model simulations.
- During backfilling and/or capping (which is included as a component in all of the active sediment removal alternatives proposed in Section 5.2.1), the extent to which this residual material mixes with placed cap/backfill material is uncertain, but determines the post-remediation PCB concentration of the cap/backfill materials. For specification in the model, the post-dredging residual concentration will be multiplied by a reduction efficiency to specify the concentration of the cap/backfill material following placement. The cap/backfill reduction efficiency used for CMS model simulations in areas of wet removal with subsequent capping or backfilling will be specified based on an assessment of the technical literature and experience on other sites. Existing data from other sites where sediment

remediation projects have been conducted provide information on the amount of entrainment of residual sediments during placement of cap/backfill material which results in a post-placement concentration that is higher than that of the source material (e.g., Alcoa, 2006).

For engineered capping without prior removal, the same approach described in the second bulletized paragraph above will be used in conjunction with the pre-capping PCB concentration of the sediments in the area to be capped. Under this approach, that pre-capping PCB concentration will be multiplied by the reduction efficiency, determined as described above, to specify the PCB concentration in the cap material after placement.

The post-remediation PCB concentrations for the cap/backfill materials after placement in the above scenarios (i.e., after wet dredging with subsequent capping or backfilling or after engineered capping without removal) will be specified in the Model Input Addendum.

Assumptions for PCB Release During Dredging

Similar to post-remediation sediment PCB concentrations, estimations of PCB releases during dredging are difficult to quantify, but potentially important in determining the impacts from implementation of the remedial action. The magnitude of contaminants released during dredging is generally related to the type of equipment used, including both dredging and containment equipment. EPA's *Contaminated Sediment Remediation Guidance* (EPA, 2005e, pp. 6-22 - 6-23) reports that: "Although the degree of resuspension will be site-specific, recent analyses of field studies and available predictive models of the mass of sediment resuspended range from generally less than one percent of the mass dredged (Hayes and Wu 2001, Palermo and Averett 2003) to between 0.5 and 9 percent (NRC 2001)." The NRC (2001) document cited by EPA (2005e) indicates that values for silts and clays range from 0.5 to 4.5 percent for hydraulic dredging and from 2.5 to 9 percent for mechanical dredging. Given this range of estimates and the uncertainty in predicting a site-specific resuspension rate, the CMS model simulations of remedial scenarios that include hydraulic dredging or mechanical dredging in the wet will assume a release of 1 percent of the dredged sediment PCB mass for hydraulic dredging and 2 percent for mechanical dredging in the wet. The simulations involving mechanical dredging in the dry and/or thin-layer/engineered capping will assume conservatively that no PCB mass is released during such activities. PCB releases during dredging will be specified as a mass flux of PCBs that enters the water column at the appropriate model grid cells.

Bank Soil Removal and Stabilization Assumptions

Several of the in-river sediment remediation alternatives include bank soil removal and/or stabilization within the upper portion of the PSA where many of the banks are erosional (i.e., Reaches 5A and 5B). For these model simulations, bank stabilization will be represented in the model by setting the bank erosion rates to zero in the appropriate model grid cells.

Assumptions for Simulation of Capping and Backfill Placement

The alternatives that include sediment removal provide for replacement to grade with backfill or an engineered cap (see Section 5.2.1). The model simulations will include realistic representation of the cap/backfill properties. The assumptions used to specify the post-remediation PCB concentrations for the backfill or cap material are described above. With the exception of engineered capping, physical properties of thin-layer cap and backfill material (e.g., grain size distribution, bulk density, and TOC) will be assumed to possess the same properties as the native sediments in the model simulations. For simulation of engineered capping, bed properties in the model will be modified so as to prevent erosion of the cap material in the top model sediment layers, (e.g., this could be achieved by specifying an additional sediment class having a very high critical shear stress for erosion). This approach will allow for the simulation of subsequent deposition and erosion of new sediments on the cap surface following remediation.

For the alternatives that include thin-layer capping or engineered capping without removal, the model will represent the addition of those materials to the sediment surface (and thus the associated reduction in water depth). This will be achieved in the model by numerically altering the simulated sediment bed structure within the appropriate model grid cells to represent an “instantaneous deposition” of additional solids (to represent cap/backfill material). Following the simulated placement of the cap material, the model will track the vertical PCB distribution within the grid cell. The mass of cap material added to the bed will be based on the anticipated thin-layer or engineered cap thickness.

5.2.2.5 Metrics for Evaluation of Model Predictions

Quantitative forecast metrics will be used to differentiate the impacts of remedial alternatives on PCBs in the water column, sediment, and fish, for both the PSA and the Downstream Models. These forecast metrics will provide a basis of comparison among the alternatives, in both relative and absolute terms, using the evaluation criteria described in Section 5.2.3.

Water Column – The water column PCB load transported to downstream reaches will be quantified as the annual PCB load exiting the PSA (i.e., load passing Woods Pond Outlet) and exiting the Downstream Model domain (i.e., load passing Rising Pond Dam that enters Reach 9) at the end of the simulation.

Sediments – The model-predicted spatial distribution of PCBs within river sediments will be quantified as subreach-averaged surface (i.e., top 6-inch) sediment PCB concentrations at the end of the simulation. The time to reach various target concentrations (e.g., IMPGs) during the course of the simulations will be determined and compared, provided these targets are reached within the simulation period. In addition, the CT 1-D Analysis approach described in Section 5.2.2.2 will be used to simulate endpoint concentrations and time to reach various concentration targets for average sediment concentrations within the impoundments of the Connecticut portion of the River.

Floodplain – Due to the large uncertainty in model predictions of changes in floodplain soil PCBs, soil concentrations will not be used as a metric to evaluate the impacts of sediment remediation on the floodplain. Rather, the annual PCB flux from the River to the floodplain in the PSA will be computed at the end of the simulation to evaluate the change in mass of PCBs transported from the river to the floodplain due to the various sediment remedial alternatives.

Fish Tissue – End-of-simulation results for autumn-average whole body fish PCB concentrations will be evaluated for each reach simulated.[30] Fillet-based largemouth bass concentrations will be estimated by dividing the predicted whole body fish concentrations by a factor of 1.7.[31] Fish tissue concentrations calculated for the evaluation of ecological receptors will utilize weighted averages of simulated PCB concentrations in the modeled fish species, based on receptor-specific size and species preferences and site-specific abundances. The abundances, size and species preferences will be developed based on available site and literature data. In addition to endpoint concentrations, the temporal response of fish concentrations will be compared among

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[30] The use of an autumn average is consistent with the season during which most of the sampling has been conducted (BBL and QEA, 2003).

[31] The food chain model is designed to predict contaminant levels in whole-body fish. In order to evaluate model scenario outcomes for game fish fillet PCB concentrations on a wet weight basis (the endpoint for human consumption), modeled whole-body results will have to be converted to their fillet equivalent. Reconstructed whole body PCB concentrations were regressed against those of fillet samples for the GE 2002 largemouth bass samples to determine a suitable conversion factor; the regression analysis yielded a slope of 1.7 ± 0.28 (95% CI) with an $R^2 = 0.69$. There is some uncertainty in the comparison of PCB concentrations in reconstructed whole-body and fillet samples from the EPA data set, which resulted in a regression slope of 9.4 ± 2.2 (95% CI) with an $R^2 = 0.26$. Given this uncertainty, a conservative value of 1.7 based on the GE data set will be used to estimate fillet-based wet-weight PCB concentrations from model estimates of whole body concentrations. It should be noted that the value of 1.7 is similar to that obtained in other systems (Amrhein et al. 1999).

alternatives, in terms of the time that each alternative takes to achieve reductions to various target levels (e.g., IMPGs) over the course of the simulation. Finally, the CT 1-D Analysis approach described in Section 5.2.2.2 will be used to simulate endpoint concentrations and time to reach various concentration targets for average fish tissue concentrations within the impoundments of the Connecticut portion of the River.

5.2.2.6 Proposed Modifications to the Model Code

Based on GE's review of EPA's model codes, GE proposes making a series of additions to the code to more efficiently conduct model simulations of sediment remedial alternatives during the CMS. These modifications will consist of developing computer code and model pre-processors to represent "active" remediation technologies in the simulations as described in Section 5.2.2.4. These code changes will facilitate the following within the model:

- modification of simulated sediment PCB concentrations to reflect removal and subsequent placement of an engineered cap or backfill material;
- including the PCB loads that result from resuspension during dredging in the water column mass balance;
- setting specified bank erosion rates to zero following bank stabilization; and
- changing the model bed structure by adding the appropriate thickness of solids to represent placement of and engineered cap (without prior sediment removal) or a thin layered cap.

The model code to be developed will perform these functions according to the approximate remediation schedule developed for each alternative (based on the areal production rates specified in Table 5-2).

GE will provide the revised code to EPA for review within 30 days of approval of this CMS Proposal. This submittal will consist of a separate letter proposal for EPA approval.

5.2.3 Alternatives for Managing Removed Sediments/Soil

For the sediment/riverbank remedial alternatives that involve removal of sediments or bank soils, there are a variety of available options for managing the removed materials. The sediment/soil management technologies and process options that were retained from the two-step screening process described in Section 4.5 (herein referred to as management alternative components) will be combined in the CMS into comprehensive sediment/soil management alternatives for detailed evaluation. These management alternatives will be developed and evaluated for a combination of removed sediments/bank soils under the remediation alternatives described above and removed floodplain soils under the floodplain remediation alternatives discussed in Section 5.3 below. The alternative components include options for handling different aspects of the sediment/soil management process – i.e., dewatering (where necessary), treatment, and disposal of the removed sediments and soils, as described below. As such, each alternative component cannot be implemented alone, but will be combined with other alternative components as appropriate to cover the sequence of sediment/soil management from removal to ultimate disposition (i.e., dewatering, where necessary, followed by treatment and/or disposal).

Dewatering Alternative Components

Mechanical Dewatering using Plate and Frame Filter Press

This alternative component would involve mechanically dewatering removed sediments/soils using a plate and frame filter press. The goal of mechanical dewatering would be to decrease the water content of (and, hence, increase the solids content of) the material that would require final disposal. Mechanical dewatering would be most applicable to sediments. Effluent from the dewatering process would require treatment prior to discharge to surface water, and solids that remain after dewatering would require disposal, using one of the disposal options described below.

Gravity Dewatering using Stockpiling

This alternative component would involve gravity dewatering using a stockpile to allow free liquids to gravity drain. The liquids would be collected within a sump for proper treatment/disposal. Gravity dewatering would be especially effective for sediments and soils composed of sands and gravels. The goal of gravity dewatering (as with mechanical dewatering) would be to decrease the water content of (and, hence, increase the solids content of) the material that would require final disposal. For this alternative component, a disposal option would also be needed (as described below).

Treatment Alternative Components

Ex Situ Stabilization/Solidification

This alternative component would involve stabilizing and/or solidifying the removed material by *ex situ* mixing with Portland cement, fly ash, lime, kiln dust, or some other stabilization agent. The goal of the stabilization/solidification process would be to dewater the removed material to facilitate its transport, to reduce the leachability of the chemical constituents in the removed material, and/or to modify the material's structural properties (compressive strength) to make it more compatible with disposal. For this alternative component, a disposal option would also be needed (as described below).

Chemical Extraction

This alternative component would involve a chemical extraction process in which an extraction fluid/solvent is mixed with the removed material and the PCBs are removed from the solid media into an extracting fluid to desorb solid-phase PCBs from the matrix. Chemical extraction could be applied to removed sediments/soils to reduce the potential toxicity, mobility, and concentration of PCBs in the material. For this alternative component, a disposal option would also be needed (as described below) (unless the treatment process could achieve sufficiently low residual PCB concentrations in a timely and cost-effective manner to allow reuse of the treated material as backfill). Since the effectiveness of a given chemical extraction technique is influenced by a number of site-specific factors, performance of treatability tests using sediments/soils from representative reaches of the Rest of River may be warranted, at least prior to implementation, to select the most effective extraction technique. GE is currently considering the need for such treatability tests at this time.

Thermal Desorption

This alternative component would involve a thermal desorption process, which physically separates the PCBs from the removed sediment/soil by adding heat to the material to volatilize the PCBs. The volatilized PCBs are then condensed/collected as a liquid, captured on activated carbon, and/or destroyed in an afterburner. The removed liquid PCBs would require treatment/disposal. Thermal desorption could be applied to reduce the potential toxicity, mobility, and concentration of PCBs in the removed material. Depending on the final PCB concentration in the treated material, a disposal option may also be needed (as described below).[32] Given some of the uncertainties associated with application of thermal desorption for Housatonic River sediments/soils, performance of treatability tests using sediments/soils from representative reaches of the Housatonic River may be warranted to evaluate the degree of effectiveness of the technology for this site and the reuse potential of the treated solids. GE is currently evaluating the need for a treatability study for this technology.

Disposal Alternative Components

Local Disposal in CDF

This alternative component would be a final disposal option for removed materials. It would entail pumping or placing the PCB-containing materials into a local in-water CDF, which would be constructed to permanently isolate PCB-containing material from the environment (potentially incorporating liners and/or steel sheeting). The materials would settle out and the accompanying water would evaporate, percolate through the walls/into the ground, and/or be released through a water release mechanism (e.g., overflow weir, filter cell). After operation, the CDF would be capped, graded, and likely seeded.

Local Disposal in Upland Disposal Facility

This alternative component would also be a final disposal option for removed materials. This alternative would entail transporting the PCB-containing removed materials via trucks, barge, and/or rail to an upland disposal facility that would be constructed in close proximity to the site. This option would typically require dewatering of the removed materials before placement in the disposal facility.

Off-Site Disposal in Permitted Landfill

This alternative component is another final disposal option for removed materials. This alternative would entail transporting the PCB-containing dewatered materials via trucks or rail to an existing off-site solid waste and/or TSCA landfill. Sediment/ soil with PCB concentrations < 50 mg/kg would be disposed of in a solid waste landfill permitted to accept such wastes. Materials with PCB concentrations ≥ 50 mg/kg would be disposed of

[32] If the treatment process could achieve sufficiently low residual PCB concentrations and could accommodate sufficient quantities of sediment/soil to do so in a timely and cost-effective manner, reuse of the treated materials as backfill could also be considered. However, the treated solids may not support microbial life without amendment, which could limit potential applications.

in a TSCA-regulated landfill. Prior to off-site transport and disposal, some removed materials may require stabilization.

5.2.4 Application of Evaluation Criteria

The Reissued RCRA Permit specifies three "General Standards" and six "Selection Decision Factors" that must be applied in the CMS evaluations (Special Permit Condition II.G). The General Standards are: (1) overall protection of human health and the environment; (2) control of sources of releases; and (3) compliance with federal and state applicable or relevant and appropriate requirements (ARARs) (or the basis for an ARAR waiver). The Selection Decision Factors are: (1) long-term reliability and effectiveness; (2) attainment of IMPGs; (3) reduction of toxicity, mobility, or volume of wastes; (4) short-term effectiveness; (5) implementability; and (6) cost. The Permit states that GE shall, in the CMS Report, recommend the combination of corrective measures that, in GE's opinion, "is best suited" to meet the General Standards, "in consideration of" the Selection Decision Factors, "including a balancing of those factors against one another" (Special Permit Condition II.G.3).

For purposes of the evaluations in the CMS, these standards and factors will be applied first to the in-river sediment/riverbank remediation alternatives identified in Section 5.2.1 (and any others developed during the CMS). The relevant standards and factors will then be applied to the sediment/soil management alternatives developed in the CMS as described in Section 5.2.3. In applying the cost factor, a cost estimate will be developed for each relevant combination of such "front-end" and "back-end" alternatives. Based on these evaluations, the CMS Report will recommend a combined alternative for addressing sediments and erodible riverbanks and, if that alternative involves removal, managing the removed sediment/soil.

The General Standards and Selection Decision Factors to be applied in evaluating the sediment remedial alternatives are described below. A full description of the evaluation and results will be provided in the CMS Report.

5.2.4.1 General Standards

This subsection describes how the General Standards specified in the Reissued RCRA Permit will be applied in the CMS to the sediment remediation alternatives.

1. Overall Protection of Human Health and the Environment

Each remedial alternative for sediments will be evaluated based on its ability to provide "overall protection of human health and the environment." In making these evaluations, protection of human health and the environment will be assessed in accordance with the RAOs described in Section 3.1 above. As required by the Permit, these evaluations will take into account EPA's Human Health and Ecological Risk Assessments. Further, as EPA explained in the preamble to the NCP, "[t]he overall assessment of protection draws on the assessments conducted under the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs" (55 Fed. Reg. 8720, Mar. 8, 1990). Hence, those other criteria will be considered in the evaluation of protectiveness where relevant. A more specific discussion of how the "overall protection" standard will be applied in the CMS is set forth below.

To implement this standard from a human health standpoint, each alternative will be evaluated in terms of the extent to which it would achieve a condition in which PCB concentrations in the sediments and biota in the Rest of River do not present significant risks of harm to health, as determined by reference to EPA's cancer risk range ($1x10^{-6}$ to $1x10^{-4}$) and a non-cancer Hazard Index of 1. This evaluation will take account of EPA's HHRA. For the different alternatives, this objective may be achieved through one or a combination of the various retained technologies and process options – e.g., removing bioavailable sediments, covering such sediments, implementation of MNR, and/or implementation of institutional controls (such as maintenance of biota consumption advisories).[33] Further, as discussed above, the long-term and short-term effectiveness of the alternatives will be considered, as relevant, in applying the health protection standard.

Each alternative will also be evaluated in terms of the extent to which it would provide "overall protection" of the environment. As discussed in Section 3.1, this evaluation will consider the extent to which the alternative would achieve a condition in which PCB concentrations in bioavailable sediments and biota in the Rest of River allow the maintenance of healthy local populations and communities of biota that inhabit, or consume other biota from, the River in this area. These evaluations will take account of EPA's ERA and will consider the extent to which the local populations and communities of the receptors in question utilize the Rest of River as all or part of their habitat or home range.

[33] Thus, this evaluation of human health protection is different from evaluating the achievement of the human health-based IMPGs (discussed below under the Selection Decision Factors), since human health may be protected through means other than achievement of the IMPGs, such as maintenance of institutional controls.

In addition, as also discussed above, the evaluation of overall environmental protection will consider the long-term and short-term effects of the alternative. EPA's *Ecological Risk Assessment Guidance for Superfund* specifies that "[m]anagement of ecological risks must take into account the potential for impacts to the ecological assessment endpoints from implementation of various remedial options," and must "balance: (1) residual risks posed by site contaminants before and after implementation of the selected remedy with (2) the potential impacts of the selected remedy on the environment independent of contaminant effects" (EPA, 1997, p. 8-3). Further, EPA's *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* makes clear that evaluating "overall" protection of the environment includes consideration of ecological harm resulting from implementation of the remedial alternative, and that in some cases, even though an ecological risk assessment may have shown adverse affects, active remediation may not be "in the best interest of the overall environment" if the remediation would cause more ecological harm than leaving the contamination in place (EPA, 1999a, p. 6).[34]

The environmental protection objective may be achieved through one or a combination of the various retained technologies and process options.

2. Control of Sources of Releases

Each sediment remedial alternative will be evaluated based on its ability to reduce or minimize further PCB releases within the Rest of River. These evaluations will focus primarily on the alternatives for addressing in-place sediments and riverbanks. These evaluations will consider, for example, the extent to which each alternative would reduce future releases of PCB-containing soils from the Rest of River riverbanks to the River via erosion. They will also consider the extent to which each alternative would mitigate the impacts of future flood events that could cause buried PCB-containing sediments to become exposed within the River and to be transported within the River or onto the floodplain for potential human or ecological exposure.

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[34] That guidance states:

> "Whether or not to clean up a site based on ecological risk can be a difficult decision at some sites. When evaluating remedial alternatives, the NCP highlights the importance of considering both the short-term and long-term effects of the various alternatives, including the no action alternative, in determining which ones 'adequately protect human health and the environment.' Even though an ecological risk assessment may demonstrate that adverse ecological effects have occurred or are expected to occur, it may not be in the best interest of the ***overall environment*** to actively remediate the site. At some sites, especially those that have rare or very sensitive habitats, removal or *in-situ* treatment of the contamination may cause more long-term ecological harm (often due to wide spread physical destruction of habitat) than leaving it in place. Conversely, leaving persistent and/or bioaccumulative contaminants in place where they may serve as a continuing source of substantial exposure, may also not be appropriate." (EPA, 1999a, p. 6; emphasis added.)

3. Compliance with Federal and State ARARs

The CMS will evaluate how each remedial alternative would meet applicable or relevant and appropriate requirements (ARARs) under federal and state law, or, when such a requirement would not be met, the basis for a waiver under the NCP. This standard will be applied both to the alternatives for addressing in-river sediments/riverbanks and to the alternatives for managing removed sediments and soil. To apply this standard, GE will identify potential ARARs for all such alternatives, and list them in tables in the CMS Report. These will include chemical-specific ARARs specifying numerical standards or criteria for key chemicals of interest, location-specific ARARs pertinent to the types of locations at which remedial actions may occur, and action-specific ARARs relating to implementation of the remedial alternatives.[35] In identifying such ARARs, GE will consider the NCP provisions defining ARARs (40 CFR § 300.5), as well as EPA guidance on identifying ARARs (EPA, 1988b, 1989). Specifically, GE will identify as ARARs requirements that meet the following criteria:

First, to be an ARAR, a requirement must have been either enacted into law or formally promulgated as a regulation under federal or state law after notice-and comment rulemaking. Thus, GE will limit its review to such enacted or promulgated requirements, not agency guidance, advisories, or policies.

Second, the requirements must be either "applicable" or "relevant and appropriate." To be "applicable," a requirement must "specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance" in the Rest of River (40 CFR § 300.5). "'Applicability' implies that the remedial action or circumstances at the site satisfy all of the jurisdictional prerequisites of a requirement" (EPA, 1988b, p. 1-10). "Relevant and appropriate" requirements are those that, while not applicable, "address problems or situations sufficiently similar to those encountered at [the Rest of River] site that their use is well suited to the particular site" (40 CFR § 300.5). In some circumstances, "a requirement may be relevant but not appropriate for the site-specific situation" (*id*.). In general, the determination of whether a requirement is relevant *and* appropriate "involves a comparison of a number of site-specific factors, including the characteristics of the remedial action, the hazardous substances present at the site, or the physical circumstances of the site, with those addressed in the statutory or regulatory requirement" (EPA, 1988b, p. 1-10).

[35] The identification of ARARs in the CMS Report should be considered preliminary and solely for the purpose of evaluating the remedial alternatives. The actual ARARs for the Rest of River remedy will be proposed by EPA in its proposed Permit modification to select corrective measures for the Rest of River under Special Condition II.J of the Permit.

Third, ARARs are limited to "substantive" requirements (40 CFR § 300.5), as opposed to "administrative" requirements. EPA has explained that "substantive" requirements are those "that pertain directly to actions or conditions in the environment" (EPA, 1988b, p. 1-11).[36] By contrast, "administrative" requirements are "those mechanisms that facilitate the implementation of the substantive requirements of a statute or regulation," including "the approval of, or consultation with administrative bodies, consultation, issuance of permits, documentation, reporting, recordkeeping, and enforcement" (*id*.).[37] Thus, in the CMS Report, GE will identify as ARARs specific substantive requirements, and not requirements that would be considered administrative as described above, such as permit/approval requirements, consultation requirements, requirements for submitting particular plans, training requirements, inspection and procedural monitoring requirements, and recordkeeping and reporting requirements.

Fourth, for state requirements to constitute ARARs, they must be promulgated requirements of general applicability, legally enforceable, and more stringent than federal requirements (CERCLA § 121(d)(2)(A); 40 CFR § 300.5; EPA, 1989, pp. 7-2 to 7-3, 7-7). GE will implement this criterion in its identification of ARARs in the CMS Report.

Based on its review of the remedial alternatives described above, GE has developed a list of the categories of potential ARARs that it anticipates will be identified and applied during the CMS. This list is provided in Table 5-3. (Note that this table covers potential ARARs both for the sediment remedial alternatives and for the floodplain remedial alternatives discussed in Section 5.3 below.)

Finally, in addition to identifying potential ARARs, GE will consider whether such ARARs should be waived under CERCLA and the NCP. CERCLA and the NCP set forth a number of conditions in which a waiver of ARARs would be appropriate – e.g., that compliance with the requirement "will result in greater risk to human health and the environment" than other alternatives, or that "compliance with the requirement is "technically impracticable from an engineering perspective," or that an alternative will achieve an equivalent standard of

[36] According to EPA (1988b, p. 1-11), such requirements include "quantitative health- or risk-based restrictions upon exposure to types of hazardous substances (e.g., MCLs establishing drinking water standards for particular contaminants), technology-based requirements for actions taken upon hazardous substances (e.g., incinerator standards requiring particular destruction and removal efficiency), and restrictions upon activities in certain special locations (e.g., standards prohibiting certain types of facilities in floodplains)."

[37] As EPA has further explained: "In general, administrative requirements prescribe methods and procedures by which substantive requirements are made effective for purposes of a particular environmental or public health program. For example, the requirement of the Fish and Wildlife Coordination Act to consult with the U.S. Fish and Wildlife service, Department of the Interior, and appropriate State agency before controlling or modifying any stream or other water body is administrative." (EPA, 1988b, pp. 1-11 to 1-12.)

performance "through use of another method or approach" (CERCLA § 121(d)(4)(B), (C), & (D); 40 CFR § 300.430(f)(1)(ii)(C*)(2), (3), & (4)*). In accordance with the Reissued RCRA Permit, a determination of whether any of the identified potential ARARs would meet the conditions for a waiver will be made in the CMS, and the bases for any proposed waivers will be provided in the CMS Report.

5.2.4.2 Selection Decision Factors

This subsection describes how the Selection Decision Factors specified in the Permit will be applied in the CMS to the sediment remediation alternatives.

1. Long-Term Reliability and Effectiveness

Each remedial alternative for sediments/riverbanks will be evaluated in terms of its long-term reliability and effectiveness. This factor will be applied both to the alternatives for addressing in-river sediments/riverbanks and, to the extent relevant, to the alternatives for managing removed sediments and soil. Application of this factor will involve a number of considerations:

First, the magnitude of residual risk associated with the alternative will be considered. This will involve an assessment of the extent to which the alternative would mitigate long-term potential exposure to residual PCB levels in the Rest of River surface water, sediments, and biota and the extent to which and time over which the alternative would reduce the level of exposure to such PCBs. This assessment will rely on the results of the application of the PCB fate, transport, and bioaccumulation model (described above) to the alternative in question so as to estimate the resulting PCB concentrations in water, sediment, and fish tissue. These results will then be combined with information on exposure to such residual PCB concentrations by human and ecological receptors, given other aspects of the alternative (e.g., engineering or institutional controls), so as to assess the extent to which and timing over which the alternative would reduce exposure levels.

Second, the adequacy and reliability of the alternative will be assessed. This will involve consideration of: (a) the reliability of the operation, monitoring, and maintenance requirements for the alternative; (b) the availability of labor and materials needed for such operation, monitoring, and maintenance; (c) whether the technologies have been used under similar conditions; and (d) whether the combination of technologies (if any) have been used together effectively.

Third, any potential long-term adverse impacts of the alternative on human health or the environment will be assessed. This will include identification and evaluation of: (a) any potential exposure routes resulting from implementation of the alternative and the resulting potentially affected populations; (b) any impacts of dewatering, treatment, and disposal facilities on human health or the environment; (c) any adverse impacts on biota and their habitat, including impacts that might disrupt local populations or impair the sustainability of local populations; (d) any long-term impacts on the natural environment and aesthetics, including consideration of the uses of the area for recreational or other activities; (e) any adverse impacts on wetlands or other environmentally sensitive areas resulting from implementation of the alternative; and (f) potentially available measures that may be employed to mitigate such impacts.

2. Attainment of IMPGs

Each sediment/riverbank remediation alternative will be evaluated based on its ability to attain the relevant IMPGs – i.e., those applicable to sediments and fish tissue. These evaluations will focus on the "front-end" alternatives for addressing in-place sediments and riverbanks, and will be based on the results of the PCB fate, transport, and bioaccumulation model in predicting PCB concentrations in water and fish tissue. Those modeled concentrations will be compared with the relevant IMPGs. Both the IMPGs based on Reasonable Maximum Exposure (RME) and those based on Central Tendency Exposure (CTE) will be considered. Where the IMPGs consist of ranges, the evaluation will consider whether the predicted sediment or fish tissue concentrations fall within those IMPG ranges and, if so, where in those ranges the predicted concentrations would fall.

In addition, where applicable, these evaluations will include an assessment of the time period in which the given alternative would result in attainment of the IMPGs (or IMPG ranges) (if it would do so) and the extent to which that alternative would accelerate such attainment relative to natural processes.

3. Reduction of Toxicity, Mobility, or Volume

The CMS Report will provide an evaluation of the reduction of toxicity, mobility, or volume of waste achieved by each alternative, to the extent applicable. This factor will be applied initially to the alternatives for addressing in-place sediments, since some of them (i.e., those involving removal or *in situ* containment) would reduce the volume or mobility of the PCBs in the sediments. In addition, this factor will be applied to the management alternatives for removed sediments/soils.

In applying this factor to the sediment/soil management alternatives, the discussion in the CMS will include, where applicable: (a) a description of the treatment process to be used and the materials to be treated in the alternative; (b) an estimate of the amount of hazardous waste to be destroyed or treated; (c) the degree of expected reductions in toxicity, mobility, or volume; (d) the degree to which the treatment is irreversible; and (e) the type and quantity of residuals produced by the treatment.

4. Short-Term Effectiveness

An evaluation of the short-term effectiveness of each remedial alternative will be made. This factor involves consideration of the impacts to nearby communities, workers, and/or the environment during implementation of the alternative. This factor will be applied both to alternatives for addressing in-river sediments/riverbanks and to the alternatives for managing removed sediments and soil. Such impacts will include, where applicable, impacts and risks associated with: (a) active remediation activities, such as excavation and/or containment, as well as the necessary ancillary site work (e.g., construction of access roads, staging/handling facilities, etc.); (b) associated dewatering and/or treatment operations for removed sediments/soils; (c) transportation of removed sediments/soils from, and backfill materials to, the site; and (d) local disposal activities. The impacts from such activities will include: (i) impacts on local communities in terms of disruption of normal activities, effects on quality-of-life considerations, and risks to public health and safety; (ii) impacts on the environment in the affected areas, including impacts on biota and their habitat and on wetlands and any other environmentally sensitive areas; and (iii) risks to the remediation workers.

5. Implementability

The CMS Report will also provide an evaluation of the implementability of the remediation alternatives. This factor will be applied both to the alternatives for addressing in-place sediments and riverbanks and to sediment/soil management alternatives. The evaluation of the implementability of each such alternative will consider: (a) the general availability of the technology(ies)/process option(s) involved; (b) the ability of such technology(ies)/process option(s) to be constructed and operated, given relevant site characteristics; (c) the reliability of such technology(ies)/process option(s); (d) local regulatory and zoning restrictions; (e) the ease of undertaking additional corrective measures at a later date if necessary; (f) the ability to monitor the effectiveness of the alternative; (g) the need for and extent of coordination with other agencies; and (h) the availability of resources for application of the alternative, including suitable on-site or off-site dewatering, treatment, storage, and/or disposal facilities.

6. **Cost**

The estimated cost of each alternative will be provided in accordance with the Permit. For those in-river remediation alternatives involving sediment/bank soil removal, a matrix will be generated showing combinations of those alternatives with appropriate and pertinent sediment/soil management alternatives, and a cost estimate will be provided for each combination.

5.3 Methodology for Evaluating Potential Corrective Measures for Floodplain Soils

5.3.1 Introduction

The retained technologies/process options for addressing floodplain soil (listed in Section 4.4.7) have been incorporated into several remedial alternatives that address in-place floodplain soil. These remedial alternatives are described below in Section 5.3.2, and range from no action to extensive floodplain soil removal, with various alternatives in between. This section also describes the methodology that will be used to determine the areal extent and volume of remediation associated with the various floodplain remediation alternatives. In addition, for the alternatives that involve floodplain soil removal, management of those soils will be considered in conjunction with evaluation of the management alternatives for removed sediments and bank soils, as described in Section 5.3.4. As with the sediment remediation alternatives, given that the performance of the CMS may lead to the identification of other alternatives that may warrant detailed evaluation under the Permit, additional floodplain soil remediation alternatives beyond those identified in this section may be developed and evaluated during preparation of the CMS Report.

The proposed methods for evaluating floodplain soil remedial alternatives are based upon the spatial delineation of the floodplain developed by EPA as part of its HHRA and ERA.[38] This delineation divided the floodplain into various areas, over which averaging of soil PCB concentrations was conducted to evaluate risk, and is thus applicable for evaluating attainment of IMPGs or other target levels in the assessment of remedial alternatives. The types of floodplain areas to be used in these evaluations in the CMS are described below.

[38] As discussed in Section 2.2.3, the floodplain for the Rest of River is defined as the 1 mg/kg PCB isopleth in Reaches 5 and 6, and the portion of the 100-year floodplain containing PCBs in reaches below Woods Pond Dam. For simplicity, these areas are referred to throughout this section as the “floodplain.”

- The HHRA divided the floodplain into 90 exposure areas (EAs) for the assessment of direct human contact. Specific exposure scenarios and receptors were assigned to each area. The HHRA then combined this information with spatially averaged PCB concentrations to calculate risk. Several of the EAs contain overlying direct contact subareas, which are typically characterized by a different and/or more frequent exposure scenario (e.g., a large EA considered for general recreation may contain as a subarea a stretch of soil along the river that is considered for the bank fishing scenario). A map of the direct contact EAs and subareas delineated by EPA is provided in Figures 5-1a and 5-1b. These EAs and subareas will be used in the CMS for application of the IMPGs based on direct human contact. This application will be based on the same exposure scenarios and receptors identified in the HHRA for these EAs and subareas, unless there is a significant modification in the use of an area or GE proposes and justifies use of an alternate exposure scenario for a given area.

- There are a number of farm areas located fully or partially within the floodplain, which are shown in Figures 5-2a and 5-2b. These areas will be used in the CMS for application of the IMPGs based on agricultural products consumption, unless a given farm area is no longer used or will no longer be used for raising farm animals or the growing of crops intended for consumption by humans.

- For ecological receptors, EPA has mapped and classified habitat types suitable for various species within the PSA (Woodlot, 2002). These habitat areas, which also overlap with the human health EAs, are shown in Figure 5-3 and will be used as follows for application of the ecological IMPGs that apply in the floodplain:

    - EPA’s database identifies 68 vernal pools (including both temporary and permanent pools) in the floodplain of the PSA. However, EPA’s ERA states that only 27 of these vernal pools were identified as suitable breeding habitat for wood frogs, the representative amphibian for which IMPGs were developed (ERA, Vol.. 5, Appendix E, Attachment E.4, p. 2). Nevertheless, to be conservative and since the amphibian IMPGs apply to species other than wood frogs, GE proposes to evaluate all 68 vernal pools identified in the EPA database. These vernal pools are shown on Figure 5-3 and will be used for application of the amphibian IMPGs and assessment of impacts on the local amphibian population, using the modeling approach described in Section 5.3.2.3 below and Appendix C.

    - The habitat for short-tailed shrews, which represented omnivorous and carnivorous mammals for IMPG development, coincides with much of the floodplain within the PSA (see Figure 5-3). As such, this overall area will be considered as a single averaging area for evaluating attainment of the IMPGs for shrews.

- The habitat for wood ducks, the species used to represent insectivorous birds for IMPG development, covers the entire floodplain in the PSA (see Figure 5-3). As discussed in Section 3.3.2.1, target floodplain soil levels have been derived from the IMPGs for insectivorous birds, assuming that sediment PCB concentrations are equal to certain selected levels. These target floodplain levels will be applied to the overall floodplain within the PSA as a single averaging area.

5.3.2 Development and Identification of Corrective Measure Alternatives To Address Floodplain Soil

Several floodplain soil remediation alternatives have been developed for evaluation in the CMS. Based on review of the areas delineated by EPA for evaluation of human health and ecological risks, GE has developed a set of alternatives based on human health considerations and will then evaluate, as a supplement to each alternative, the need for and extent of additional remediation based on ecological considerations.

For human health protection, two types of floodplain remediation alternatives have been developed (apart from the "no action" alternative). The first type involves soil removal/replacement as necessary to achieve certain sets of human health-related IMPGs (or in the case of agricultural uses, floodplain soil PCB concentrations derived from the related IMPGs, as described in Section 3.3.1) over the applicable averaging areas. The second type involves removal and replacement of all soils within a given depth having PCB concentrations that exceed certain concentration thresholds. In addition, for these "threshold-based" alternatives, the average floodplain soil PCB concentrations that would result from a given alternative will then be evaluated to quantify the extent to which it achieves or exceeds the health-based IMPGs within the various averaging areas. Based on this evaluation, adjustments to the remediation for such alternative (i.e., increases or decreases in the extent of removal) may be made for particular areas.

All of these alternatives focus on remediation of the top foot of floodplain soil, since, given current and reasonably anticipated uses in the floodplain, that depth increment represents the soil to which human and ecological receptors would most likely be exposed. In addition, all of the alternatives will include the use of EREs and Conditional Solutions, as described in Section 4.4.2, as necessary to address reasonably anticipated future uses and activities that would not be addressed by the given alternative (e.g., residential use of properties where such use is reasonably anticipated and which would not meet the standards for such use, or reasonably anticipated activities involving exposure to soil deeper than one foot).

The following subsections describe first the health-based remediation alternatives – i.e., those based on achieving certain sets of IMPGs or those based on removal of PCB-containing soils above certain concentration thresholds – followed by a discussion of potential adjustments to the latter alternatives. The supplemental evaluations that GE will conduct to address ecological considerations are then described. As explained above, other alternatives in addition to those described in these subsections may be identified during the CMS and evaluated in the CMS Report.

5.3.2.1 Health-Based Initial Alternatives

The range of floodplain soil remediation alternatives to be evaluated in the CMS will include those listed below. These alternatives have been selected to encompass a broad range of target PCB concentrations and a broad range in the extent of remediation. They include both alternatives based on achieving specified average PCB concentrations (based on IMPGs) within various types of averaging areas and alternatives based on removing all soils with PCB concentrations above certain thresholds.

Floodplain Alternative 1 (FP 1) – No Action

The FP 1 ("no action") alternative has been included as required by the NCP and to provide a baseline against which other alternatives can be assessed in the CMS Report. FP 1 would not include any active or passive remediation, and no monitoring efforts would be implemented.

Floodplain Alternative 2 (FP 2) – Remediation to Achieve Upper-Bound RME IMPGs

The FP 2 alternative would involve removal and replacement of floodplain soils as necessary to achieve average PCB concentrations in the top foot in the various averaging areas that are equal to the upper-bound health-based RME IMPGs approved by EPA. These IMPGs consist of the floodplain soil IMPGs (or, for agricultural areas, corresponding target soil levels derived from the IMPGs) based on RME exposures and on a 10^{-4} cancer risk or a non-cancer hazard index (HI) of 1, whichever is lower. Specifically, these would include:

- For the direct contact EAs and subareas (see Figures 5-1a and 5-1b), the RME IMPGs for direct contact based on a 10^{-4} cancer risk or a non-cancer HI of 1 (whichever is lower), as specified in Table 3-1; and
- For the farm areas used for pasture or growing crops (see Figures 5-2a and 5-2b), the target floodplain soil levels corresponding to the pertinent agricultural products RME IMPGs based on a 10^{-4} cancer risk or a non-cancer HI of 1 (whichever is lower), as specified in Table 3-3, with such target levels to be

calculated as described in Section 3.3.1, including adjustments for the portions of the cropland in the floodplain.

Floodplain Alternative 3 (FP 3) – Remediation to Achieve Combination of Upper-Bound and Mid-Range RME IMPGs

The FP 3 alternative is the same as FP 2 except that, in certain heavily used areas, the removal and replacement of soils would be designed to achieve the RME IMPGs (or corresponding target soil levels for agricultural areas) based on a 10^{-5} cancer risk or a non-cancer HI of 1 (whichever is lower), as specified in Table 3-1 or derived from Table 3-3. For direct contact exposures, these areas would consist of frequently used areas such as trails, access points, and known recreational areas. Specifically, they would include the following EAs (see Figure 5-1a):

- EAs 4 and 12 – established foot trails running through both MA Fish & Wildlife land and private land located close to residential properties;
- EA 26a – MA Fish & Wildlife land with trail access and an adjacent parking area;
- EA 35a and 37a – trail along easements running through both private property (EA 35a) and MA Fish & Wildlife land (EA 37a) with an adjacent parking area;
- EA 39 – John Decker Canoe Launch (MA Fish & Wildlife land) and parking area;
- EA 40 – MA Fish & Wildlife land adjacent to the Lenox Sportsman Club property;
- EAs 47, 52, and 53 – river access/canoe launches with corresponding parking areas located along October Mountain Road;
- EAs 57, 58, and 59 – land surrounding Woods Pond with road access; and
- EA 60a – Canoe launch adjacent to Woods Pond Footbridge with an adjacent parking area.

In addition, for farm areas used for pasture or growing crops, alternative FP 3 would be designed to achieve target floodplain soil PCB levels derived from the mid-range IMPGs listed in Table 3-3. The remaining areas, which have much less current or anticipated use and/or difficult access, would be remediated to achieve the upper-bound IMPGs described in FP 2.

Floodplain Alternative 4 (FP 4) – Remediation to Achieve Mid-Range RME IMPGs

The FP 4 alternative would involve removal and replacement of floodplain soils as necessary to achieve average PCB concentrations in the top foot in the various averaging areas that are equal to the mid-range health-based RME IMPGs approved by EPA. These IMPGs consist of the floodplain soil IMPGs (or, for agricultural areas, corresponding target soil levels) based on RME exposures and on a 10^{-5} cancer risk or a non-cancer HI of 1, whichever is lower. Specifically, these would include:

- For the direct contact EAs and subareas (see Figures 5-1a and 5-1b), the RME IMPGs for direct contact based on a 10^{-5} cancer risk or a non-cancer HI of 1 (whichever is lower), as specified in Table 3-1; and
- For the farm areas used for pasture or growing crops (see Figures 5-2a and 5-2b), the target floodplain soil levels corresponding to the pertinent agricultural products RME IMPGs based on a 10^{-5} cancer risk or a non-cancer HI of 1 (whichever is lower), as specified in Table 3-3, with such target levels to be calculated as described in Section 3.3.1, including adjustments for the portions of the cropland in the floodplain.

Floodplain Alternative 5 (FP 5) – Remediation of Soils with PCBs ≥ 50 mg/kg in Top Foot

The FP 5 alternative would involve removal and replacement of soils within the top foot of the floodplain that contain a PCB concentration of 50 mg/kg or greater.

Floodplain Alternative 6 (FP 6) – Remediation of Soils with PCBs ≥ 25 mg/kg in Top Foot

The FP 4 alternative would involve removal and replacement of soils within the top foot of the floodplain that contain a PCB concentration of 25 mg/kg or greater.

Floodplain Alternative 7 (FP 7) – Remediation of Soils to Achieve Most Stringent IMPGs (But Not Below 2 mg/kg)

The FP 7 alternative would involve removal and replacement of floodplain soils as necessary to achieve average PCB concentrations in the top foot in the various averaging areas that are equal to the most stringent health-based RME IMPGs. These IMPGs consist generally of the floodplain soil IMPGs designated as "points of departure" in the IMPG tables presented in Section 3 – namely:

- For the direct contact EAs and subareas (see Figures 5-1a and 5-1b), the RME IMPGs based on a 10^{-6} cancer risk for direct contact, as specified in Table 3-1, except that where such values are lower than 2 mg/kg (the residential Performance Standard in the Consent Decree), a concentration of 2 mg/kg will be used, since it is considered protective for unrestricted use; and
- For the farm areas used for pasture or growing crops (see Figures 5-2a and 5-2b), the target floodplain soil levels corresponding to the pertinent agricultural products RME IMPGs based on a 10^{-6} cancer risk, as specified in Table 3-3, with such target levels to be calculated as described in Section 3.3.1, including adjustments for the portions of the cropland in the floodplain.

Under the foregoing alternatives, the PCB concentrations within the top foot of soil will be calculated from the available floodplain soil data collected from within that depth increment. If more than one sample was collected from the top foot at given location, the average of those sample results will be used to represent the top-foot PCB concentration at that location. The use factors applied in the HHRA to account for reduced exposure in areas of the floodplain that are difficult to access will be applied in determining the extent of remediation for the IMPG-based alternatives (FP 2, 3, 4, and 7), but will not be applied in the initial determinations for the PCB threshold-based alternatives (FP 5 and FP 6). The areal extent and volume of soil removal associated with these alternatives will be calculated using the methodology described in Section 5.3.3.

5.3.2.2 Adjustments to Threshold-Based Alternatives

In addition to evaluating the alternatives listed above, GE will consider certain adjustments to the PCB threshold-based alternatives (FP 5 and FP 6). For this purpose, the average PCB concentrations in the top foot of soil that would result from implementation of the threshold-based alternative will be calculated for each human exposure area (or subarea) and agricultural area. The resulting averages will then be compared to the applicable IMPGs (or, for agricultural areas, corresponding target soil levels). Based on that comparison, adjustments may be made to the alternative for particular areas or groups of areas. If such adjustments are made, the alternative with the adjustments will also be evaluated in the CMS Report. Some examples of potential adjustments that may be made include the following:

- If a given alternative results in a calculated post-remediation average PCB concentration in a given area or areas that still exceeds the range of applicable direct contact IMPGs for RME exposures (as listed in Table 3-1), the extent of soil remediation in such area(s) may be increased so as to achieve an average concentration within that range of IMPGs.

- Conversely, if the threshold-based remediation provided by a given alternative reduces average PCB concentrations in certain areas to levels that are lower than particular direct contact IMPGs, the extent of soil remediation in such area(s) may be reduced. As an example, if a given alternative results in a post-remediation average PCB concentration in an area that is lower than the applicable RME IMPGs based on either a 10^{-5} cancer risk or a non-cancer HI of 1, then the volume of soil removal in that area may be reduced so that the average post-remediation concentration achieves but is not significantly lower than those IMPGs. In considering such adjustments, GE will take account of the likely frequency of use of the EAs involved.

- Another potential adjustment to these alternatives will be consideration of MNR in certain reaches of the floodplain where the soil PCB concentration is at or slightly above the target concentration and conditions are favorable for natural recovery.

5.3.2.3 Supplemental Evaluations Based on Ecological Considerations

For each of the floodplain remedial alternatives described above, GE will consider the need for and scope of additional remediation to achieve levels considered protective of ecological receptors. This evaluation will be made separately for amphibians (represented by wood frogs) and for omnivorous/carnivorous mammals (represented by short-tailed shrews) and insectivorous birds (represented by wood ducks), as described below.

Assessment of Amphibian Population Protection

For each of the above health-based alternatives, GE will calculate the average PCB concentration that would remain in the 68 PSA vernal pools described in Section 5.3.1 above. Based on review of these concentrations, GE will then evaluate the need for and extent of additional remediation in those vernal pools to protect amphibians. The alternatives to be considered in that evaluation will range from no additional remediation in the vernal pools to remediation of all the pools that still exceed the lower bound of the amphibian IMPG range (3.27 mg/kg in sediments, as noted in Table 3-4), with various alternatives in between, such as remediating a given portion of the vernal pools to the IMPG levels.

In making this evaluation, GE will assess the extent of additional remediation (if any) needed to protect the local amphibian population. To do so, GE proposes to use EPA's wood frog population model described in the ERA (Vol. 5, Appendix E, Attachment E.4), with minor modifications, to evaluate and compare the effects on the

PSA amphibian population of remedial alternatives that would achieve the amphibian IMPGs to varying degrees.

The wood frog population model developed by EPA was used in the ERA to evaluate the effects of PCB exposure on the long-term sustainability of the wood frog population in the PSA, which EPA defined as those frogs breeding within the vernal pools that were identified as having suitable wood frog breeding habitat (Vol. 5, Appendix E, Attachment E.4, p. 2). EPA used this model in the ERA to demonstrate that the presence of PCBs in vernal pool sediments in the PSA increased the probability of wood frog population extinction by increasing the rate of metamorph malformations, which were assumed to result in mortality or sterility. This model accounts for migration of frogs between pools, and includes quantitative exposure-response relationships that allow evaluation of the effects of PCBs at various concentrations in vernal pool sediments on metamorph malformations and thus (under the model's assumptions) on long-term population sustainability. Based on these inputs, the model provides estimates of the probability that the wood frog population would fall below a given threshold number or go extinct by the end of the modeled period.

EPA's model thus provides a tool that can be used to evaluate and compare the effects of different remedial alternatives for addressing vernal pools on the sustainability of the local amphibian population in the PSA. GE's proposed approach to using the EPA model for such evaluations is described in Appendix C. As discussed in that appendix, to optimize the model for use in evaluating such remedial alternatives, GE has made a number of minor adjustments to the model. These include:

- Modifying the model so that PCB impacts are not predicted to occur at concentrations below the lower bound of the IMPG range;
- Assuming conservatively that all PCB-related malformations in metamorphs result in mortality;
- Expanding the model run time to ensure that it would cover the period for any necessary remediation and recovery;
- Adjusting the survival and fecundity rates in the model to limit the probability of the population going extinct (even without any PCB impacts) over the longer run time; and
- For use in evaluating active remedial alternatives, adjusting EPA's survival multiplier to account for the impacts of temporary habitat destruction caused by remediation.

In addition, since EPA's model was developed for only the 27 PSA vernal pools identified in the ERA as having suitable breeding habitat for wood frogs, it was necessary to develop a procedure for extending the model to apply to all 68 vernal pools in the PSA. This extension is based on the concept that since EPA selected wood frogs to represent all amphibians for purposes of assessing risks and establishing IMPGs, the risk of wood frog population extinction, as estimated by the model, can likewise be used as a surrogate to represent population-level effects on the overall amphibian population in the PSA. The methods that GE proposes to use to apply the model to all 68 vernal pools are also described in Appendix C.

With these modifications and extensions, the EPA model will be used in the CMS to evaluate the impacts of various remedial alternatives for addressing vernal pools on the long-term sustainability of the amphibian population in the PSA. Appendix C provides an example of how the model will be used to make such evaluations.

Assessment of Omnivorous Mammals and Insectivorous Birds

For each of the above health-based alternatives, GE will calculate the average soil concentrations that would remain in the habitat for short-tailed shrews and for wood ducks, which consist of most and all of the floodplain of the PSA, respectively, as shown on Figure 5-3. Those average concentrations will then be compared to the IMPGs for omnivorous/carnivorous mammals (identified in Table 3-4) and to the target floodplain soil levels that have been derived from the IMPGs for insectivorous birds (as discussed in Section 3.3.2.1). Based on these comparisons, as well as consideration of the other relevant Permit criteria and factors, an evaluation will be made of the need for and scope of additional remediation to address these receptor groups.

5.3.3 Determination of Areal Extent and Removal Volume for Remedial Alternatives

This section provides an overview of the procedures to be used in the CMS to estimate the areal extent and volume of floodplain soil to be remediated for the floodplain remedial alternatives described above (and any others identified during the CMS). In summary, these procedures will make use of a spatially interpolated representation of the floodplain soil PCB data – based on use of Thiessen polygons modified by natural community boundaries (EPA's "super habitats") or elevation – which provides a continuous coverage of PCB concentrations over the floodplain within Reaches 5 through 8. A detailed description of the spatial interpolation method used to provide this continuous coverage is provided in Appendix D. Using this continuous coverage, the procedures that will be employed to estimate the areal extent and volume of floodplain soil to be removed under a given remedial alternative will depend on the type of alternative being evaluated, as summarized below and described in more detail in Appendix D.

5.3.3.1 Target Level-Based Alternatives

Determination of areal extent and removal volume for the target level-based alternatives described in Section 5.3.2.1 (Alternatives FP 2, FP 3, FP 4, and FP 7) will involve identifying the extent of remediation necessary to achieve the target level as a spatial average soil PCB concentration in a given area. The method will be based on the spatially-interpolated PCB data coverage described in Appendix D and will proceed on an area-by-area basis. For a given averaging area (e.g., direct contact EA or subarea or farm area), this method will be implemented in four steps (summarized on Figure 5-4):

1) The applicable target PCB value (i.e., IMPG or, for agricultural use areas, target soil concentration) for the averaging area of the floodplain being evaluated will be assigned based on the applicable human exposure scenario and target level of risk reduction (e.g., cancer risk of 10^{-5}) specified for that alternative. For areas having multiple use types, the lowest IMPG value will be used for that given area. If the given averaging area is an agricultural field, the target PCB level will be adjusted based on the portion of the field that is located within the floodplain, as described in Section 3.3.1 and Appendix D.

2) The PCB exposure point concentration (EPC) for the given area will then be calculated. The EPC will be defined as the 95% UCL on the spatially-weighted mean of the data from that area or the maximum measured value, whichever is lower, consistent with the approach utilized by EPA in the HHRA.[39] The 95% UCL will be computed using the modified Halls Bootstrap method, as described in Appendix D. However, if the given area contains sampling data that are sufficiently dense, uniform, and representative, the spatially-weighted arithmetic mean will be used in place of the 95% UCL for computing the EPC. Finally, in computing the spatially-weighted mean, the interpolated PCB concentrations will be multiplied by use accessibility factors if the given averaging area is a direct contact EA or subarea (consistent with the HHRA), as described in Appendix D.

[39] The use of 95% UCLs for this purpose should not be regarded as a precedent for the averaging technique that may be used in designing the Rest of River remedy. It is anticipated that additional soil sampling would be conducted as part of remedial design, which may allow use of spatially weighted arithmetic averaging.

3) The EPC calculated for the area being evaluated will then be compared with the target PCB value to determine if remediation of soil would be necessary to achieve that value.

4) If remediation is required in a given averaging area to achieve the target PCB level, the approximate areal extent and volume will then be calculated using an iterative process. First, a portion of the given area will be "flagged" for remediation (starting with the highest concentrations) and the interpolated PCB values will be replaced with the applicable "clean" soil concentration (i.e. one-half the typical PCB detection limit). Then, the EPC will be recomputed based on the modified spatial PCB distribution within that area and compared again with the target PCB level. This sequential replacement of concentrations with ½ MDL and recalculation of the EPC will be repeated until the amount of remediation is sufficient to reduce the EPC to a level that is at or below the target PCB level specified for that area.

These steps then will be repeated for all remaining discrete averaging areas of the floodplain (e.g., direct contact EAs and agricultural fields for agricultural products consumption). This method will account for overlapping of averaging areas such that remediation is not "double-counted."

This same approach will be followed in the supplemental evaluations based on ecological considerations (described in Section 5.3.2.3) to determine the areal extent and volume of removal that would be needed to achieve a given target ecologically based PCB level in the relevant ecological habitat. In these applications, however, the approach will first take into account the removal associated with the basic alternative to achieve the health-based target levels. For example, when removal of a portion of a vernal pool located within a direct contact EA is necessary to reduce the spatial mean below the target risk level for the direct contact use, that removal will be taken into account when the vernal pool is subsequently evaluated for the target PCB level for amphibians.

The volume will be calculated as the product of the total area delineated for removal during this procedure and the one-foot removal depth.

5.3.3.2 Threshold-Based Alternatives

Determination of areal extent and removal volume for the threshold-based alternatives described in Section 5.3.2.1 (Alternatives FP 5 and FP 6) will also be based on the spatially interpolated PCB data coverage described in Appendix D. The method will consist of identifying, from the interpolated PCB concentration coverage, the locations within the floodplain where soil PCB concentrations exceed the threshold concentration specified for the given alternative. Note that the use accessibility factors developed by EPA for the HHRA will not be applied in this step. The volume will then be calculated as the product of the total area of the locations identified to exceed the threshold and the one-foot removal depth.

5.3.3.3 Alternatives Containing Adjustments to Meet Target Levels

Estimation of areal extent and removal volume for floodplain alternatives in which adjustments are made to the threshold-based alternatives (as described in Section 5.3.2.2) will consist of a combination of the two methods described above. For example, consider a threshold-based initial alternative that is then adjusted to achieve certain target IMPGs in various averaging areas. Once areas are identified for remediation based upon the not-to-exceed threshold method (described in Section 5.3.3.2), the UCL method described above would be used to recalculate the spatially-weighted means for the relevant averaging areas. These resulting averages would then be compared to the target IMPGs. If adjustments are warranted, the iterative procedure described in Section 5.3.3.1 would be used to determine the removal necessary to achieve the target IMPGs.

5.3.4 Alternatives for Managing Removed Soil

For the floodplain remediation alternatives that involve soil removal, soil management will be necessary. The CMS will develop and evaluate management alternatives for removed floodplain soils in conjunction with the management alternatives for removed sediments and bank soils. Thus, as described in Section 5.2.3, management alternatives based on the components identified in that section will be considered and evaluated in the CMS (as appropriate) for floodplain soils as well as sediments and bank soils.

5.3.5 Application of Evaluation Criteria

The floodplain remediation alternatives will be evaluated based on the three "General Standards" and six "Selection Decision Factors" specified in the Reissued RCRA Permit, as identified in Section 5.2.4 above. As with the sediment remediation alternatives, these standards and factors will be applied first to the in-place floodplain remediation alternatives identified in Section 5.3.2 (and any others developed during the CMS). The relevant standards and factors will then be applied to the soil management alternatives developed in the CMS, as described in Section 5.3.4, in conjunction with the sediment management alternatives discussed in Section 5.2.3. Again, in applying the cost factor, a cost estimate will be developed for each relevant combination of "front-end" and "back-end" alternatives. Based on these evaluations, the CMS Report will recommend a combined alternative for addressing floodplain soil and, if the alternative involves removal, managing the removed soils.

The General Standards and Selection Decision Factors to be applied in evaluating the floodplain soil remedial alternatives are described below. A full description of the evaluation and results will be provided in the CMS Report.

5.3.5.1 General Standards

The General Standards specified in the Permit will be applied to the floodplain soil remediation alternatives, using the same basic approaches described in Section 5.2.4.1 for the sediment alternatives, with appropriate modifications to apply to the floodplain soil alternatives, as described below.

1. Overall Protection of Human Health and the Environment

Each remedial alternative for floodplain soils will be evaluated based on its ability to provide overall protection of human health and the environment. As with the sediment remediation alternatives, overall protection of human health and the environment will be assessed in accordance with the RAOs described in Section 3.1 above, will take into account EPA's HHRA and ERA, and will also consider other evaluation criteria (especially long-term and short-term effectiveness) as relevant.

Specifically, from a human health standpoint, each alternative will be evaluated in terms of the extent to which it would achieve a condition in which PCB concentrations in the floodplain soils in the Rest of River do not present significant risks of harm to health, as determined by reference to EPA's cancer risk range ($1x10^{-6}$ to $1x10^{-4}$) and a non-cancer HI of 1. This evaluation will take account EPA's HHRA, as well as any long-term and short-term effects of the alternative relating to human health.

From the environmental standpoint, each alternative will be evaluated based on whether it would provide "overall protection" of the environment. This will involve consideration of the extent to which the alternative would achieve a condition in which PCB concentrations in the floodplain soils allow the maintenance of healthy local populations and communities of biota that inhabit or consume biota from the floodplain in the Rest of

River area, taking into account EPA's ERA; and it will also consider whether the alternative would cause more environmental harm than leaving the contamination in place.

For the different alternatives, the protection of human health and the environment may be achieved through one or a combination of the various retained technologies and process options for floodplain soils (including soil removal, as well as institutional controls such as EREs, Conditional Solutions, and biota consumption advisories) and, in some cases, through use of the adjustments described above.

2. Control of Sources of Releases

Each floodplain soil remedial alternative will be evaluated based on its ability to reduce or minimize possible further PCB releases, if that factor is applicable to the alternative in question.

3. Compliance with Federal and State ARARs

Each floodplain soil remedial alternative will be evaluated based on its ability to meet ARARs under federal and state law. The CMS Report will identify chemical-specific, location-specific, and action-specific ARARs for the floodplain remedial alternatives, based on the same criteria discussed in Section 5.2.4.1 for the identification of ARARs. Table 5-3 includes a list of the categories of potential ARARs that GE anticipates will be identified and applied during the CMS. In the CMS, GE will evaluate how each floodplain remedial alternative would meet the ARARs that would apply to it. If such ARARs would not be met, GE will consider the potential grounds for waiver of the ARAR under the NCP, as described in Section 5.2.4.1 above, and will provide the basis for any proposed waiver in the CMS Report.

5.3.5.2 Selection Decision Factors

In addition to applying the General Standards, the floodplain soil remediation alternatives will be evaluated based on the Selection Decision Factors specified in the Permit. These factors will be applied in much the same way as described for the sediment remediation alternatives in Section 5.2.4.2, with appropriate modifications to apply to floodplain soil alternatives.

1. Long-Term Reliability and Effectiveness

Each remedial alternative for floodplain soils will be evaluated in terms of its long-term reliability and effectiveness. Application of this factor will involve, first, an assessment of the extent to which the alternative would mitigate long-term potential exposure to residual PCB levels in the Rest of River floodplain and the extent to which and time over which the alternative would reduce the level of exposure to such PCBs. This assessment will rely on the methodology described in Section 5.3.3 to estimate the average PCB concentrations that would remain in place in the floodplain soil after application of the alternative. Those estimates will be combined with information on exposure to such PCB concentrations by human and ecological receptors, given other aspects of the alternative (e.g., institutional controls), so as to assess the reduction in exposure levels.

In addition, the evaluation of long-term reliability and effectiveness will include an assessment of the adequacy and reliability of each alternative and any potential long-term adverse impacts of the alternative on human health or the environment, taking into account the same parameters and considerations identified for these factors in Section 5.2.4.2.

2. Attainment of IMPGs

Each floodplain soil remediation alternative will be evaluated based on its ability to attain the IMPGs applicable to floodplain soil (or, in some cases, the target floodplain soil levels derived from such IMPGs, as discussed in Section 3.3 above). To make such evaluations, the average floodplain soil PCB concentrations resulting from a given alternative, with any appropriate adjustments, will be estimated for the pertinent averaging areas using the methodology described in Section 5.3.3, and those average concentrations will be compared to the relevant IMPGs (or target floodplain soil levels). In these evaluations, both the RME and CTE IMPGs will be considered. Where the IMPGs (or target levels) consist of ranges, the evaluation will consider whether the estimated soil concentrations fall within those ranges and, if so, where in those ranges the estimated concentrations would fall.

3. Reduction of Toxicity, Mobility, or Volume

The CMS Report will provide an evaluation of the reduction of toxicity, mobility, or volume of waste achieved by each alternative, to the extent applicable. This factor will be applied initially to the alternatives for addressing in-place floodplain soils, since some of them (e.g., those involving removal) would reduce the volume or mobility of the PCBs in the soil. In addition, this factor will be applied to the soil management alternatives for removed soils. In discussing the application of this factor to the soil management alternatives, the CMS Report will include, where applicable, the same information described under this factor in Section 5.2.4.2.

4. Short-Term Effectiveness

An evaluation of the short-term effectiveness of each floodplain remedial alternative will be made. This evaluation will involve an assessment of the impacts to nearby communities, the environment, and remediation workers during implementation of the alternative, including, where applicable, impacts and risks from excavation and/or containment of soils (as well as the necessary ancillary site work) and from any associated treatment, transportation, and/or local disposal of removed soils. As with the sediment remediation alternatives, the impacts from such activities will include impacts on local communities, the environment, and workers, as discussed in Section 5.2.4.2.

5. Implementability

The implementability of the floodplain soil remediation alternatives, including both the alternatives for addressing in-place floodplain soil and the alternatives for managing removed soil, will be evaluated based on the same considerations identified for implementability in Section 5.2.4.2.

6. Cost

The estimated cost of each alternative will be provided in accordance with the Permit. For those in-place remediation alternatives involving soil removal, a matrix will be generated showing combinations of those alternatives with appropriate and pertinent soil management alternatives, and a cost estimate will be provided for each combination.

6. Development of CMS Report

6.1 CMS Report

The CMS Report will evaluate remedial alternatives for the Rest of River sediments (including erodible riverbanks) and floodplain soils and will recommend a set of alternatives for addressing each medium. More specifically, the report will describe a number of site-wide remedial alternatives for addressing in-place sediments, a number of site-wide alternatives for addressing floodplain soils, and a number of alternatives for managing removed sediments and soils. Using the methods described in Section 5 and based on the Reissued RCRA Permit criteria, the CMS Report will present a detailed analysis of the remedial alternatives being considered for each medium, as well as a comparative analysis of the alternatives. In presenting these analyses, the CMS Report will discuss the benefits and drawbacks of each alternative and will apply to each alternative the General Standards and Selection Decision Factors listed in the Permit, as also described in Section 5.

The CMS Report will conclude with a recommendation as to which remedial alternatives for sediments and floodplain soils would, in GE's opinion, be best suited to meet the General Standards in the Permit, in consideration of the Selection Decision Factors and the balancing of those factors against one another. The CMS Report will also identify potential ARARs for the final recommended alternatives and the basis for a waiver of any ARAR.

6.2 Schedule

As discussed in Section 5.2.2, GE is planning to provide EPA with an interim deliverable, the Model Input Addendum, which will specify a number of the input parameters and values that GE proposes to use in conducting the model simulations of sediment remedial alternatives in the CMS. GE anticipates submitting that Model Input Addendum to EPA for review and approval by April 15, 2005. In addition, as also discussed in Section 5.2.2, GE will provide a number of proposed revisions to the model code (listed in Section 5.2.2.6) to EPA for review and approval within 30 of EPA approval of this CMS Proposal.

In accordance with the Reissued RCRA Permit, GE currently anticipates that the CMS Report will be submitted to EPA within 180 days of EPA's approval of this CMS Proposal. In the event that it becomes apparent during the course of the CMS that additional time is necessary to complete sufficient model runs or other studies to provide a meaningful and complete evaluation of remedial alternatives, GE will request an extension of time from EPA and provide a justification for that request.

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Tables

Table 3-1 – IMPGs for PCBs Based on Human Direct Contact (Soil/Sediment)

Type of Area/Exposure Scenario	Receptor	RME or CTE	Assumed Frequency of Use	IMPGs (in mg/kg)			
				Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer
Residential (Actual/Potential Lawn areas)	All	RME	150 d/yr	**2*** (per Consent Decree)			
Residential (banks, steep slopes, wet areas)	All	Both	Variable	Use IMPGs for general recreation scenarios based on appropriate exposure frequencies for parcel-specific conditions			
High-use general recreation	Young child (high use)	RME	90 d/yr	**1.3***	13	134	**4.6***
		CTE	30 d/yr	18	184	1,842	32
	Young child (low use)	RME	15 d/yr	**8.0***	80	802	**27***
		CTE	15 d/yr	37	368	3,684	63
	Older child	RME	90 d/yr	**3.9***	39	388	**27***
		CTE	30 d/yr	51	514	5,143	176
	Adult	RME	90 d/yr	**1.4***	14	143	**38***
		CTE	30 d/yr	63	630	6,305	234

Table 3-1 – IMPGs for PCBs Based on Human Direct Contact (Soil/Sediment)

Type of Area/Exposure Scenario	Receptor	RME or CTE	Assumed Frequency of Use	IMPGs (in mg/kg)			
				Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer
Medium-use general recreation	Young child	Not assessed		NA	NA	NA	NA
	Older child	RME	60 d/yr	**5.8***	58	582	**40***
		CTE	30 d/yr	51	514	5,143	176
	Adult	RME	60 d/yr	**2.1***	21	215	**58***
		CTE	30 d/yr	63	630	6,305	234
Low-use general recreation	Young child	Not assessed		NA	NA	NA	NA
	Older child	RME	30 d/yr	**12***	116	1,165	**80***
		CTE	15 d/yr	103	1,029	10,286	353
	Adult	RME	30 d/yr	**4.3***	43	429	**115***
		CTE	15 d/yr	126	1,261	12,610	468

Table 3-1 – IMPGs for PCBs Based on Human Direct Contact (Soil/Sediment)

Type of Area/Exposure Scenario	Receptor	RME or CTE	Assumed Frequency of Use	IMPGs (in mg/kg)			
				Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer
Bank fishing	Older child	RME	30 d/yr	**6.2***	62	619	**42***
		CTE	10 d/yr	52	524	5,237	180
	Adult	RME	30 d/yr	**2.6***	26	256	**56***
		CTE	10 d/yr	70	702	7,015	220
Dirt biking/ATVing	Older child	RME	90 d/yr	**2.0***	20	205	**14***
		CTE	30 d/yr	29	290	2,901	99
Marathon canoeist	Adult	RME	150 d/yr	**0.78***	7.8	78	**13***
		CTE	90 d/yr	5.8	58	575	25
Recreational canoeist	Older child	RME	30 d/yr	**6.2***	62	619	**42***
		CTE	15 d/yr	35	349	3,491	120
	Adult	RME	60 d/yr	**1.2***	12	121	**28***
		CTE	30 d/yr	13	129	1,286	73

Table 3-1 – IMPGs for PCBs Based on Human Direct Contact (Soil/Sediment)

Type of Area/Exposure Scenario	Receptor	RME or CTE	Assumed Frequency of Use	IMPGs (in mg/kg)			
				Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer
Waterfowl hunting	Older child	RME	14 d/yr	**41***	408	4080	**140***
		CTE	7 d/yr	233	2325	23,253	399
	Adult	RME	14 d/yr	**9.0***	90	904	**196***
		CTE	7 d/yr	75	752	7,518	537
Agricultural use (based on direct contact by farmer)	Adult	RME	40 d/yr	**1.2***	12	118	**43***
		CTE	10 d/yr	42	419	4,195	348
High-use commercial (groundskeeper scenario)	Adult	RME	150 d/yr	**1.8***	18	177	**25***
		CTE	150 d/yr	17	166	1,664	57
Low-use commercial (groundskeeper scenario)	Adult	RME	30 d/yr	**8.9***	89	885	**126***
		CTE	15 d/yr	166	1,664	16,642	571

Table 3-1 – IMPGs for PCBs Based on Human Direct Contact (Soil/Sediment)

Type of Area/Exposure Scenario	Receptor	RME or CTE	Assumed Frequency of Use	IMPGs (in mg/kg)			
				Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer
Utility worker	Adult	RME	5 d/yr	**17***	169	1,694	**242***
		CTE	5 d/yr	209	2,093	20,933	718
Sediments	Older child	RME	36 d/yr	**4.5***	45	453	**31***
		CTE	12 d/yr	36	365	3,645	125
	Adult	RME	36 d/yr	**1.3***	13	135	**40***
		CTE	12 d/yr	28	280	2,800	152

Notes:
*Points of departure, as specified by EPA.
CTE = central tendency exposure
d/yr = days per year
EPA = United States Environmental Protection Agency
IMPGs = interim media protection goals
mg/kg = milligrams per kilogram
PCBs = polychlorinated biphenyls
RME = reasonable maximum exposure

Table 3-2 – IMPGs for Fish and Waterfowl Tissue Based on Human Consumption

Tissue Type and Constituent	Assessment Type	RME or CTE	IMPGs (in mg/kg for PCBs and ng/kg for TEQ)				
			Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer – Child	Non-Cancer – Adult
Bass fillets – PCBs	Deterministic	RME	**0.0019***	0.019	0.19	**0.026***	**0.062***
		CTE	0.049	0.49	4.9	0.19	0.43
	Probabilistic	RME (5th percentile)	**0.0064***	0.064	0.64	**0.059***	**0.12***
		CTE (50th percentile)	0.057	0.57	5.7	0.71	1.5
Trout fillets – PCBs	Deterministic	RME	**0.0048***	0.048	0.48	**0.069***	**0.16***
		CTE	0.11	1.1	11	0.40	0.93
	Probabilistic	RME (5th percentile)	**0.014***	0.14	1.4	**0.13***	**0.27***
		CTE (50th percentile)	0.12	1.2	12	1.5	3.1

Table 3-2 – IMPGs for Fish and Waterfowl Tissue Based on Human Consumption

Tissue Type and Constituent	Assessment Type	RME or CTE	IMPGs (in mg/kg for PCBs and ng/kg for TEQ)				
			Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer – Child	Non-Cancer – Adult
Duck breast – PCBs	Deterministic	RME	**0.0084***	0.084	0.84	**0.12***	**0.28***
		CTE	0.066	0.66	6.6	0.25	0.58
	Probabilistic	RME (5th percentile)	**0.0075***	0.075	0.75	**0.080***	**0.17***
		CTE (50th percentile)	0.072	0.72	7.2	0.67	1.4
Bass fillets – TEQ	Deterministic	RME	**0.025***	0.25	2.5	NA	
		CTE	0.32	3.2	32	NA	
	Probabilistic	RME (5th percentile)	**0.085***	0.85	8.5	NA	
		CTE (50th percentile)	0.76	7.6	76	NA	

Table 3-2 – IMPGs for Fish and Waterfowl Tissue Based on Human Consumption

Tissue Type and Constituent	Assessment Type	RME or CTE	IMPGs (in mg/kg for PCBs and ng/kg for TEQ)				
			Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer – Child	Non-Cancer – Adult
Trout fillets – TEQ	Deterministic	RME	**0.065***	0.65	6.5	NA	
		CTE	0.70	7.0	70	NA	
	Probabilistic	RME (5th percentile)	**0.18***	1.8	18	NA	
		CTE (50th percentile)	1.6	16	163	NA	
Duck breast – TEQ	Deterministic	RME	**0.11***	1.1	11	NA	
		CTE	0.44	4.4	44	NA	
	Probabilistic	RME (5th percentile)	**0.10***	1.0	10	NA	
		CTE (50th percentile)	0.96	9.6	96	NA	

Notes:
*Points of departure, as specified by EPA.
CTE = central tendency exposure
EPA = United States Environmental Protection Agency
IMPGs = interim media protection goals
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
PCBs = polychlorinated biphenyls
RME = reasonable maximum exposure
TEQ = toxicity equivalent

Table 3-3 – IMPGs for PCBs in Agricultural Products Based on Human Consumption

Tissue Type	Farm Type	RME or CTE	IMPGs (in mg/kg-wet weight)				
			Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer Child	Non-Cancer Adult
Cow milk	Commercial dairy	RME	**0.000026***	0.00026	0.0026	**0.00030***	**0.0014***
		CTE	0.00012	0.0012	0.012	0.00047	0.0017
	Backyard dairy	RME	**0.000032***	0.00032	0.0032	**0.00030***	**0.0012***
		CTE	0.00016	0.0016	0.016	0.00047	0.0010
Beef tissue	Commercial beef	RME	**0.00033***	0.0033	0.033	**0.0077***	**0.014***
		CTE	0.0015	0.015	0.15	0.010	0.017
	Backyard beef	RME	**0.00047***	0.0047	0.047	**0.0077***	**0.013***
		CTE	0.0027	0.027	0.27	0.010	0.013
Poultry meat	Commercial poultry	RME	**0.00052***	0.0052	0.052	**0.015***	**0.021***
		CTE	0.0030	0.030	0.30	0.019	0.034
	Backyard poultry	RME	**0.0009***	0.009	0.09	**0.015***	**0.026***
		CTE	0.0054	0.054	0.54	0.019	0.027

Table 3-3 – IMPGs for PCBs in Agricultural Products Based on Human Consumption

Tissue Type	Farm Type	RME or CTE	IMPGs (in mg/kg-wet weight)				
			Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer Child	Non-Cancer Adult
Poultry eggs	Commercial poultry	RME	**0.00055***	0.0055	0.055	**0.011***	**0.025***
		CTE	0.0025	0.025	0.25	0.013	0.031
	Backyard poultry	RME	**0.00082***	0.0082	0.082	**0.011***	**0.025***
		CTE	0.0044	0.044	0.44	0.013	0.026
Exposed fruit	Commercial or backyard fruit farm	RME	Not calculated (NC)			**0.11***	NC
		CTE	NC			0.15	NC
Exposed vegetables	Commercial or backyard farm with exposed vegetables	RME	NC			**0.024***	NC
		CTE	NC			0.037	NC
Root vegetables	Commercial or backyard farm with root vegetables	RME	NC			**0.030***	NC
		CTE	NC			0.049	NC

Table 3-3 – IMPGs for PCBs in Agricultural Products Based on Human Consumption

Tissue Type	Farm Type	RME or CTE	IMPGs (in mg/kg-wet weight)				
			Cancer @ 10^{-6}	Cancer @ 10^{-5}	Cancer @ 10^{-4}	Non-Cancer Child	Non-Cancer Adult
All produce	Commercial or backyard farm with all three types of above produce	RME	NC			**0.012***	NC
		CTE	NC			0.018	NC

Notes:
*Points of departure, as specified by EPA.
CTE = central tendency exposure
EPA = United States Environmental Protection Agency
IMPGs = interim media protection goals
mg/kg = milligrams per kilogram
PCBs = polychlorinated biphenyls
RME = reasonable maximum exposure

Table 3-4 – Summary of Media-Specific IMPGs for Ecological Receptors

Receptor Group	Medium	Constituent	IMPGs
Benthic invertebrates	Sediments	PCBs	**3*** to 10 mg/kg
Amphibians (represented by wood frog)	Vernal pool sediments	PCBs	**3.27*** to 5.6 mg/kg
Fish	Fish tissue in PSA (whole body)	PCBs	**55*** mg/kg
		TEQ	**44*** ng/kg
	Fish tissue downstream of PSA (whole body)	PCBs	**55*** mg/kg for warmwater fish **14*** mg/kg for coldwater fish
Piscivorous birds (represented by osprey)	Fish tissue (whole body)	PCBs	**3.2*** mg/kg
Insectivorous birds (represented by wood duck)	Aquatic and terrestrial invertebrate prey	PCBs	**4.4*** mg/kg
		TEQ	**14*** to 22 ng/kg
Piscivorous mammals (mink and otter)	Prey items	PCBs	**0.984*** to 2.43 mg/kg
		TEQ	**16.2*** to 33 ng/kg
Omnivorous and carnivorous mammals (represented by short-tailed shrew)	Floodplain soil	PCBs	**21.1*** to 34.3 mg/kg
Threatened and endangered species (represented by bald eagle)	Fish tissue (whole body)	PCBs	**30.41*** mg/kg

Notes:
Point of departure, as specified by EPA.
EPA = United States Environmental Protection Agency
IMPGs = interim media protection goals
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
PCBs = polychlorinated biphenyls
TEQ = toxicity equivalent

Table 3-5 – Exposure Assumptions Used By EPA for Agricultural Exposure Pathways at Commercial Farms

Exposure Assumptions	Acronym	Units	Dairy		Beef		Poultry Meat		Poultry Eggs		Produce	
			CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Soil to Plant Modeling												
Soil to corn silage transfer factor	SCTF	unitless	0.0012	0.0012	0.0012	0.0012	NR	NR	NR	NR	NA	NA
Soil to grass transfer factor	SGTF	unitless	NR	NR	0.036	0.036	NR	NR	NR	NR	NA	NA
Soil to exposed vegetable transfer factor	TFexp	unitless	NA	NA	0.036	0.036	NA	NA	NA	NA	0.0018	0.0018
Soil to fruit transfer factor	TFfruit	unitless	NA	NA	NA	NA	NA	NA	NA	NA	0.0018	0.0018
Soil to root vegetable transfer factor	TFroot	unitless	NA	NA	NA	NA	NA	NA	NA	NA	0.0003	0.0003
Animal Diet Composition												
Fraction of diet that is soil	Dsoil	unitless	NR	NR	0.02	0.02	0.1	0.1	0.1	0.1	NA	NA
Fraction of diet that is corn silage	Dsil	unitless	0.55	0.55	0.44	0.44	NR	NR	NR	NR	NA	NA
Fraction of diet that is grass	Dgrass	unitless	NR	NR	0.44	0.44	NR	NR	NR	NR	NA	NA
Bioavailability from soil	BAsoil	unitless	NR	NR	1	1	1	1	1	1	NA	NA
Animal Bioconcentration												
Mammalian BCF (fat basis)	BCFmammal	unitless	3.6	3.6	3.6	3.6	NA	NA	NA	NA	NA	NA
Avian BCF (fat basis)	BCFpoultry	unitless	NA	NA	NA	NA	2.5	2.5	NA	NA	NA	NA
Avian BCF (whole food basis)	BCFegg	unitless	NA	NA	NA	NA	NA	NA	0.9	0.9	NA	NA
Animal Product Lipid Content												
Lipid content of milk	LCmilk	mg fat/mg whole food	0.046	0.046	NA	NA	NA	NA	NA	NA	NA	NA
Lipid content of beef	LCbeef	mg fat/mg whole food	NA	NA	0.099	0.146	NA	NA	NA	NA	NA	NA
Lipid content of poultry meat	LCpoultry	mg fat/mg whole food	NA	NA	NA	NA	0.0741	0.136	NA	NA	NA	NA
Lipid content of egg	LCegg	mg fat/mg whole food	NA	NA	NA	NA	NA	NA	1	1	NA	NA

Notes:
CTE = central tendency exposure
EPA = United States Environmental Protection Agency
mg = milligram
NA= not applicable to scenario
NR = not relevant to scenario based on local farming practices
RME = reasonable maximum exposure

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Table 3-6 – Exposure Assumptions Used By EPA for Agricultural Exposure Pathways at Backyard Farms

Exposure Assumptions	Acronym	Units	Dairy		Beef		Poultry Meat		Poultry Eggs		Produce	
			CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Soil to Plant Modeling												
Soil to corn silage transfer factor	SCTF	unitless	NR	NR	NR	NR	NR	NR	NR	NR	NA	NA
Soil to grass transfer factor	SGTF	unitless	0.036	0.036	0.036	0.036	NR	NR	NR	NR	NA	NA
Soil to exposed vegetable transfer factor	TFexp	unitless	NA	NA	NA	NA	NA	NA	NA	NA	0.0018	0.0018
Soil to fruit transfer factor	TFfruit	unitless	NA	NA	NA	NA	NA	NA	NA	NA	0.0018	0.0018
Soil to root vegetable transfer factor	TFroot	unitless	NA	NA	NA	NA	NA	NA	NA	NA	0.0003	0.0003
Animal Diet Composition												
Fraction of diet that is soil	Dsoil	unitless	0.01	0.01	0.02	0.02	0.1	0.1	0.1	0.1	NA	NA
Fraction of diet that is corn silage	Dsil	unitless	NR	NR	NR	NR	NR	NR	NR	NR	NA	NA
Fraction of diet that is grass	Dgrass	unitless	0.59	0.59	0.98	0.98	NR	NR	NR	NR	NA	NA
Bioavailability from soil	BAsoil	unitless	1	1	1	1	1	1	1	1	NA	NA
Animal Bioconcentration												
Mammalian BCF (fat basis)	BCFmammal	unitless	3.6	3.6	3.6	3.6	NA	NA	NA	NA	NA	NA
Avian BCF (fat basis)	BCFpoultry	unitless	NA	NA	NA	NA	2.5	2.5	NA	NA	NA	NA
Avian BCF (whole food basis)	BCFegg	unitless	NA	NA	NA	NA	NA	NA	0.9	0.9	NA	NA
Animal Product Lipid Content												
Lipid content of milk	LCmilk	mg fat/mg whole food	0.046	0.046	NA	NA	NA	NA	NA	NA	NA	NA
Lipid content of beef	LCbeef	mg fat/mg whole food	NA	NA	0.099	0.146	NA	NA	NA	NA	NA	NA
Lipid content of poultry meat	LCpoultry	mg fat/mg whole food	NA	NA	NA	NA	0.0741	0.136	NA	NA	NA	NA
Lipid content of egg	LCegg	mg fat/mg whole food	NA	NA	NA	NA	NA	NA	1	1	NA	NA

Notes:
CTE = central tendency exposure
EPA = United States Environmental Protection Agency
mg = milligram
NA= not applicable to scenario
NR= not relevant to scenario based on local farming practices
RME = reasonable maximum exposure

Table 4-1 – Initial Screening of Technologies for In-River Sediment

General Response Action	Remedial Technology	Description	Screening Based on Technical Implementability
No Action	No Action	Ongoing natural attenuation of PCBs in sediment, with no active or passive remediation and no associated long-term monitoring or controls.	Retained.
Engineering/ Institutional Controls	Engineering/ Institutional Controls	Implementing physical, legal, and/or administrative controls to limit potential exposure to PCBs in sediment.	Retained.
Monitored Natural Recovery (MNR)	MNR	Monitoring the natural physical, chemical, and/or biological processes that contain, destroy, or reduce the bioavailability or toxicity of chemical constituents in sediment.	Retained.
	Enhanced MNR	Accelerating the natural recovery process by engineering means, such as placement of a thin layer of clean sediment, or construction of dams or other engineered structures to alter the rate of sedimentation in portions of the River.	Retained.
Removal	Dredging	Physically removing PCB-containing sediment via dredging. Dredging may be performed using mechanical or hydraulic dredging techniques.	Retained.
In Situ Containment	Capping	Placing a clean layer of isolating material (e.g., clean sand, gravel cobbles, sorbents, geofabrics, etc.) over sediment to contain and stabilize the PCB-containing sediment and to sequester those sediments from the biologically active zone within the sediment bed and from the overlying water column.	Retained.
	Rechannelization	Permanently redirecting the river into a newly constructed channel and covering/isolating the material in the original channel in place.	Retained.
In Situ Treatment	Physical	Injecting and/or mixing an immobilization agent into the sediment, to reduce the mobility of PCBs in the sediment.	Not retained. *In situ* process not yet sufficiently developed for sediment or successfully implemented full-scale for PCBs. EPA's December 2005 *Contaminated Sediment Remediation Guidance* states that "[t]he lack of an effective delivery system … has hindered the application of in-situ stabilization systems." Also, there is a lack of good process controls, particularly for mixing conditions and curing temperatures encountered with in-place sediments (Kita and Kubo, 1983). The lack of adequate process controls has relegated use to instances when the contaminated sediment can be isolated from the water body (Board on Environmental Studies and Toxicology, 2001).

Table 4-1 – Initial Screening of Technologies for In-River Sediment

General Response Action	Remedial Technology	Description	Screening Based on Technical Implementability
In Situ Treatment (cont'd)	Chemical	Injecting chemical surfactants/solvents or oxidants into the treatment area to remove or destroy PCB constituents.	Not retained. Technology has not been demonstrated full-scale for PCBs in sediment. EPA's December 2005 *Contaminated Sediment Remediation Guidance* states that "most techniques for in-situ [chemical] treatment of sediments are in the early stages of development…" Developing an effective *in situ* delivery system for reagents has been problematic. While some studies are underway, the projects remain in the research stages and have not been applied full-scale (Hong and Hayes, 2006; Mikszewski, 2004).
	Biological	Introducing microorganisms and/or nutrients into the treatment zone to increase ongoing biodegradation rates of PCBs in sediment.	Not retained. Not yet successfully implemented full-scale for PCBs. Effective delivery of reagents to the sediment has not been successfully demonstrated. Studies by GE on anaerobic biodegradation of PCBs in Housatonic River sediments have not achieved significant reductions in PCB concentrations (Bedard et al., 1995, 1998). Poor performance of *in situ* biological remediation often results from the key contaminants not being bioavailable to microorganisms and from preferential feeding by microorganisms on substrates other than the target compounds (Renholds, 1998).

Notes:
Shading indicates that the remedial technology has not been retained for further evaluation at this time based on currently available information.
EPA = United States Environmental Protection Agency
PCBs = polychlorinated biphenyls
ppm = parts per million

Table 4-2 – Secondary Screening - Evaluation of Process Options for In-River Sediment

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
A. No Action					
No Action	No Action	No remedial measures or monitoring conducted. Would take account of changing conditions through the ongoing natural attenuation of PCBs in sediments.	Appropriate for areas that already meet cleanup goals. In other areas, ongoing natural recovery processes (e.g., dispersion, silting-over with cleaner sediments) may somewhat reduce the potential for human and/or ecological exposure to PCBs in sediment over time. No monitoring performed to track effectiveness.	Readily implementable.	Retained per NCP and for comparison to other options.
B. Engineering/Institutional Controls					
Engineering/ Institutional Controls	Physical Access Restrictions	Constraints, such as fencing and signs, placed along River to limit access.	Would reduce potential for human exposure to PCBs in sediments. Could be used during remedy implementation and, potentially in some areas, on a longer-term basis. Would require routine monitoring and maintenance.	Readily implementable. Materials, personnel, and equipment are readily available. Would require property owner agreement.	Retained.
	Activity Restrictions on Fishing and/or Hunting	Restrictions, such as catch-and-release fishing restrictions and/or restrictions on certain types of waterfowl hunting, put in place along the River to prohibit or limit such activities.	Would reduce potential for human exposure to PCBs through ingestion of fish or waterfowl containing PCBs.	Implementable through fishing and hunting license programs. Would require coordination with the appropriate agencies.	Retained.
	Biota Consumption Advisories	Advisories established/maintained to limit biota consumption. Would include advisory brochures and posting of signs along the river.	Would reduce potential for human exposure to PCBs through ingestion of fish or other biota containing PCBs. Would require routine monitoring and maintenance of signs.	Readily implementable, already in place. Would require coordination with appropriate agencies.	Retained.

Table 4-2 – Secondary Screening - Evaluation of Process Options for In-River Sediment

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
C. Monitored Natural Recovery (MNR)					
MNR	MNR	Monitoring of natural physical, chemical, and/or biological processes that are continuing to break down or sequester PCBs in sediments.	Reductions in potential exposure to human and ecological receptors would continue to occur through natural processes over time (e.g., dispersion, silting-over with cleaner sediments). Natural recovery processes have been observed in Rising Pond and portions of Woods Pond. Monitoring would be performed to track effectiveness and rate of recovery.	Readily implementable and minimally intrusive. Activities would be limited to river sampling from a boat and/or shoreline. Access, materials, personnel, and equipment are readily available.	Retained.
Enhanced MNR	Enhanced Sedimentation	Constructing dams or other engineered structures to alter the rate of sedimentation in portions of the River and increase the rate of natural recovery.	Would reduce potential for human and/or ecological exposure to PCBs in sediment over time. Effectiveness dependent upon hydraulic conditions created and loading rates and quality of sediment deposited. Greatest effectiveness in low-energy aquatic environments (e.g., impoundments). Would require long-term maintenance.	Technically implementable, but could alter local habitat and River use. Administrative issues would arise due to impacts on surface water elevations and flood impacts, which could affect compliance with applicable substantive requirements. Potential flooding resulting from installation of structure(s) could affect community acceptance.	Not retained. This option would require flooding of adjacent land areas, could negatively impact local habitat and recreational uses, and would likely involve significant administrative constraints.
	Thin-Layer Capping	Placing a thin layer (a few inches) of clean material over the sediment to provide reduction of sediment PCB concentrations in biologically active zone and to accelerate natural recovery.	Would reduce potential for human and/or ecological exposure to PCBs in sediment. Greatest effectiveness in low-energy aquatic environments. Can provide a base for sustained long-term reduction in surficial PCB concentrations. May require long-term monitoring.	Readily implementable. Equipment, materials, and personnel are readily available.	Retained.

Table 4-2 – Secondary Screening - Evaluation of Process Options for In-River Sediment

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
D. Sediment Removal					
Dredging	Mechanical Dredging in the Wet	Removing PCB-containing sediment using conventional earthmoving equipment (e.g., clamshell bucket) through the water column.	Would reduce potential long-term exposure to human and ecological receptors through removal of PCB-containing sediments, but may increase short-term exposure due to resuspension and release of PCBs during removal process. Also, difficulties have been noted in achieving consistently low residual PCB concentrations. Would disturb upper sediments and expose deeper sediments, which may be more contaminated. May still need to cap in some areas after removal.	Technically implementable in areas where access to sediments is feasible using land- or barge-based equipment. Important that removal areas be capable of being adequately contained using resuspension controls. Equipment, materials, and personnel are readily available. Would require necessary access permissions.	Retained.
	Mechanical Dredging in the Dry	Removing PCB-containing sediment using conventional earthmoving equipment (e.g., excavator) after dewatering the removal area (e.g., via pump bypass, rechannelization, sheetpiling diversion, etc.).	Would reduce potential exposure to human and ecological receptors through removal of PCB-containing sediments. Allows greater removal precision than dredging through water column. Difficulties have been noted in achieving low residual PCB concentrations in surface sediments without complete dewatering of river bottom or when NAPL is present. Potential for PCB release during flooding events. May still need to cap in some areas after removal. Implemented in Upper ½-Mile and 1½-Mile Reaches of the River.	Technically implementable in areas that can be contained/dewatered and where access to sediments is feasible using land-based equipment or equipment in dewatered area. Equipment, materials, and personnel are readily available. Would require necessary access permissions.	Retained.

Table 4-2 – Secondary Screening - Evaluation of Process Options for In-River Sediment

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
D. Sediment Removal (cont'd)					
Dredging (cont'd)	Hydraulic Dredging	Removing and transporting sediment in a liquid slurry form using a hydraulic pump or compressed air (e.g., horizontal auger, cutterhead dredge, PNEUMA pump, etc).	Would reduce potential long-term exposure to human and ecological receptors through removal of PCB-containing sediments, but may increase short-term exposure due to resuspension/release of PCBs during dredging. Difficulties have been noted in achieving low residual PCB concentrations in surface sediments, especially when debris is present and as result of resuspension/ redeposition of finer grained sediments. Effectiveness could be limited by presence of debris, and thus mechanical dredging may be required as an initial step. May still need to cap in some areas after removal.	Technically implementable in areas where access to the sediments is feasible, water depths and velocities are adequate to support dredge movement and use, and a sufficiently large area is available to support sediment storage/dewatering operations). Important that removal areas be capable of being adequately contained using resuspension controls. Equipment, materials, and personnel are readily available. Would require necessary access permissions.	Retained.
E. *In Situ* Containment					
Capping	*In Situ* Capping	Placing a clean subaqueous cover material over sediments containing PCBs, with a thickness suitable to create a clean bioavailable zone. Where necessary, may include a sorptive media (e.g., organic carbon, organoclay) and/or physical barrier (e.g., an impermeable geofabric, clay, AquaBlok™) sufficient to reduce the flux of PCB to the water column. Can be used by itself or after initial removal of sediments.	Would reduce the long-term potential exposure to human and ecological receptors by providing a clean cover over the PCB-containing sediments, and (where necessary) providing sorptive capacity to sequester PCBs in groundwater which have the potential to migrate upward through the cap. Post-construction maintenance and/or monitoring would be required. Implemented in the Upper ½-Mile Reach (in conjunction with removal).	Implementable. Capping by itself is most readily implementable in deeper, lower-energy reaches of the river. Implementation in shallower, higher-energy environments may require some sediment removal prior to capping to address flood storage concerns and support future river uses. Equipment, materials, and qualified personnel needed are available. Would require access agreements from the property owners adjacent to the areas of the river to be capped.	Retained.

Table 4-2 – Secondary Screening - Evaluation of Process Options for In-River Sediment

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
E. *In Situ Containment* (cont'd)					
Rechanneliza-tion	Rechanneliza-tion	Permanently redirecting the River into a newly constructed channel, containing the material in the original channel in place (i.e., by covering), and restoring the channel to surrounding grade.	Would reduce potential exposure to human and ecological receptors to PCBs through constructing a new channel and backfilling the channel under several feet of clean material. Would require long-term monitoring and maintenance, as well as deed restrictions related to materials remaining in existing channel.	Technically implementable in river reaches where property is available and river configuration is conducive to rechannelization (e.g., oxbows). Equipment, materials, and personnel are readily available. Would need to acquire sufficient tracts of land for rechannelization and obtain agreements from those property owners.	Not retained for further evaluation as a large-scale or site-wide remedial alternative due primarily to the administrative hurdles relative to the other i*n situ* containment options. Retained for potential use in certain stretches (e.g., oxbow areas) where it could be more implementable.

Notes:
Shading indicates not retained as representative process option based on currently available information; however, this does not preclude them from future consideration/use, as new information becomes available.
NCP = National Contingency Plan
PCBs = polychlorinated biphenyls

Table 4-3 – Initial Screening of Technologies for In-Place Erodible Riverbank Soil

General Response Action	Remedial Technology	Description	Screening Based on Technical Implementability
No Action	No Action	Ongoing natural attenuation of PCBs in riverbank soil, with no active remediation of the riverbanks.	Retained.
Removal and Replacement	Excavation	Physically removing PCB-containing riverbank soil followed by backfilling/regarding of the riverbank with clean soil.	Retained.
Stabilization	Bank Stabilization	Armoring or isolating the riverbank soil to prevent erosion and reduce the potential mobility of PCBs from the riverbank soil.	Retained.

Notes:
Shading indicates that the remedial technology has not been retained for further evaluation at this time based on currently available information.
PCBs = polychlorinated biphenyls

Table 4-4 – Secondary Screening - Evaluation of Process Options for Erodible In-Place Riverbank Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
A. No Action					
No Action	No Action	No remedial measures or monitoring conducted.	Appropriate for areas without significant erosion and/or for areas where PCB levels of concern are not present in erodible bank materials. For erodible areas, would not stop continued erosion.	Readily implementable.	Retained per NCP and for comparison to other options.
B. Removal and Replacement					
Excavation	Mechanical	Excavating PCB-containing soils using conventional earthmoving equipment (e.g., excavators), backfilling select excavated areas with clean material, and stabilizing the riverbank using erosion-resistant measures.	Would reduce amount of PCB-containing material eroding into the River through removal. Would need to replace excavated soil as necessary and would likely require armoring over some backfill areas. Implemented in Upper ½-Mile and 1½-Mile Reaches of the River. May require long-term monitoring and maintenance.	Implementable. Equipment, materials and personnel are readily available. Potential difficulties include implementation on steep banks and in forest and wetland areas and remote areas not accessible by serviceable roadways.	Retained.
C. Erosion Control					
Bank Stabilization	Armor Stone	Placing stones on the riverbank to create a barrier to destructive flow or wave action. The size or weight of the armor stone is determined by the flow, wave, or ice forces expected at the location of the structure. May include a goesynthetic separation layer and /or temporary structures to provide dry work environment or reduce potential for dispersing suspended solids.	Could significantly reduce potential erosion through isolation of PCB-containing riverbank soils. Implemented in Upper ½-Mile and 1½-Mile Reaches of the River. Would require long-term monitoring and maintenance.	Implementable, but may require some bank soil removal before placing armor stone. Armor stone is quickly installed from either land or water, and is adaptable to a wide variety of shoreline conditions. May require a filter layer of gravel or crushed stone to prevent intermixing of bank soil with the armor layer. Equipment, materials, and personnel are readily available. Potential difficulties include work in forest and wetland areas and possible access issues in certain areas.	Retained.

Table 4-4 – Secondary Screening - Evaluation of Process Options for In-Place Riverbank Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
C. Erosion Control (cont'd)					
Bank Stabilization (cont'd)	Revetment Mats	Placing double layers of woven fabric forms filled with concrete or grout, reno mattresses (stone-filled wire baskets), or cellular (cabled) concrete mats on the slope to be protected. The size or weight of the revetment mats would be based on calculated flow, wave, and/or ice forces expected at the location of the bank stabilization structure. Could include an anchoring mechanism to keep the revetment mat in place, a geosynthetic separation layer or gravel filter layer, and/or the placement of a temporary structure to reduce the potential for dispersing suspended solids.	Could significantly reduce potential erosion through isolation of PCB-containing riverbank soils. Construction of these measures may temporarily affect vegetation and benthic communities, but impacts would be mitigated over time. Would require long-term monitoring and maintenance.	Implementable, but may require some bank soil removal before placing revetment mats. A simple, fast, and economical technique for the placement of concrete for slope protection both above and below the water without the need for dewatering. Equipment, materials, and personnel are readily available. Potential difficulties include work in forest and wetland areas and possible access issues in certain areas.	Retained.
	Retaining Walls	Constructing a retaining wall (e.g., sheetpile, timber, concrete) along the riverbank to stabilize and protect the bank from erosion. Would be designed to create a rigid barrier for earth and water while resisting the lateral pressures imposed by the riverbank soils.	Could significantly reduce potential erosion through isolation of PCB-containing riverbank soils behind the walls. Implemented in Upper ½-Mile Reach of the River (steel sheeting). Greatest effectiveness for high, steep banks. Would require long-term monitoring and maintenance.	Implementable. Equipment, materials, and personnel are readily available. May require soil removal to remove bank soil located on the river side of the wall. May need to address any associated loss in flood storage capacity related to installation. Would result in the loss of bank habitat. Other potential difficulties include implementation in forest and wetland areas, possible access issues in certain areas, the need for potentially significant ongoing maintenance, and potential safety issues depending on the height of the wall. Also this option has higher cost than other stabilization techniques.	Not retained due to availability of other bank stabilization process options with wider applicability and lower costs.

Table 4-4 – Secondary Screening - Evaluation of Process Options for In-Place Riverbank Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
Bank Stabilization (cont'd)	Gabions	Using mesh containers that are filled with crushed stone to form flexible structures such as retaining walls, seawalls, and channel linings. May include a goesynthetic or gravel separation layer and /or temporary structures to provide dry work environment or reduce potential for dispersing suspended solids. The permeability and flexibility of gabions make them suitable where the retained material is likely to be saturated and where the bearing quality of the soil is poor.	Could significantly reduce potential erosion through isolation of PCB-containing riverbank soils. Implemented in 1½-Mile Reach of the River. Greatest effectiveness for low, steep banks. Would require long-term monitoring and maintenance.	Implementable. Equipment, materials, and personnel are readily available. Potential difficulties include work in forest and wetland areas and possible access issues in certain areas.	Not retained due to availability of other bank stabilization process options with wider applicability and lower costs.

Notes:
Shading indicates not retained as representative process option based on currently available information; however, this does not preclude them from future consideration/use, as new information becomes available.
NCP = National Contingency Plan
PCBs = polychlorinated biphenyls

Table 4-5 – Initial Screening of Technologies for In-Place Floodplain Soil

General Response Action	Remedial Technology	Description	Screening Based on Technical Implementability
No Action	**No Action**	**Ongoing natural attenuation of PCBs in floodplain soil, with no active or passive remediation or monitoring performed.**	**Retained.**
Engineering/ Institutional Controls	Engineering/ Institutional Controls	Implementing physical, legal, and/or administrative controls to limit potential exposure to PCBs in soil by humans and/or ecological receptors.	Retained.
Monitored Natural Recovery (MNR)	MNR	Monitoring the natural processes (primarily physical) that contain or reduce the bioavailability of PCBs in floodplain soil.	Retained.
Removal and Replacement	Excavation	Physically removing PCB-containing floodplain soil followed by backfilling as necessary, with clean soil. Typical excavating equipment would include backhoes and bulldozers.	Retained.
In Situ Containment	Capping	Placing material (e.g., clean soil or sand, geofabrics, etc.) over PCB-containing floodplain soil to mitigate potential exposure for human and ecological receptors.	Retained.
In Situ Treatment	Physical Immobilization	Mixing an immobilization agent into the floodplain soil to reduce the potential mobility of PCBs in the floodplain soil.	Retained.
	Biological	Introducing microorganisms and/or nutrients into the treatment zone to increase ongoing biodegradation rates of PCBs in floodplain soil.	Not retained. Not successfully implemented full scale for PCBs (i.e., resulting in significant reduction in PCB concentration). While aerobic and anaerobic biodegradation of PCBs are known to occur both naturally and through enrichment, no processes or sites were identified where significant reductions in PCB concentrations have been documented due to biological treatment. Problems have been noted with design of an effective nutrient delivery and containment system for materials injected or mixed into the soils to promote degradation (Renholds, 1998).
	Chemical	Injecting chemical surfactants/solvents or oxidants into the treatment area to remove or destroy PCB constituents.	Not retained. Not well suited for shallow *in situ* floodplain soils spread over a relatively large area. Not successfully implemented full scale for PCBs. Problems have been noted with design of an effective chemical delivery and containment system for materials injected or mixed into the soils to promote degradation (Renholds, 1998). EPA has noted that while injecting chemical surfactants/solvents to treat soils is common in oil field applications, "it has found limited application in the environmental arena" (EPA, 2006). When using oxidants for *in situ* chemical treatment, the effectiveness can be greatly affected by site stratigraphy, soil oxidant demand, and pH. Chemical oxidation usually requires multiple applications, and some unreacted oxidants may remain in the subsurface (EPA, 2006).

Table 4-5 – Initial Screening of Technologies for In-Place Floodplain Soil

General Response Action	Remedial Technology	Description	Screening Based on Technical Implementability
In Situ Treatment (cont'd)	Thermal	Heating PCB-containing soil to remove and/or destroy PCBs.	Not retained. Not well suited for shallow *in situ* floodplain soils spread over a relatively large area. Not successfully implemented full scale for PCBs. Thermal treatment would require installation of numerous electrodes and/or injection/extraction wells to allow for sufficient coverage. If thermal treatment were applied to the floodplain soils at temperatures sufficient to volatilize or destroy the PCBs, the soils would need to be amended with nutrients or removed/covered with new soil (if vitrified) following treatment to support vegetative growth.

Notes:
Shading indicates that the remedial technology has not been retained for further evaluation at this time based on currently available information.
PCBs = polychlorinated biphenyls
ppm = parts per million

General Electric Company
Housatonic River – Rest of River
CMS Proposal

Table 4-6 – Secondary Screening - Evaluation of Process Options for In-Place Floodplain Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
A. No Action					
No Action	No Action	No remedial measures or monitoring conducted.	Appropriate for areas that already meet cleanup goals, areas where potential human exposure is not reasonably anticipated, and areas where the damages anticipated due to remediation outweigh the potential benefits. In other areas, reductions in potential exposure to human and ecological receptors would only occur through natural recovery processes (e.g., covering of affected soils through deposition of cleaner material). No monitoring performed to track effectiveness.	Readily implementable.	Retained per NCP and for comparison to other options.
B. Engineering/Institutional Controls					
Engineering/ Institutional Controls	Access Restrictions	Physical constraints, such as fencing and signs, placed around a floodplain area containing PCBs to limit access.	Would reduce potential human and ecological exposure to PCBs in floodplain soil. Could be used during implementation of remedial actions and, in some instances, on a longer-term basis. Would require monitoring and maintenance.	Technically and administratively implementable. Would require property owner agreement.	Retained.
	Land Use Restrictions	Legal constraints, such as EREs, placed on properties to reduce the potential for human exposure to PCBs in floodplain soil. May include restrictions on future changes to different types of land use (e.g., to residential use) and on future activities (e.g., excavation).	Would reduce potential for human exposure to PCB-containing floodplain soils. Would require monitoring and maintenance. Implemented at non-Rest of River portions of the GE-Pittsfield/Housatonic River Site.	Technically and administratively implementable. Would require property owner agreement.	Retained.
	Conditional Solutions	A Conditional Solution requires GE to conduct remediation to achieve the applicable standards for the property's current use (if necessary) and to agree to conduct additional remediation in the future to address actual changes in the property's use, if necessary and if the property owner meets certain conditions.	Would effectively protect human health. Has been effectively used at the non-Rest of River portions of the GE-Pittsfield/ Housatonic River Site. Long-term monitoring would be required.	Technically and administratively implementable.	Retained.
	Consumption Advisories	Advisories established/maintained to limit consumption of certain biota or agricultural products. Already in place for frogs, turtles, and/or ducks along certain portions of the River.	Would reduce potential for human exposure by placing restrictions on the uptake of certain biota and agricultural products.	Readily implementable. Commonly used throughout nation. Would require minimal activities, equipment, and personnel. Would require coordination with appropriate agencies. Would require adequate signage, brochures, etc.	Retained.

Table 4-6 – Secondary Screening - Evaluation of Process Options for In-Place Floodplain Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
C. Monitored Natural Recovery (MNR)					
MNR	MNR	Reliance on ongoing, naturally occurring processes to contain or reduce the bioavailability of PCBs in soils, with long-term monitoring to assess the rate of recovery or attenuation. Physical processes such as natural burial via deposition with cleaner material would likely be the predominant recovery mechanism.	Could be effective at reducing potential exposure to human and ecological receptors over time. Long-term monitoring would be performed to evaluate the extent to which and rate at which ongoing natural attenuation processes are effectively achieving remedial goals.	Readily implementable. Personnel and equipment are readily available. Work could be performed with minimal intrusive activity at affected properties.	Retained for potential applicability in areas with PCBs slightly above target goals, difficult-to access areas, and/or areas with unique or sensitive habitat.
D. Removal					
Excavation and Replacement	Mechanical	Removing material using conventional earthmoving equipment (e.g., excavators) and backfilling the excavated area with clean material. Dewatering may be required in some locations.	Would significantly reduce potential exposure to human and ecological receptors through removal of PCB-containing floodplain soils. Implemented in floodplain adjacent to Upper ½-Mile and 1½-Mile Reaches of the River. Would need to replace excavated soil as necessary.	Implementable in most areas. Equipment, materials, and personnel are readily available. May be difficult to implement in forest and wetland areas and remote areas not accessible by serviceable roadway. Would need access permission from property owners.	Retained.
E. *In-Situ* Containment					
Capping	Cover (Soil or Pavement)	Placing soil fill and topsoil or pavement over the PCB-containing floodplain soil to provide a barrier to contact. May require clearing, grubbing, and site grading prior to cover placement.	Could significantly reduce potential exposure to human and ecological receptors. Would require post-construction institutional controls and monitoring.	Implementable in most areas. Soil removal may be required prior to placement to maintain flood storage. Equipment, materials, and personnel are readily available. Would need access permission from property owners.	Retained.
	Engineered Barrier	Placing multiple layers of cover material over the underlying soil, which include an impermeable layer and may include a combination of sand, gravel, clay, geosynthetics, asphalt and/or topsoil with vegetation planted on the top. Barrier would be designed to isolate and contain underlying soils, prevent direct contact, and minimize potential for PCB migration. May require clearing, grubbing, and site grading prior to barrier placement.	Could significantly reduce potential exposure to human and ecological receptors through isolation of PCB-containing floodplain soils. Would require institutional controls and long-term monitoring and maintenance.	Implementable in most areas. Soil removal may be required prior to placement to maintain flood storage. Venting may be required to prevent gas buildup if covering over decaying vegetation. Equipment, materials, and personnel are readily available. Would need access permission from property owners.	Retained.

Table 4-6 – Secondary Screening - Evaluation of Process Options for In-Place Floodplain Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
E. *In-Situ* Containment (cont'd)					
Physical	Immobilization	Mixing floodplain soils *in situ* with Portland cement, activated carbon, fly ash, or other stabilization agent to reduce bioavailability of PCBs in soil.	Could reduce the bioavailability of PCBs in floodplain soil, thereby reducing the potential for human or ecological exposure. Would require treatability testing to determine site-specific effectiveness. Problems/challenges include volume increase and freeze/thaw integrity issues. May require that a soil cover be placed over the treated material to sustain vegetation and provide habitat for floodplain organisms. Would require a long-term monitoring and maintenance plan.	Technically implementable. Specialized equipment, materials, and operating personnel are available. However, may not be administratively implementable. May not be compatible with current or future uses of floodplain. May create flood storage issues due to volume expansion. May be difficult to obtain property owner permission in certain areas. Not well suited for large, shallow-depth application.	Not retained. *In situ* immobilization may not be compatible with floodplain habitat or agricultural use and potential future uses of floodplain areas. In addition, resulting volume increase could result in flood storage issues and potential freeze/thaw integrity issues. Option is best suited for deeper applications within a relatively small footprint (rather than a large, shallow-depth application such as the floodplain soils).

Notes:
Shading indicates not retained as representative process option based on currently available information; however, this does not preclude them from future consideration/use, as new information becomes available.
EREs = Environmental Restrictions and Easements
NCP = National Contingency
PCBs = polychlorinated biphenyls

Table 4-7 – Initial Screening of Technologies for Management of Removed Sediment and Soil

General Response Action	Remedial Technology	Description	Screening Based on Technical Implementability
Solids Dew`atering	Mechanical	Pumping or feeding slurry of dredged material through a filtration device or subjected to centrifugal forces for dewatering purposes. Examples of mechanical dewatering equipment include: belt filter press, plate and frame filter press, and solid-bowl (centrifuge) equipment.	Retained.
	Gravity	Allowing removed sediment and soil to settle and consolidate on a lined, bermed pad and/or in a tank, basin, or other device.	Retained.
Ex Situ Treatment	Physical	Physically stabilizing the removed materials through mixing immobilization agents, and/or separating PCB-containing solids via particle separation.	Retained.
	Biological	Landfarming or amending sediment/soil to enhance the biodegradation of PCBs using microorganisms and nutrients in an aerobic or anaerobic environment.	Not retained. *Ex situ* biological treatment approaches have been field tested extensively by GE and others. No processes have been identified that have successfully demonstrated significant reductions in PCBs, nor was any full-scale application of *ex situ* biological treatment to remediate PCBs in sediment or soil noted. In general, this process is slow and labor intensive, and full-scale implementation would require use of large tracts of land for set-up and operation.
	Chemical	Mixing chemical surfactants/solvents with excavated PCB-containing sediment/soil to remove or destroy PCBs. Removed PCBs would require treatment/disposal.	Retained.
	Thermal	Heating PCB-containing sediment/soil to remove and/or destroy PCBs.	Retained.
Local Disposal	Confined Disposal Facility (CDF)	Placing PCB-containing sediment/soil in a disposal facility constructed within a water body.	Retained.
	Upland Disposal	Placing PCB-containing sediment/soil in an upland disposal facility located or constructed in close proximity to the River.	Retained.
Off-site Disposal	Off-site Disposal	Transporting PCB-containing sediment/soil to an off-site permitted facility for disposal.	Retained.
Beneficial Reuse	Beneficial Reuse	Using treated material in beneficial ways, such as cover material for solid waste landfills, or converting it into useable products such as cement, light weight aggregate, or glass tile.	Not retained. To date, few dredged sediment sites have used beneficial reuse, mainly due to the lack of cost-effective uses (EPA, 2005e). No sites have been identified where a beneficial reuse technology was successfully applied full-scale to treat sediments or soils with PCB concentrations comparable to those in Rest of River. It is unlikely that a significant portion of the treated site materials would have PCB content low enough to be candidates for beneficial reuse.

Notes:
Shading indicates that the remedial technology has not been retained for further evaluation at this time based on currently available information.
PCBs = polychlorinated biphenyls

Table 4-8 – Secondary Screening - Evaluation of Process Options for Management of Removed Sediment and Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
A. Solids Dewatering (primarily applicable to sediments)					
Mechanical	Belt Filter Press	Slurry drops onto a perforated belt where gravity drainage takes place. Thickened solids are pressed between a series of rollers to further dewater solids.	Reliable. May require pretreatment to enhance dewatering.	Implementable. Equipment, materials, and operating personnel are available. Would require treatability testing prior to implementation. May require large tract of land.	Not retained. Generally does not achieve cake solids concentrations as high as plate and frame press and is thus less efficient.
	Plate and Frame Filter Press	Slurry is pumped into cavities formed by a series of plates covered by a filter cloth. Liquids are forced through filter cloth and dewatered solids collected in the filter cavities.	Reliable, with proper pre-treatment steps. May require pretreatment to enhance dewatering. Generally, plate and frame presses achieve lower water contents in solids cake than belt filter presses.	Implementable. Equipment, materials, and operating personnel are available. Would require treatability testing prior to implementation. May require large tract of land.	Retained.
	Solid Bowl (Centrifuge)	Slurry is fed through a central pipe that sprays into a rotating bowl. Centrate discharges out of the large end of the bowl and solids are removed from tapered end of the bowl by means of a screw conveyer.	Historically, process has required frequent maintenance and often experienced operational difficulties. Cake solids are typically lower than those attained by filter presses.	Implementable for certain types of sediments. Centrifuge operation is not efficient when feed composition is variable. Equipment, materials, and operating personnel are available.	Not retained. The variability of sediment /soil composition could make this process difficult to control, and it produces lower cake solids than other options.
	Evaporator	Excess water is evaporated from slurry.	Reliable. May require pretreatment to enhance dewatering.	Potentially implementable, but likely not practical. May produce drier cake than required, and has higher cost than other mechanical dewatering options. Not usually employed for sediments.	Not retained due to higher energy requirement and higher cost than other dewatering process options.
Gravity Settling	Stockpile	Material is placed in a stockpile, and free liquids are allowed to drain off and are collected.	Reliable. Already implemented in upstream reaches. Effectiveness primarily applies to mechanically dredged sediments.	Implementable. Equipment, materials, and operating personnel are readily available. Would require adequate space for dewatering structures and agreement with landowner.	Retained.

Table 4-8 – Secondary Screening - Evaluation of Process Options for Management of Removed Sediment and Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
A. Solids Dewatering (primarily applicable to sediments) (cont'd)					
Gravity Setting (cont'd)	Thickener	Slurry enters thickener and settles into circular tank. Sediment thickens and consolidates at the bottom of the tank. Pretreatment with chemical addition used to enhance settleability.	May be effective when used as a pre-treatment step in conjunction with other dewatering technologies. A site-specific study would be required to verify effectiveness.	Implementable. Equipment, materials, and operating personnel are available. Would require adequate space for dewatering structures and agreement with landowner.	Not retained since stockpiling (retained as the representative process option) requires less space and is less expensive. May be used as a component of other processes.
	Settling Basin	Slurry enters settling basin and is allowed to settle, drain, and consolidate in bottom. Pretreatment with chemical addition used to enhance settling.	May be effective when used as a pre-treatment step in conjunction with other dewatering technologies. A site-specific study would be required to verify effectiveness.	Implementable. Equipment, materials, and operating personnel are readily available. Would require adequate space for dewatering structures and agreement with landowner.	Not retained since stockpiling (retained as the representative process option) requires less space and is less expensive. May be used as a component of other processes.
	GeoTubes	Slurry is pumped into fabric tubes, and consolidates as liquids are forced out. The liquids are collected, and the consolidated solids are removed from the tubes for subsequent management. Polymer addition is a critical component.	Effectiveness primarily limited to hydraulically dredged sediments. A site-specific study would be required to verify effectiveness. System has been used for hydraulically dredged sediments with PCBs from the Fox River and Grasse River, but issues have been noted.	Implementable. Equipment, materials, and operating personnel are available. Would require adequate space for dewatering structures and agreement with landowner.	Not retained since stockpiling (retained as the representative process option) requires less space and is less expensive. Could be considered if hydraulic dredging were employed.
B. *Ex Situ* Treatment					
Physical	*Ex Situ* Stabilization/ Solidification	Mixing the removed materials *ex situ* with Portland cement, fly ash, lime, kiln dust, or some other stabilization agent. May be used for dewatering only, to reduce the leachability (i.e. mobility) of the chemical constituents, or to modify the material's structural properties.	Would reduce the mobility and toxicity of PCBs but would increase disposal volume because of addition of stabilization agents. Commonly used to reduce free moisture for disposal purposes, and can be used to reduce chemical constituent toxicity and mobility. Would not require long-term operation and maintenance.	Implementable. Equipment, materials, and operating personnel are available. Would require sufficient space to conduct the treatment and processing activities, as well as agreement with the relevant property owner.	Retained.

Table 4-8 – Secondary Screening - Evaluation of Process Options for Management of Removed Sediment and Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
B. *Ex Situ* Treatment (cont'd)					
Physical (cont'd)	Particle Separation	Physically separating the finer grained PCB-containing particulates for subsequent management and treatment, through particle size separation techniques.	Effectiveness dependent upon association between PCBs and grain size. Could reduce the volume of material requiring treatment/disposal. Less likely to be effective when oil is present. Results of study conducted by EPA on other reaches of the River indicate that highest PCB concentrations are generally associated with smallest size. Treatability testing would be necessary to evaluate effectiveness for Rest of River sediments/soils. Would not require long-term operation and maintenance.	Implementable, but would require specialized equipment and materials. Operating personnel are likely readily available. Would require sufficient space to conduct the treatment and processing activities, as well as agreement with the relevant property owner.	Not retained due to uncertain effectiveness and implementability for full-scale application to Rest of River. Could be considered later, subject to site-specific treatability testing, in effort to reduce disposal volume or cost.
Chemical	Chemical Extraction	An extraction fluid/solvent is mixed with the sediment/soil, and PCBs are removed from the solid media, into the extracting fluid. Extracting fluid is used to desorb solid-phase PCBs from the solids matrix.	Could be applied to dredged sediments and/or soils to reduce toxicity, mobility, and volume of PCBs prior to disposal. Has been used at other sites to reduce PCB concentrations. May require pretreatment prior to implementation. Effectiveness is dependent on sediment/soil type, grain size, water content, organic content, and physico-chemical properties of the chemicals present. Treatability testing would thus be warranted, at least prior to implementation, to select most effective technique for Rest of River. Would not require long-term operation and maintenance.	Implementable, but would require specialized equipment, materials, and operating personnel. Concentrated PCBs in the extract would require proper disposal. Traces of chemical/solvent remaining in the treated solids may need to be addressed, depending on the end use of the treated materials. Would require sufficient space to conduct the treatment and processing activities, as well as an agreement with the relevant property owner.	Retained. GE is currently evaluating need for treatability tests in CMS.

Table 4-8 – Secondary Screening - Evaluation of Process Options for Management of Removed Sediment and Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
B. *Ex Situ* Treatment (cont'd)					
Chemical (cont'd)	Chemical Destruction	Adding reagents to the sediment/soil to break down the PCBs. Destruction process can be achieved through several processes, including base-catalyzed dechlorination, gas-phased reduction, and sodium-based degradation.	Not been proven effective on a full-scale basis at sites with PCB-containing sediment and soil. Variability of sediment/soil composition and PCB content could make this process difficult to control. Would not require long-term operation and maintenance.	Implementability is questionable. No full-scale applications of this process option that have successfully destroyed PCBs at concentrations similar to the Rest of River sediments and soils were identified. Would require specialized equipment, materials, and operating personnel. Would require sufficient space to conduct the treatment and processing activities, as well as an agreement with the relevant property owner.	Not retained since this process has not been proven effective full-scale for materials similar to Rest of River sediments and soils, and the variability of sediment/soil composition and PCB content at this site could make this process difficult to control.
Thermal	Thermal Desorption	Physically separating PCBs from the sediment/soil by adding heat to volatilize the PCBs. Volatilized PCBs are then condensed/collected as a liquid, captured on activated carbon, and destroyed in an afterburner.	Would reduce the potential toxicity, mobility, and volume of PCBs in the removed solids via treatment and proper management and/or disposal of treatment residuals. Would require appropriate environmental and process controls. Depending on effectiveness, could be evaluated for use in reducing PCB concentrations in removed materials to levels that may allow more cost-effective disposal options or possibly reuse of treated materials as backfill. Treatability tests using sediments/soils from representative reaches of the Rest of River may be warranted to evaluate degree of effectiveness and reuse potential of treated solids. Would not require long-term operation and maintenance.	Potentially implementable. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. May require stabilization and/or dewatering before treatment. Would require an additional step to destroy the removed chemicals. Would require sufficient space to conduct the treatment and processing activities, as well as an agreement with the relevant property owner. Thermal treatment units at other sites have often been met with community resistance (e.g., New Bedford Harbor).	Retained. GE is currently evaluating need for treatability study.

Table 4-8 – Secondary Screening - Evaluation of Process Options for Management of Removed Sediment and Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
B. *Ex Situ* Treatment (cont'd)					
Thermal (cont'd)	Thermal Destruction	Using excessive heat to destroy the organic compounds (i.e., PCBs) present in the removed sediment/soil.	Would reduce the potential toxicity, mobility, and volume of PCBs in the removed solids via destruction of the PCBs with subsequent disposal of treatment residuals. Would require appropriate environmental and process controls. Would not require long-term operation and maintenance.	Potentially implementable but not practcal. Would require specialized equipment, materials, and operating personnel. May require stabilization and/or dewatering before treatment. Would require sufficient space to conduct the treatment and processing activities, as well as an agreement with the relevant property owner. Option has encountered strong community opposition at other sites (e.g., New Bedford Harbor). May encounter significant administrative constraints in securing necessary access agreements and meeting the substantive requirements of applicable regulations. More costly than thermal desorption.	Not retained due to: (a) likely community acceptance issues; (b) administrative and regulatory constraints; and (c) higher costs and lack of additional benefits compared to thermal desorption.
C. Local Disposal					
Confined Disposal Facility (CDF)	CDF	Placing PCB-containing sediment/soil in a disposal facility constructed within a water body to permanently isolate PCB-containing material.	Could effectively manage PCB-containing sediments/soils. May result in loss of aquatic habitat. Would require long-term monitoring and maintenance.	Implementable so long as suitable in-water location is identified where CDF could be constructed and transport for disposal of sediments is feasible and which would meet applicable substantive regulatory requirements (or obtain waiver). Equipment, materials, and operating personnel are available.	Retained.

Table 4-8 – Secondary Screening - Evaluation of Process Options for Management of Removed Sediment and Soil

General Response Action/ Remedial Technology	Process Option	Description	Effectiveness	Implementability	Screening
C. Local Disposal (cont'd)					
Upland Disposal	Upland Disposal Facility	Placing PCB-containing sediment/soil in an upland disposal facility constructed in close proximity to the site, following dewatering where necessary.	Could effectively manage PCB-containing soils/sediments, thereby preventing future exposure by human and ecological receptors to the removed material. Disposal in close proximity to the site would preclude the need to transport large volumes of sediment over long distances to an off-site disposal facility(ies), thereby reducing or eliminating the potential for accidents and spills during off-site transport. Depending on the location of the facility, construction could potentially result in the loss of habitat. Would require long-term operation, monitoring, and maintenance.	Implementable so long as suitable location is identified that would meet applicable substantive regulatory requirements (or obtain waiver). Equipment, materials, and operating personnel are available.	Retained.
D. Off-Site Disposal					
Off-Site Disposal	Off-site Permitted Facility	Transporting excavated sediment/soils to appropriate off-site disposal facility(ies) – TSCA facility for TSCA-regulated materials, permitted solid waste facility for other materials. May require stabilization or dewatering before off-site transport and disposal.	Would be effective for permanent disposition of removed sediment/soil. Risks of exposure and transportation accidents increase with significantly increased haul distances of materials.	Implementable so long as there is appropriate permitted off-site facility(ies) with the necessary availability and capacity, and an adequate means of transport is available.	Retained.

Notes:
Shading indicates not retained as representative process option based on currently available information; however, this does not preclude them from future consideration/use, as new information becomes available.
mg/kg = milligrams per kilogram
PCBs = polychlorinated biphenyls

Table 5-1 – Summary of Corrective Measure Alternatives for In-River Sediments

Alt.	Reach 5A	Reach 5B	Reach 5A/5B Banks	Reach 5C	Backwaters	Woods Pond	Reach 7 Impoundments	Rising Pond
SED 1	No action	No action	No action	No action	No action	No action	No action	No action
SED 2	MNR	MNR	MNR	MNR	MNR	MNR	MNR	MNR
SED 3	2' removal w/ capping	MNR	Removal/ stabilization	Combination of TLC and MNR	MNR	TLC	MNR	MNR
SED 4	2' removal w/ capping	Combination of 2' removal w/ capping and TLC (dep. on depth & velocity)	Removal/ stabilization	Combination of TLC (in shallow & depositional areas) and capping (in deeper areas)	Combination of TLC and MNR	Combination of 1.5' removal w/ capping in shallow areas and TLC in deep area	MNR	MNR
SED 5	2' removal w/ capping	1.5' - 2' removal w/ capping	Removal/ stabilization	Combination of 1.5-2' removal w/ capping (in shallow areas) and capping (in deeper areas)	Combination of TLC and MNR	Combination of 1.5' removal w/ capping in shallow areas and capping in deep area	MNR	TLC
SED 6	2' removal w/ capping	1.5' - 2' removal w/ capping	Removal/ stabilization	1.5' - 2' removal w/ capping	Removal of sediments >50 mg/kg in top 1' (w/ capping/backfill); TLC for remainder >1 mg/kg	Combination of 1.5' removal w/ capping in shallow areas and capping in deep area	TLC	Combination of TLC in shallow areas and capping in deep areas
SED 7	3-3.5' removal w/ backfill	2.5' removal w/ backfill	Removal/ stabilization	2' removal w/ capping	Removal of sediments >10 mg/kg in top 1' (w/ capping/backfill); TLC for remainder >1 mg/kg	Combination of 2.5' removal w/ capping in shallow areas and capping in deep area	Removal of higher PCB levels (e.g., >5 mg/kg) in top 1.5' (w/ capping/backfill); TLC for remainder >1 mg/kg	Comb. of removal of higher PCB levels (e.g., >5 mg/kg) in top 1.5' (w/ capping/backfill) & TLC in shallow areas and capping in deep areas
SED 8	Removal to 1 mg/kg depth horizon w/ backfill	Removal to 1 mg/kg depth horizon w/ backfill	Removal/ stabilization	Removal to 1 mg/kg depth horizon w/ backfill	Removal to 1 mg/kg depth horizon w/ backfill	Removal to 1 mg/kg depth horizon w/ backfill	Removal to 1 mg/kg depth horizon w/ backfill	Removal to 1 mg/kg depth horizon w/ backfill

Notes:
MNR – Monitored Natural Recovery
TLC – Thin-Layer Capping
All alternatives (except SED 1) include MNR for Reach 7 channel and all reaches below Rising Pond Dam

Table 5-3 – Anticipated Categories of ARARs for Evaluation in CMS

I. Potential Chemical-Specific ARARs

A. PCBs

- ***Federal ARARs***
  - Clean Water Act – national ambient water quality criteria for PCBs
- ***State ARARs***
  - Massachusetts water quality standards for PCBs
  - Connecticut water quality standards for PCBs

B. Particulate Matter

- ***Federal ARARs***
  - Clean Air Act – National Ambient Air Quality Standards for particulate matter
- ***State ARARs***
  - Massachusetts air pollution control requirements for activities with particulate emissions

II. Potential Location-Specific ARARs

A. Rivers, Streams, and Impoundments

- ***Federal ARARs***
  - Clean Water Act – EPA's Section 404(b)(1) Guidelines (under 33 USC § 1344(b))
  - Clean Water Act – Corps of Engineers Section 404(c) permit regulations (under 33 USC § 1344(c))
  - Fish and Wildlife Coordination Act requirements
- ***State ARARs***
  - Massachusetts Clean Water Act – water quality certification requirements for discharges of dredged or fill material
  - Massachusetts Wetlands Protection Act and regulations

B. Floodplains, Wetlands, and Riverbanks

- ***Federal ARARs***
  - Clean Water Act – EPA's Section 404(b)(1) Guidelines
  - Clean Water Act – Corps of Engineers Section 404(c) permit regulations
  - Executive Order 11990 for Wetlands Protection
  - Executive Order 11988 for Floodplain Management

Table 5-3 – Anticipated Categories of ARARs for Evaluation in CMS

- ***State ARARs***
  - Massachusetts Clean Water Act – water quality certification requirements for discharges of dredged or fill material
  - Massachusetts Wetlands Protection Act and regulations

C. Critical Habitat for Threatened and Endangered Species

- ***Federal ARARs***
  - Endangered Species Act and regulations
- ***State ARARs***
  - Massachusetts Endangered Species Act and regulations

D. Potential Historical or Archaeological Sites

- ***Federal ARARs***
  - National Historic Preservation Act and regulations
- ***State ARARs***
  - Massachusetts Historical Commission Act and regulations

III. Potential Action-Specific ARARs

A. Sediment/Soil Excavation, Backfilling/Restoration, and/or *In-Situ* Containment

- ***Federal ARARs***
  - Toxic Substances Control Act (TSCA) regulations on PCB Remediation Waste
  - TSCA regulations on decontamination of surfaces
  - Resource Conservation Act (RCRA) regulations on identification of hazardous waste
  - Clean Water Act – EPA's Section 404(b)(1) Guidelines
  - Clean Water Act – Corps of Engineers Section 404(c) permit regulations
  - Clean Water Act – NPDES regulations for storm water discharges
- ***State ARARs***
  - Massachusetts hazardous waste regulations on identification of hazardous waste
  - Massachusetts Clean Water Act – water quality certification requirements for discharges of dredged or fill material
  - Massachusetts air pollution control regulations for dust-generating activities

B. Temporary On-Site Accumulation and/or Storage of Excavated Sediments or Soils

- ***Federal ARARs***
  - TSCA regulations on storage of PCB Remediation Waste
  - TSCA regulations on decontamination of surfaces

Table 5-3 – Anticipated Categories of ARARs for Evaluation in CMS

- RCRA regulations for generation, less than 90-day accumulation, and/or storage (for $\geq$ 90 days) of hazardous waste (for excavated sediments/soils that constitute hazardous waste under RCRA, if any)
- Clean Water Act – NPDES regulations for storm water discharges from construction
- Clean Water Act – EPA's Section 404(b)(1) Guidelines (if there are discharges of fill material during facility construction)
- Clean Water Act – Corps of Engineers Section 404(c) permit regulations (if there are discharges of fill material during facility construction)

- ***State ARARs***
  - Massachusetts siting requirements for solid waste handling (including storage) facilities
  - Massachusetts solid waste management regulations – technical requirements for waste handling (including storage) facilities
  - Massachusetts hazardous waste management regulations for generation, less than 90-day accumulation, and/or storage (for $\geq$ 90 days) of hazardous waste, including general requirements, location standards, and technical requirements (for excavated sediments/soils that constitute hazardous waste under state regulations on basis other than PCBs $\geq$ 50 ppm, if any)
  - Massachusetts Clean Water Act – water quality certification requirements (if there are discharges of fill material during facility construction)
  - Massachusetts air pollution control regulations for dust-generating activities

C. *Ex-Situ* Physical or Chemical Treatment at On-Site Facility

- ***Federal ARARs***
  - RCRA regulations for hazardous waste management facilities, including general requirements relating to treatment and air emissions standards for process vents (if excavated sediments/soils to be treated constitute hazardous waste under RCRA)
  - Clean Water Act – NPDES regulations for storm water discharges
- ***State ARARs***
  - Massachusetts siting requirements for solid waste handling (including treatment) facilities
  - Massachusetts solid waste management regulations – technical requirements for waste handling (including treatment) facilities
  - Massachusetts hazardous waste management regulations for storage and/or treatment of hazardous waste (if excavated sediments/soils to be treated constitute hazardous waste under state regulations on basis other than PCBs $\geq$ 50 ppm)
  - Massachusetts air pollution control regulations for dust-generating activities
  - Massachusetts requirements for storage and handling of flammable liquids (if used as extraction fluids in chemical treatment)
  - Massachusetts regulations for above-ground storage tanks

Table 5-3 – Anticipated Categories of ARARs for Evaluation in CMS

D. *Ex-Situ* Thermal Desorption at On-Site Facility

- ***Federal ARARs***
  - Clean Air Act – National Ambient Air Quality Standards for particulate matter
  - Clean Air Act – National Emissions Standards for Hazardous Air Pollutants (NESHAPs) for hazardous waste combustors (if thermal desorption unit will use controlled flame combustion and will treat excavated materials that constitute RCRA hazardous waste)
  - RCRA regulations for hazardous waste management facilities (including requirements for incinerators or miscellaneous units, depending on whether thermal desorption unit will use controlled flame combustion) if facility will treat excavated materials that constitute RCRA hazardous waste)
- ***State ARARs***
  - Massachusetts air pollution control requirements relevant to emissions from thermal absorption unit
  - Massachusetts siting requirements for solid waste combustion or handling facilities (depending on whether thermal desorption unit uses controlled flame combustion)
  - Massachusetts solid waste management regulations – technical requirements for waste handling (including treatment) facilities
  - Massachusetts hazardous waste management regulations that would apply to thermal desorption facility (if excavated sediments/soils to be treated constitute hazardous waste under state regulations on basis other than PCBs $\geq$ 50 ppm)
  - Massachusetts regulations for above-ground storage tanks

E. Discharge of Treated Water from Dewatering or Treatment Facility to Housatonic River

- ***Federal ARARs***
  - Clean Water Act – NPDES discharge regulations (under 33 USC § 1342)
  - TSCA regulations for discharge of water containing PCBs to navigable waters

F. Local Disposal of Excavated Sediments or Soils

- ***Federal ARARs***
  - TSCA regulations on disposal of PCB Remediation Waste
  - TSCA regulations on decontamination of surfaces
  - RCRA regulations for hazardous waste management facilities used for disposal of hazardous waste (if disposal facility will be used for excavated sediments/soils that constitute hazardous waste under RCRA)
  - RCRA land disposal restrictions (if disposal facility will be used for excavated sediments/soils that constitute hazardous waste under RCRA)
  - Clean Water Act – NPDES regulations for storm water discharges
  - Clean Water Act – EPA's Section 404(b)(1) Guidelines (if there are discharges of fill material during facility construction)

Table 5-3 – Anticipated Categories of ARARs for Evaluation in CMS

- Clean Water Act – Corps of Engineers Section 404(c) permit regulations (if there are discharges of fill material during facility construction)

- ***State ARARs***
  - Massachusetts siting requirements for solid waste landfills
  - Massachusetts solid waste management regulations – technical requirements for landfills
  - Massachusetts hazardous waste management regulations for landfills, including general requirements, location standards, and technical requirements (if excavated sediments/soils constitute hazardous waste under state regulations on basis other than PCBs $\geq$ 50 ppm)
  - Massachusetts Clean Water Act – water quality certification requirements (if there are discharges of fill material during facility construction)
  - Massachusetts air pollution control regulations for dust-generating activities

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Figures

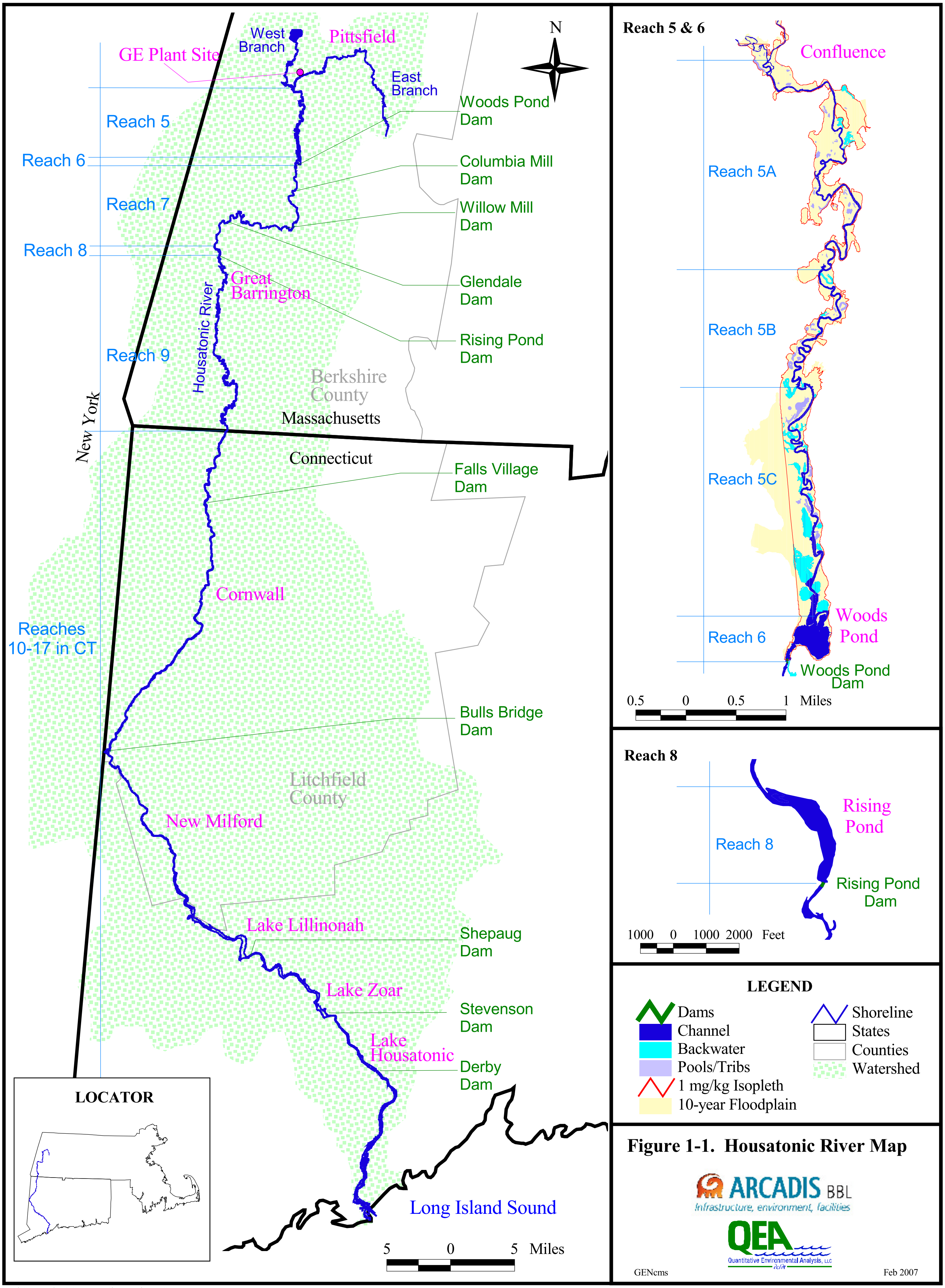

Figure 1-1. Housatonic River Map

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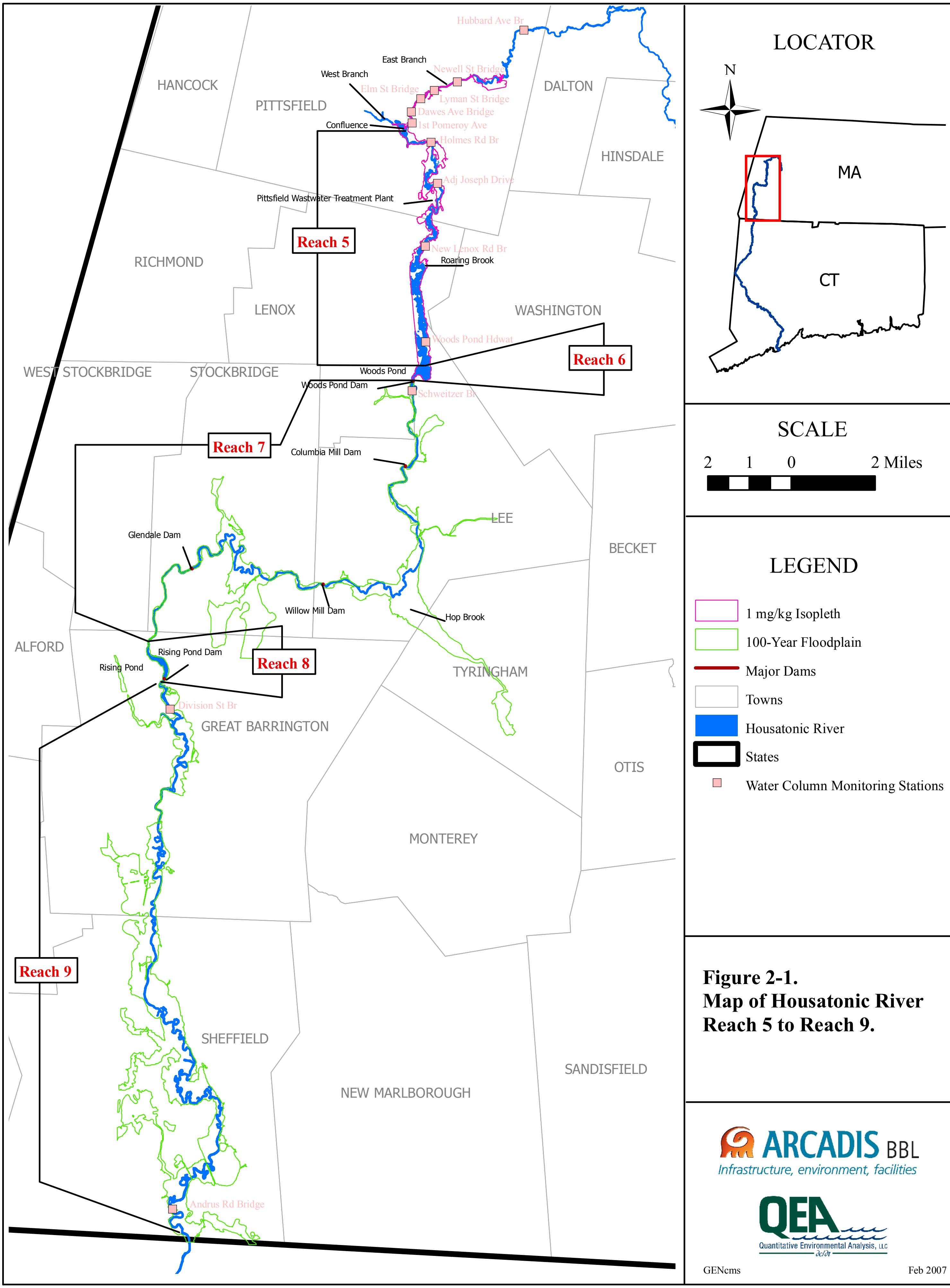

Figure 2-1.
Map of Housatonic River Reach 5 to Reach 9.

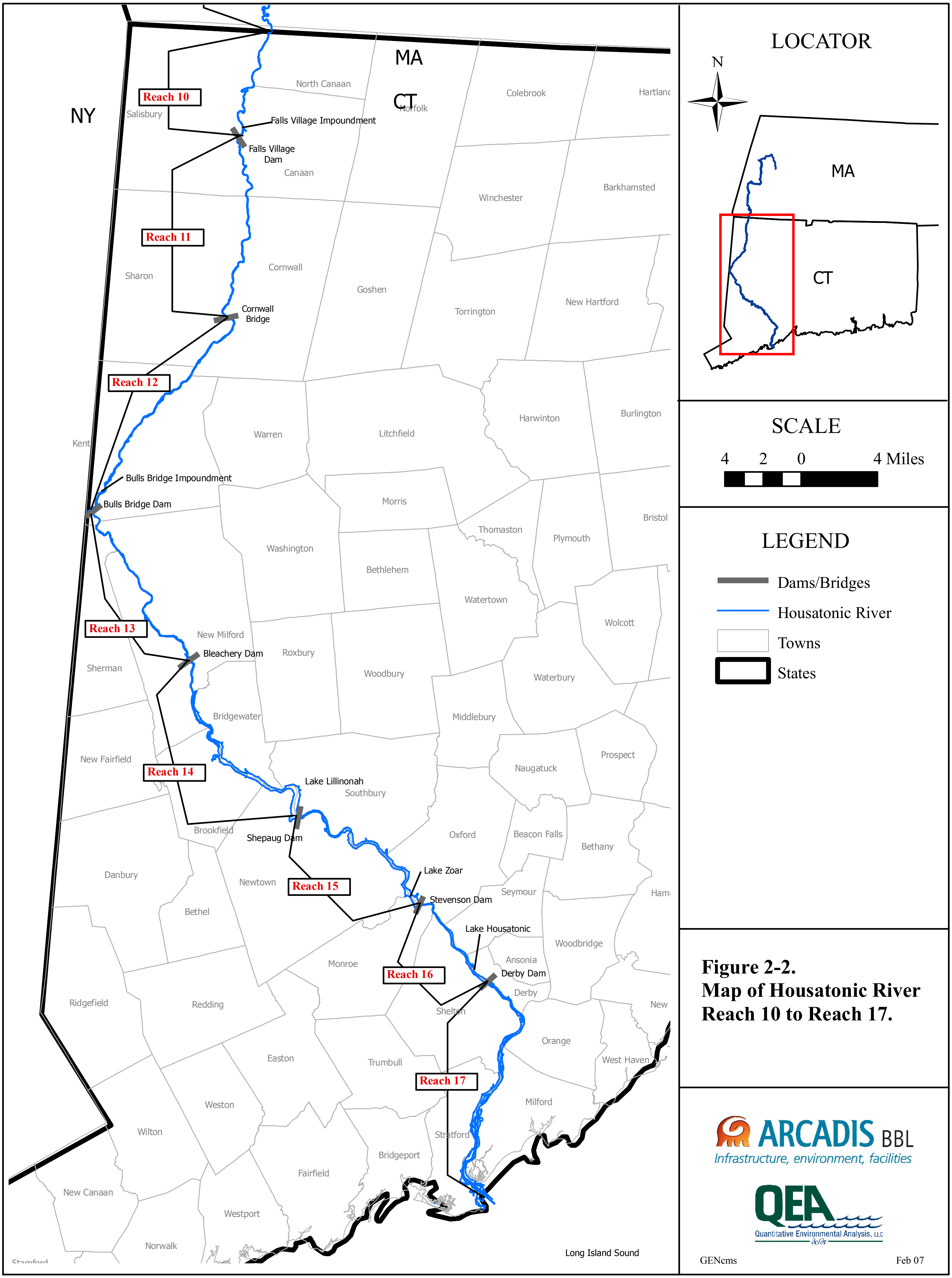

Figure 2-2.
Map of Housatonic River Reach 10 to Reach 17.

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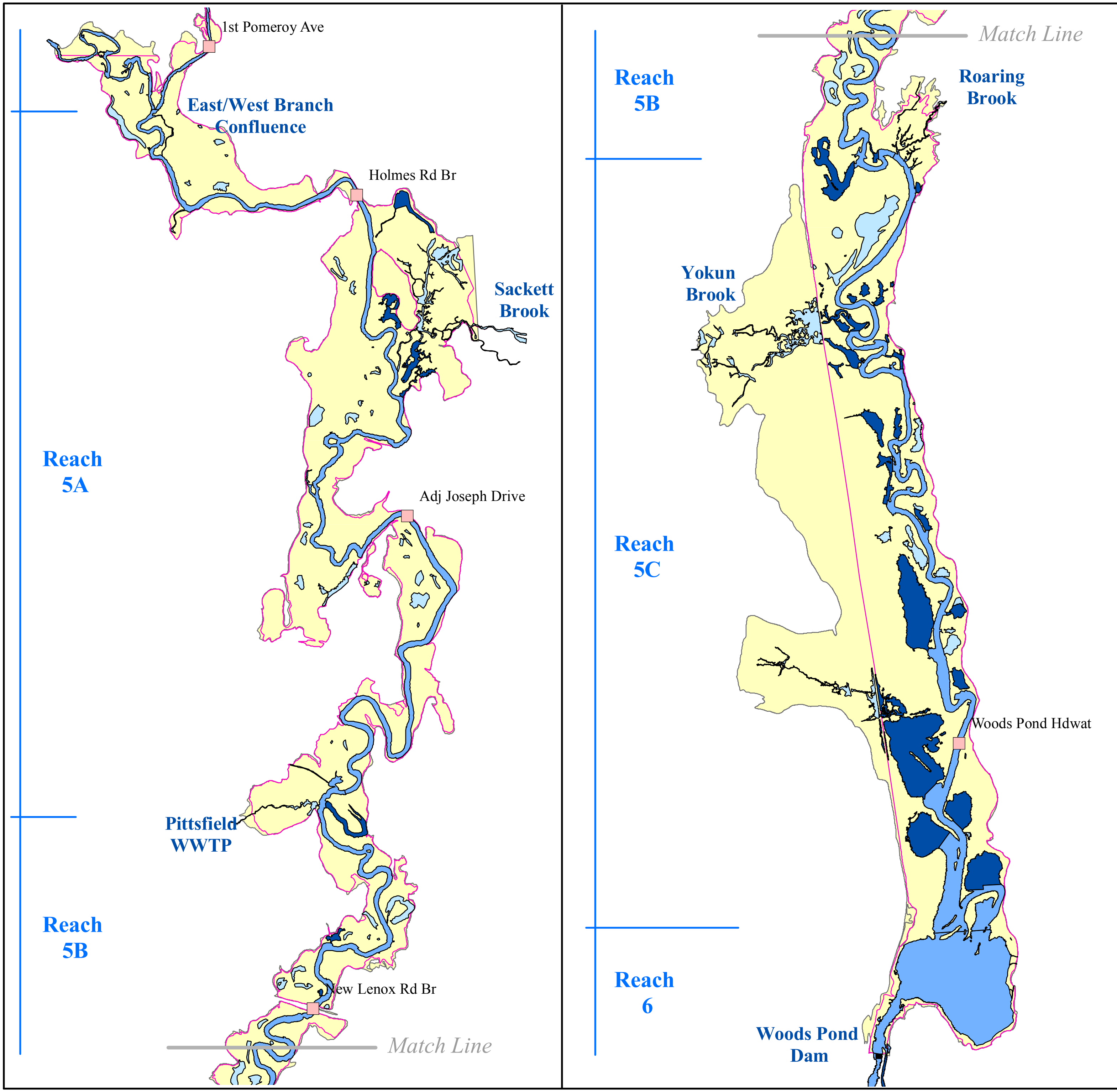

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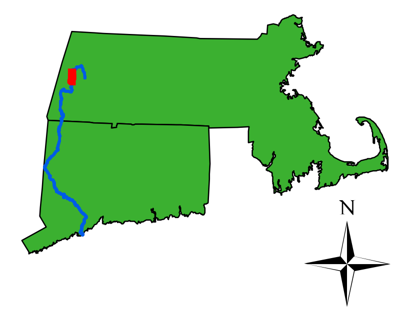

SCALE

0 0.25 0.5 Miles

LEGEND

- 1 mg/kg PCB Isopleth
- 10-Year Floodplain
- Major Dams
- Main Channel
- Backwaters
- Pools/Tributaries
- Water Column Monitoring Stations

Figure 2-3.
Map of Housatonic River from the Confluence to Woods Pond.

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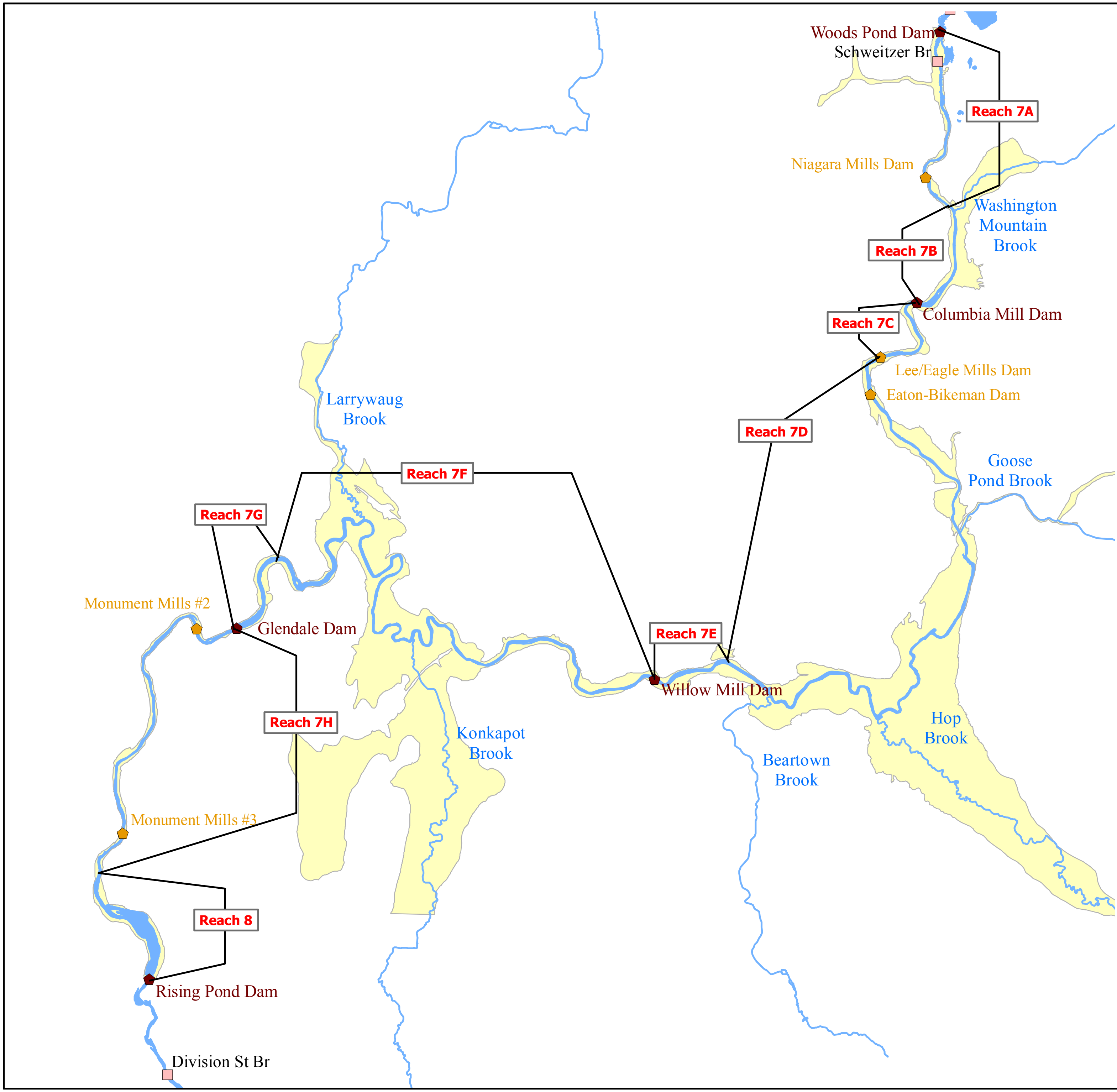

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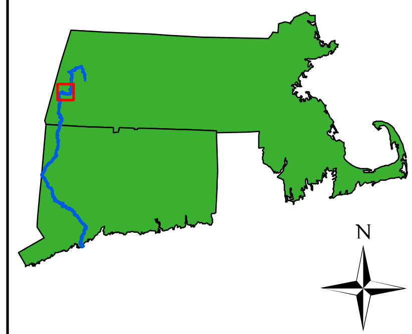

SCALE

0.5 0.25 0 0.5 Miles

LEGEND

- Housatonic River
- 100-year Floodplain
- Dams
- Former Dams
- Water Column Monitoring Stations

Figure 2-4.
Map of Housatonic River from Woods Pond Dam to Rising Pond Dam.

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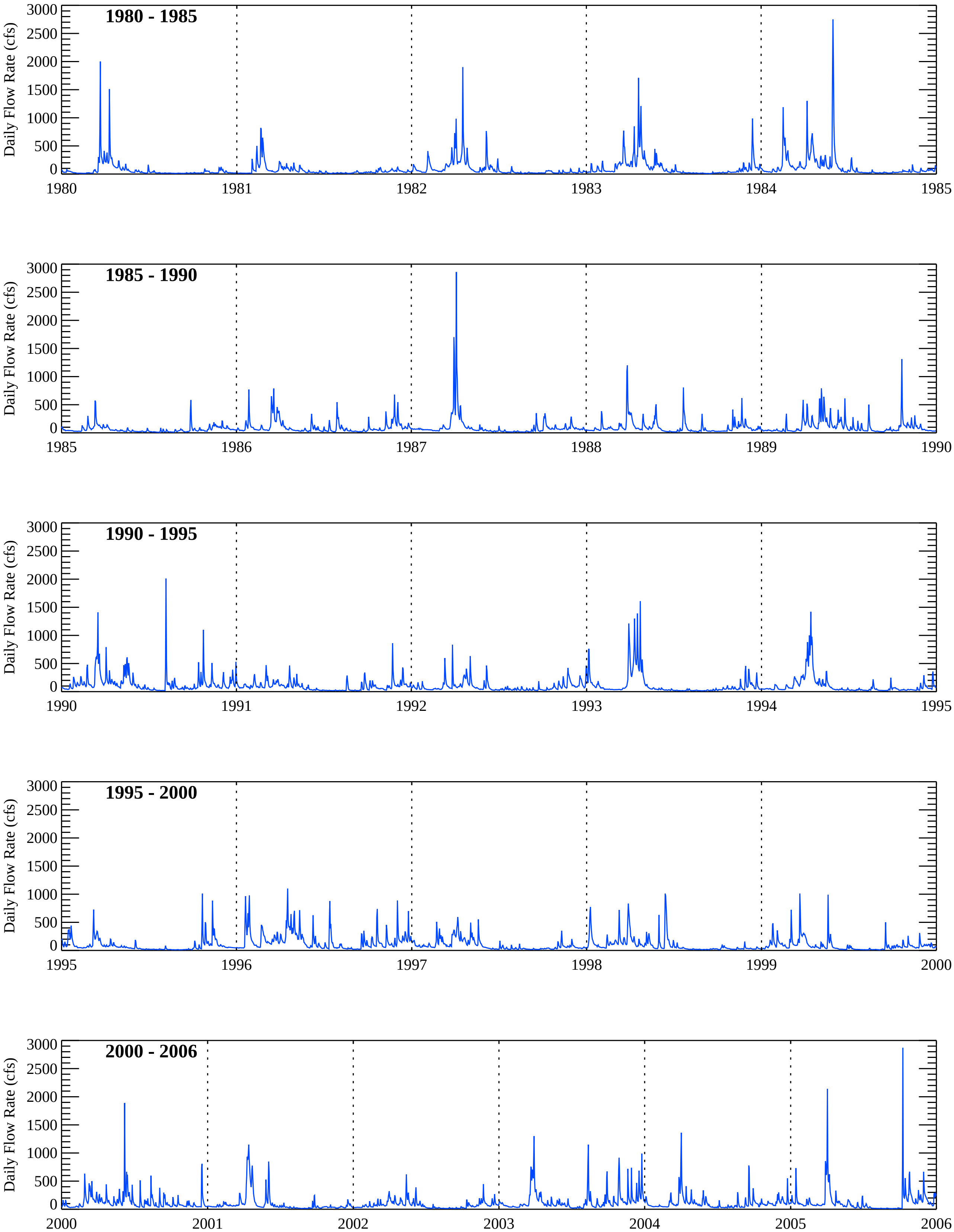
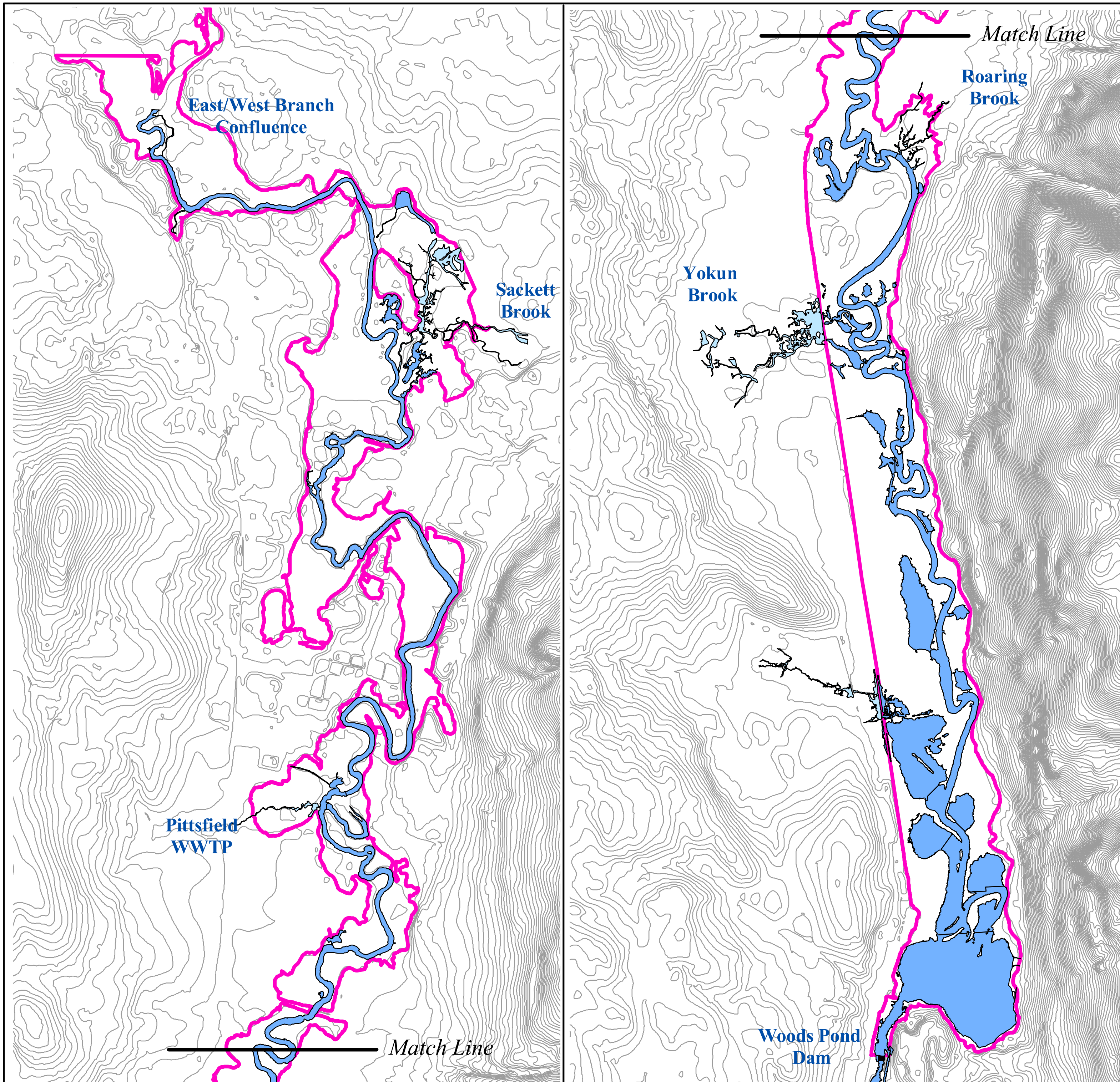


Figure 2-5. Daily average flow rate measured at USGS Coltsville gauging station for 1980-2005.

Note: Vertical lines correspond to January 1st of each year.



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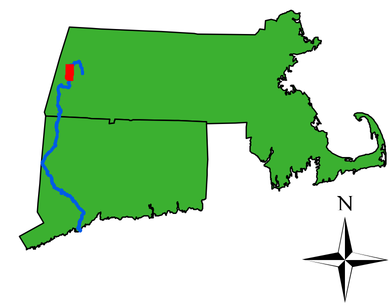

SCALE

0 0.25 0.5 Miles

LEGEND

- Major Dams
- Housatonic River
- 1 mg/kg PCB Isopleth
- 3-m Elevation Contour

Note: Elevation contour downloaded from MassGIS.

Figure 2-6. Floodplain topography between the Confluence and Woods Pond Dam.

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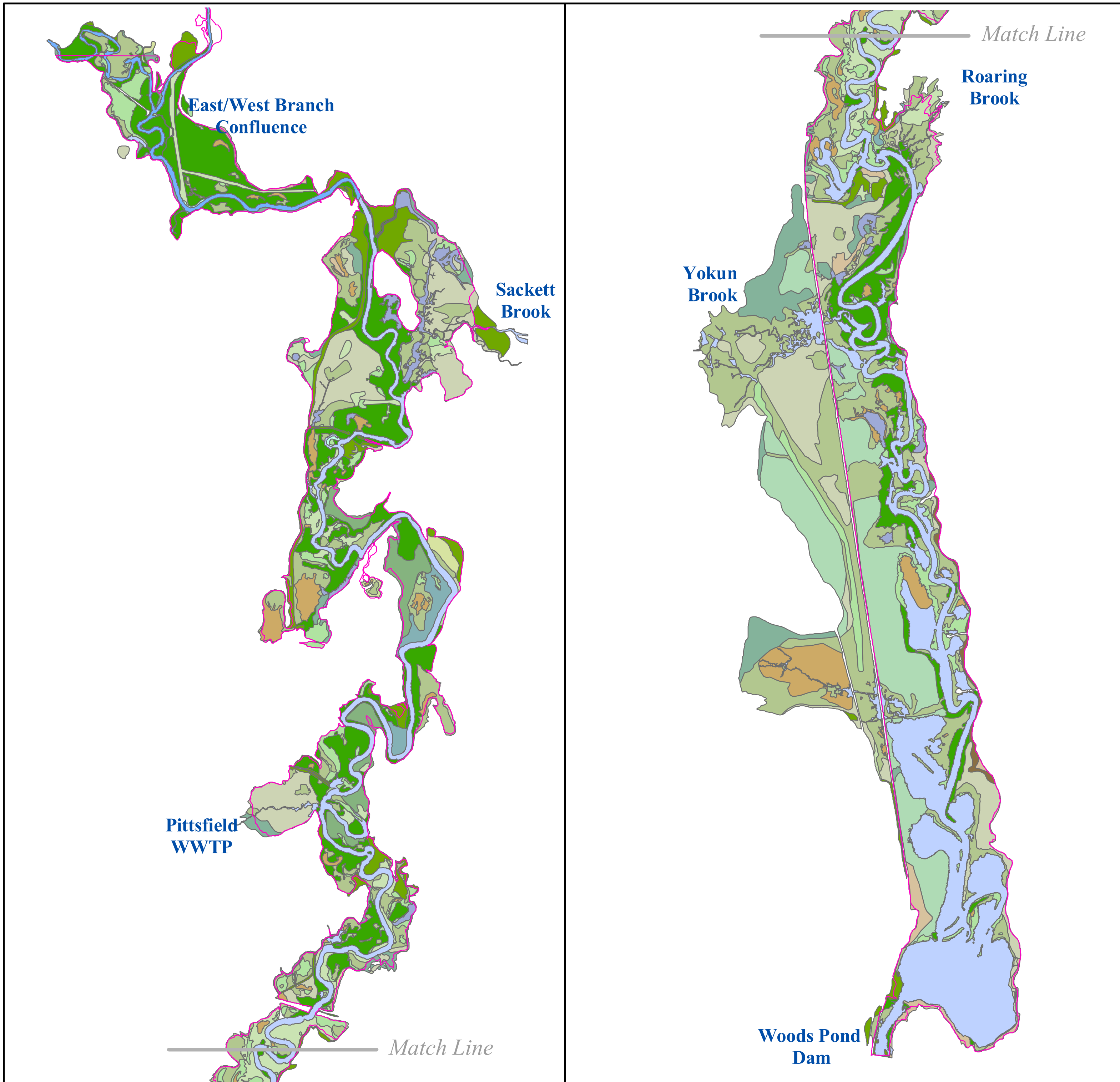

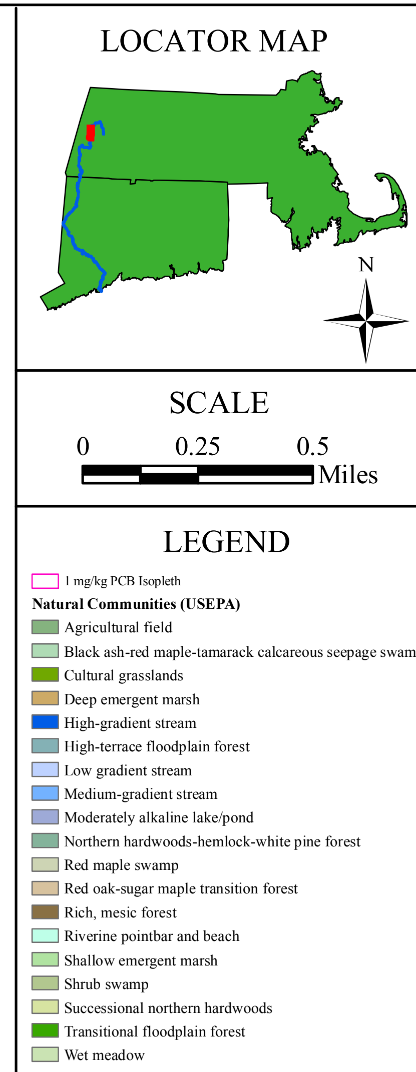

Figure 2-7. Floodplain natural communities between the Confluence and Woods Pond.

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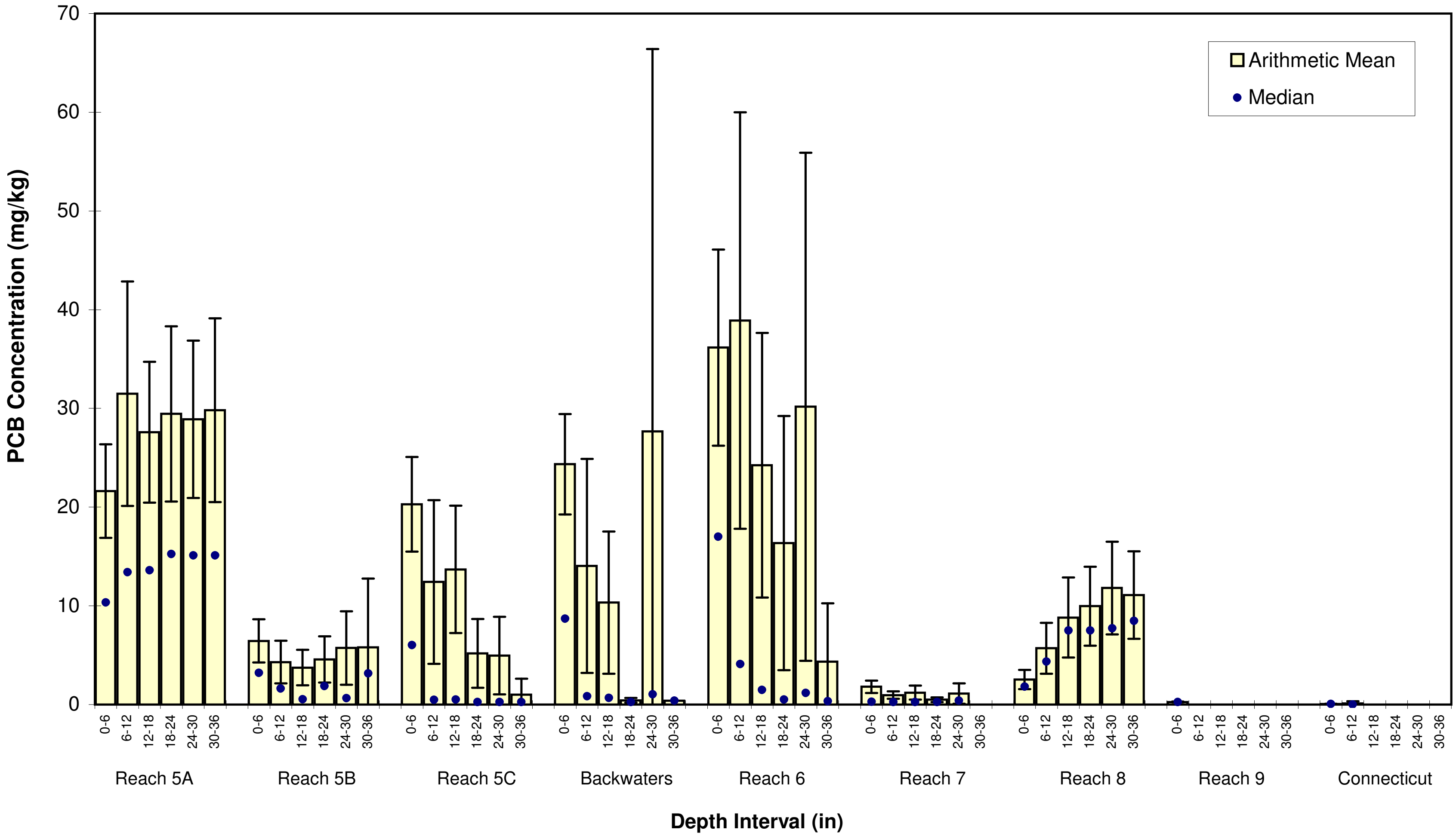

Figure 2-8. PCB concentrations in Housatonic River sediment.

Notes: Includes EPA (1998-2002), and GE (Dec. 1997-1998) sampling data. Presents arithmetic mean PCB concentration and median in the top 36 inches of sediment. Error bars represent 2 standard errors about the mean.

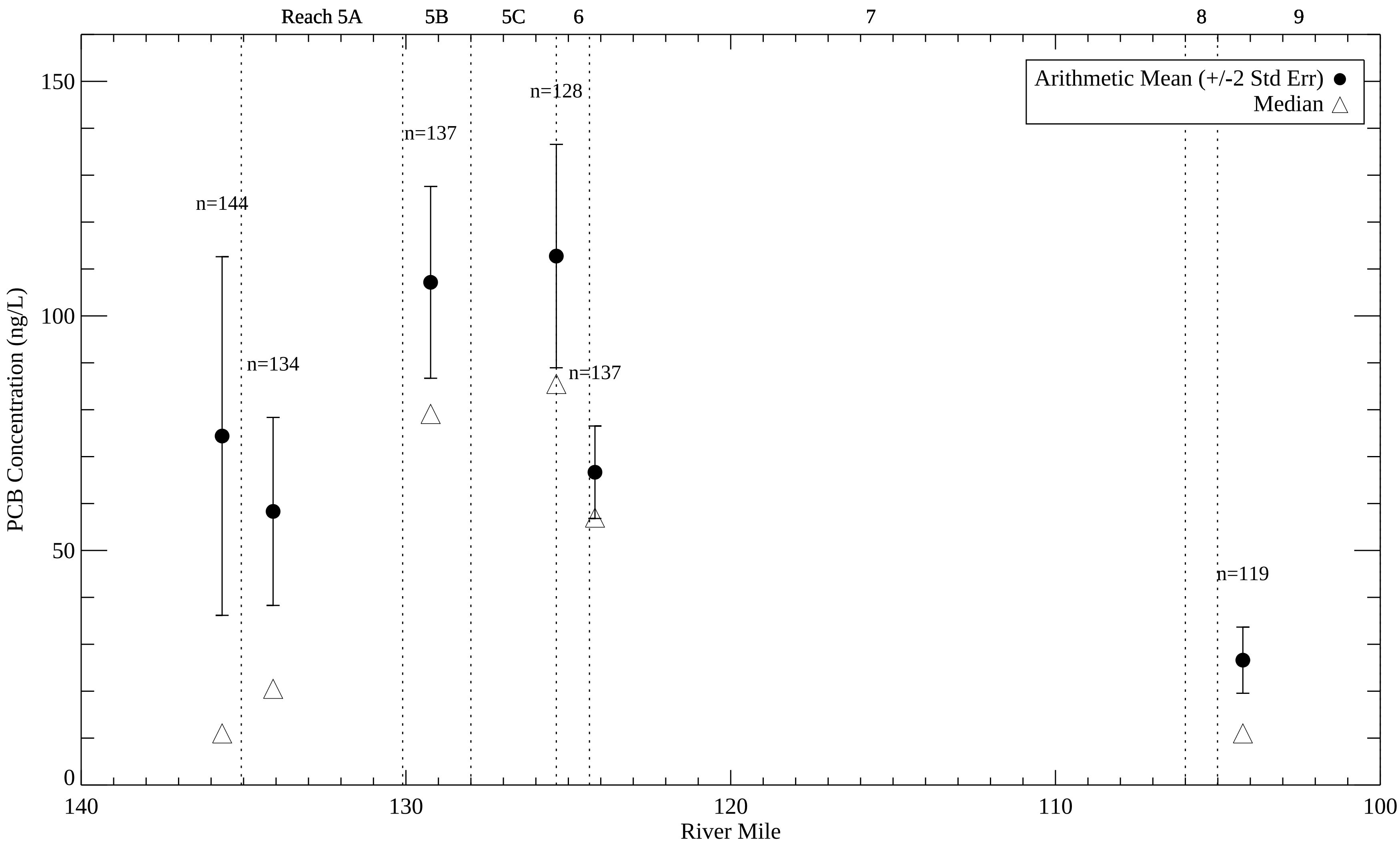

Figure 2-9. Spatial profiles of averaged water column PCB concentrations during 1996-2005.

Notes: Included all monthly and bi-weekly water column monitoring data collected by GE (1996-2005) and EPA (1998-1999). Excluded data from storm events or other specialized surface water sampling events. Data analyzed by Quanterra lab were removed.

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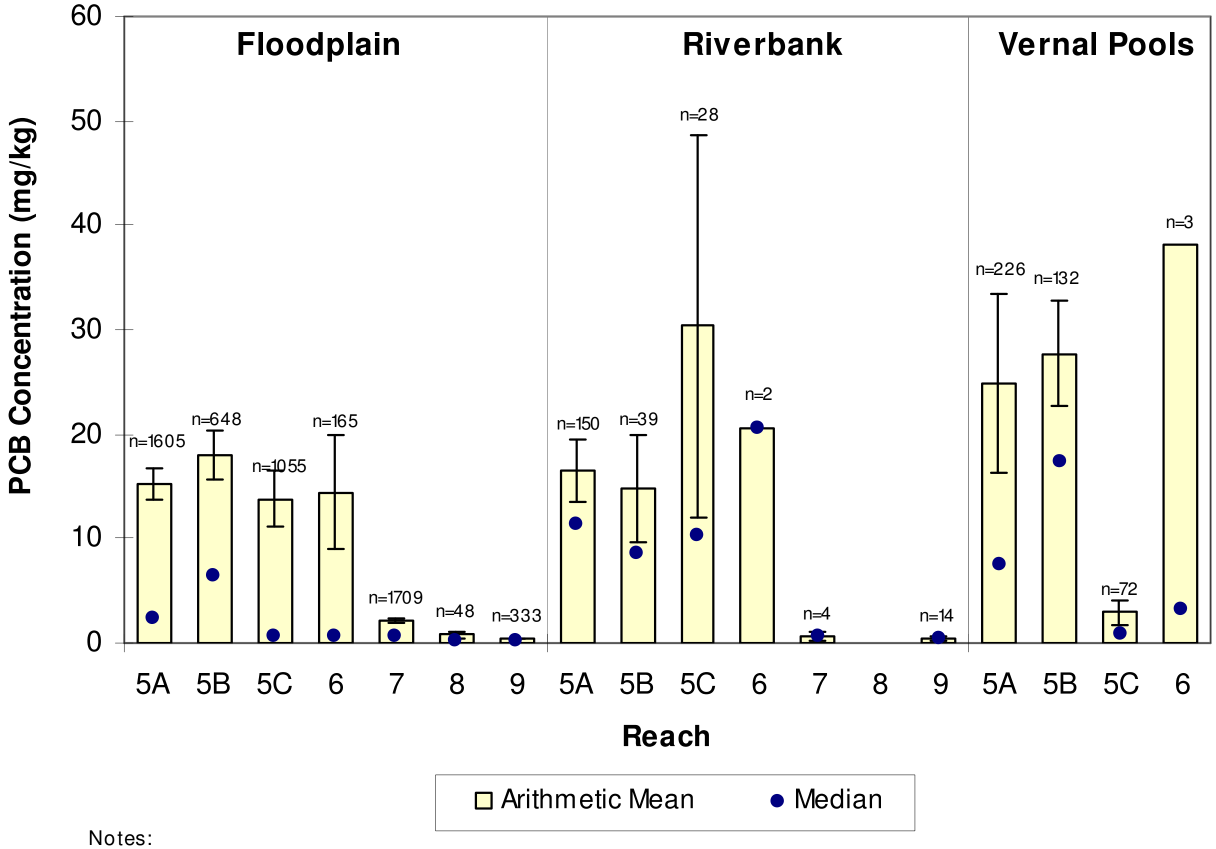

Notes:
Presents arithmetic mean and 2 standard errors for all EPA and GE floodplain, riverbank, and vernal pool soil PCB data.
n = number of samples.

Figure 2-10. PCB concentrations in Housatonic River floodplain, riverbank and vernal pool soil.

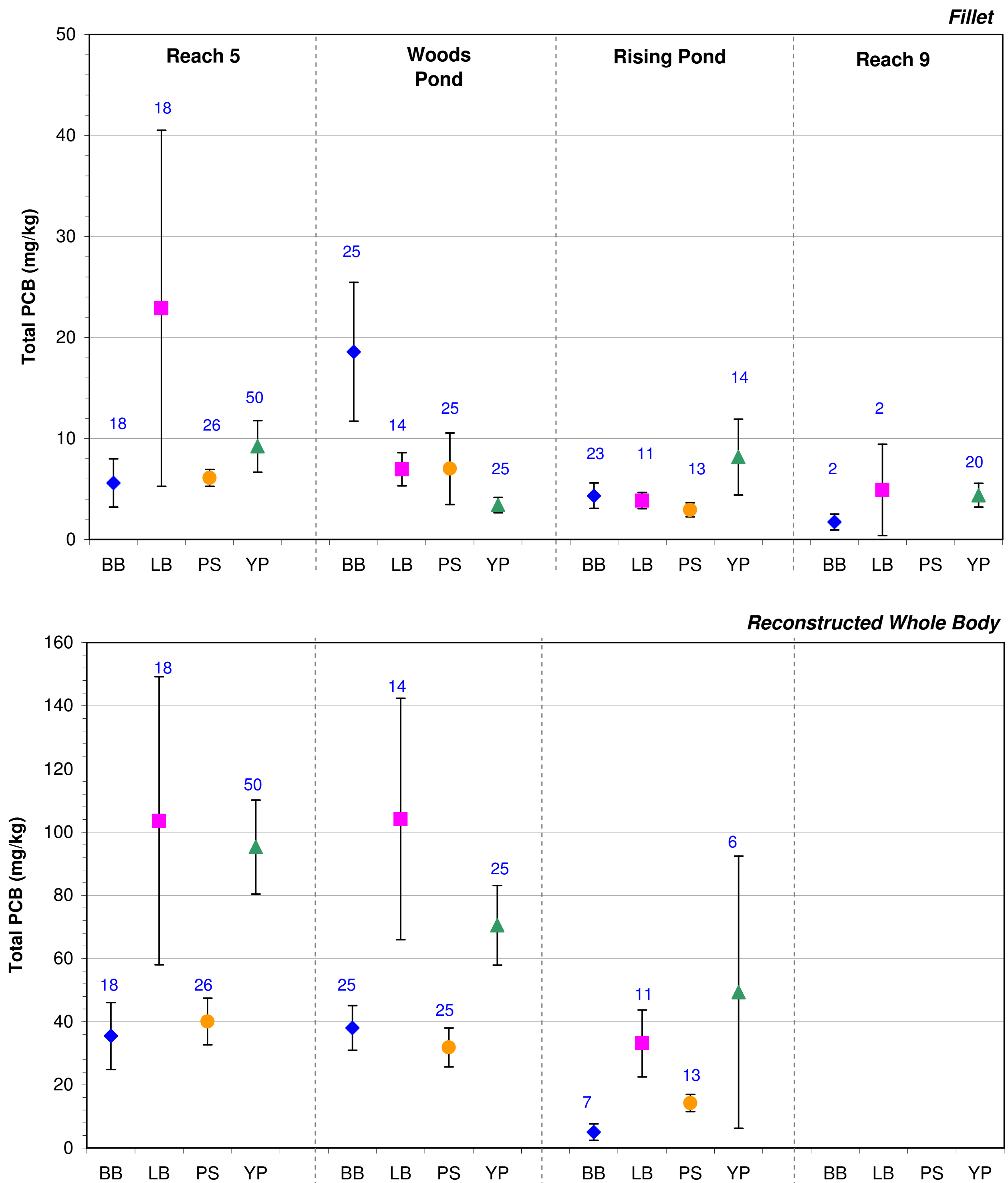

Figure 2-11. Spatial distribution of PCB levels in large fish.

Notes:
BB - Brown Bullhead; LB - Largemouth Bass; PS - Pumpkinseed; YP - Yellow Perch
Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.
Presents data collected by the EPA in 1998 with 1998 GE data for Reach 9. In Rising Pond, EPA and GE fillet data were combined

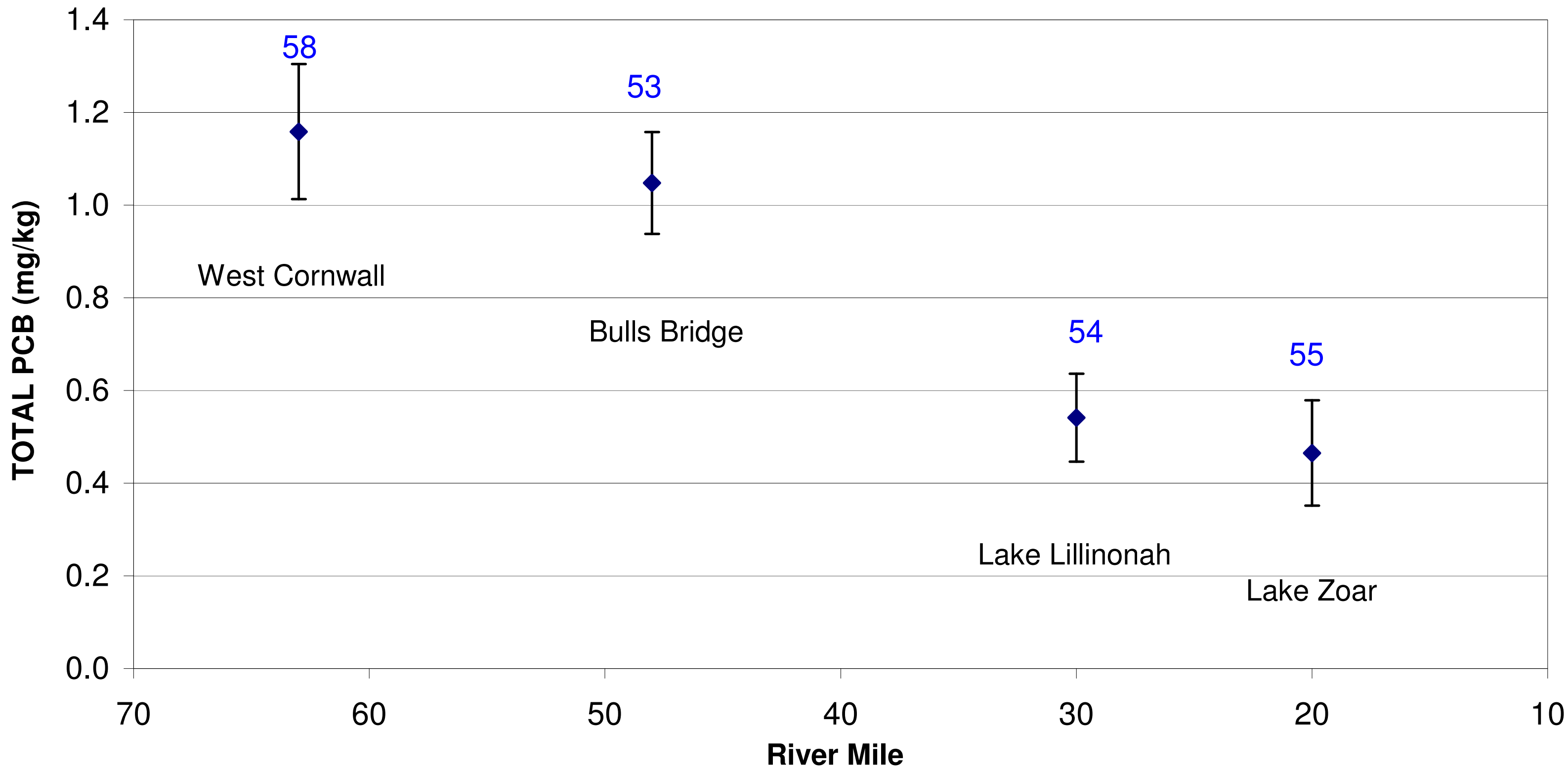

Figure 2-12. Wet weight PCB levels in smallmouth bass tissue collected from the Connecticut section of the Housatonic River.

Notes:
Data include the combined smallmouth bass fillet samples from 1994 through 2004. Source of Data: ANSP fish tissue data sheets. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.

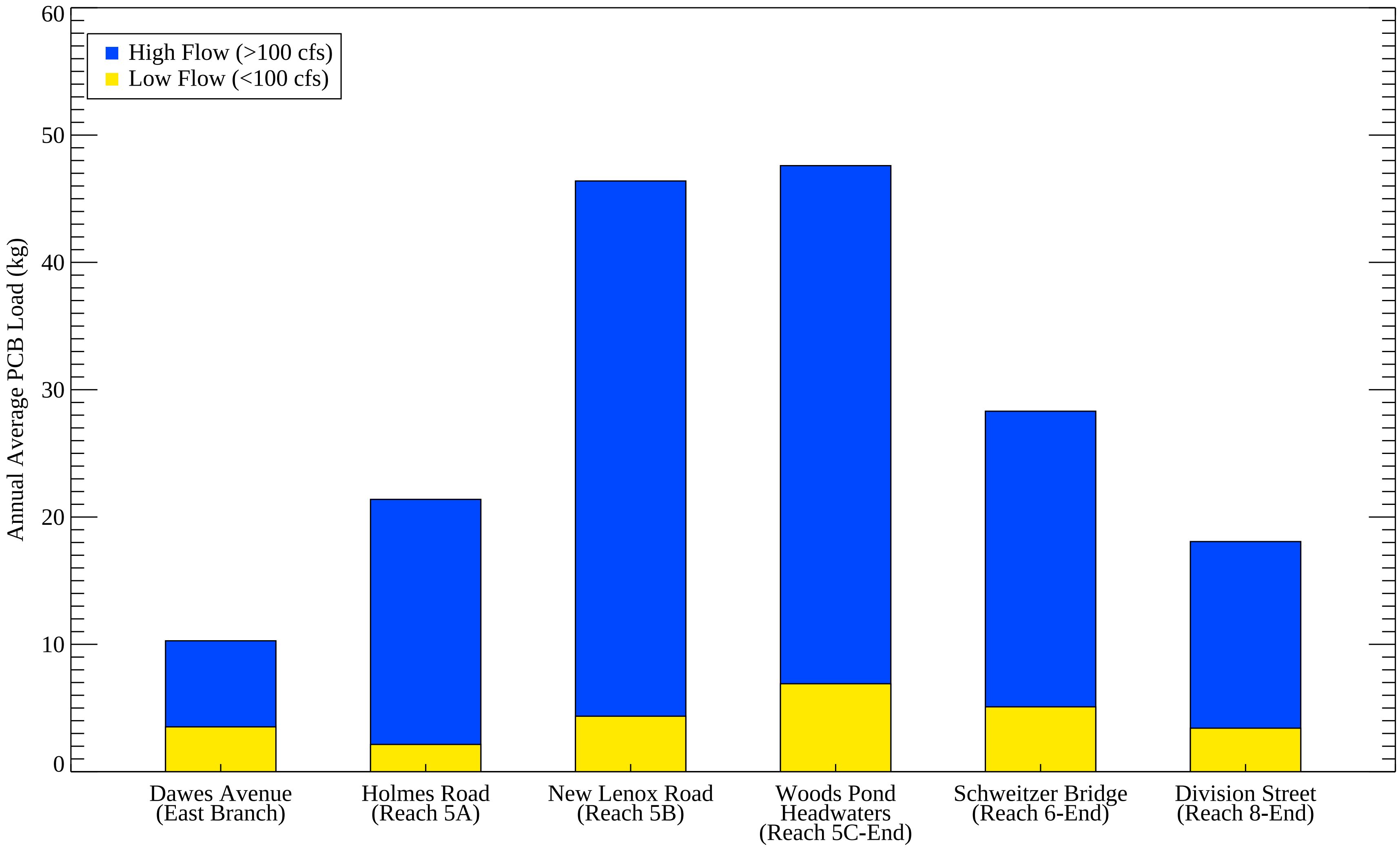

Figure 2-13. Summary of annual average PCB loadings along the Housatonic River during 1997-2005.

Note: Loads calculated using non-detect 1/2 MDL; high/low flow based on cutoff of 100 cfs in Coltsville.

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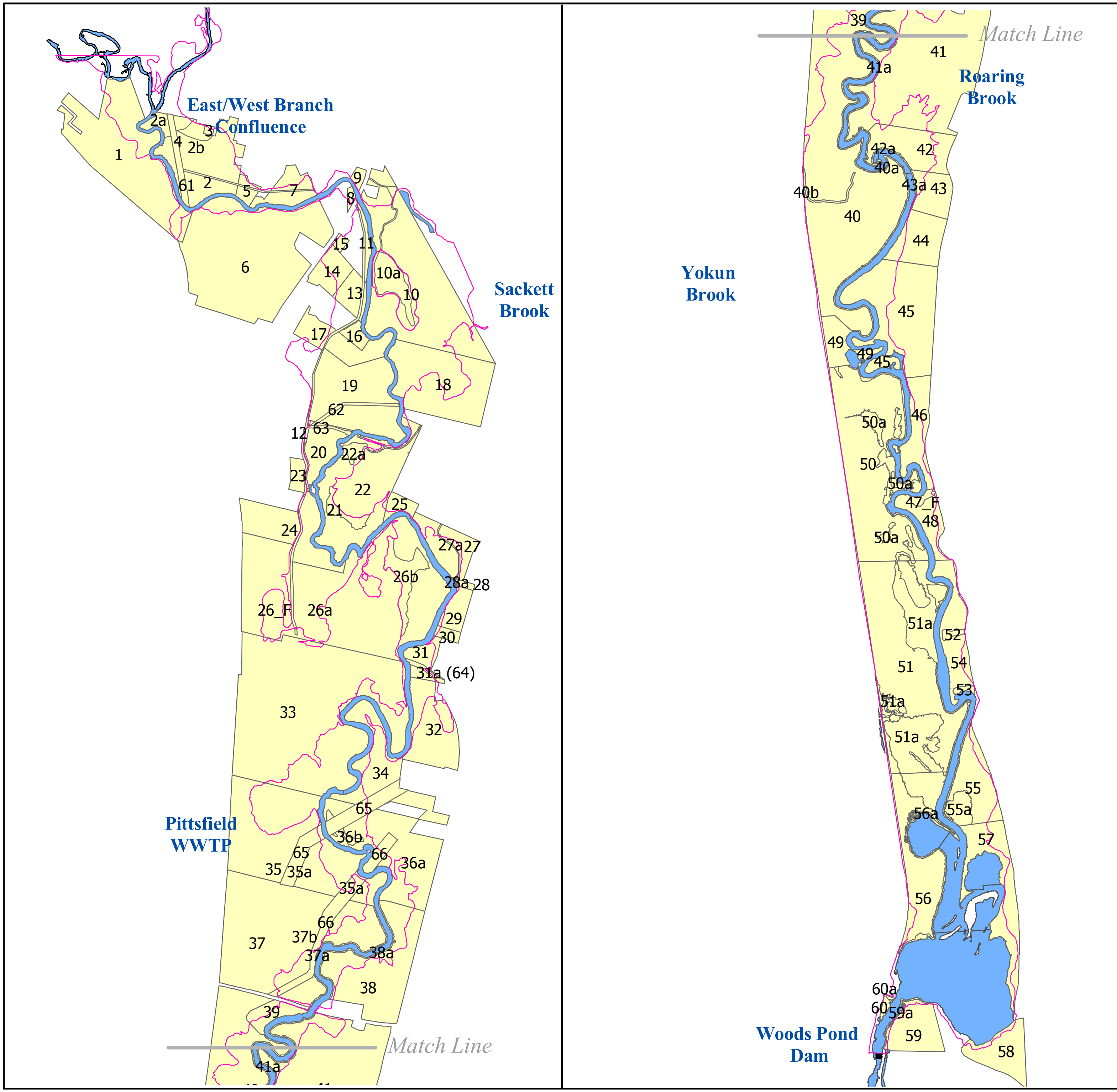

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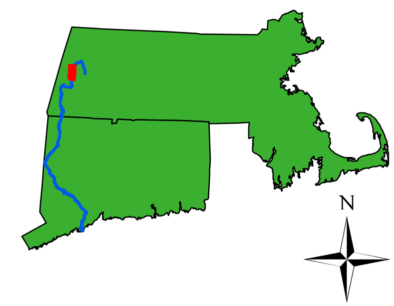

SCALE

0 0.25 0.5 Miles

LEGEND

- Exposure Areas
- 1 mg/kg PCB Isopleth
- Housatonic River
- Major Dams

Note: Exposure Areas in parentheses signify the overlapped utility corridors.

Figure 5-1a.
Map of exposure areas (EAs) for direct contact assessment in Reaches 5 & 6.

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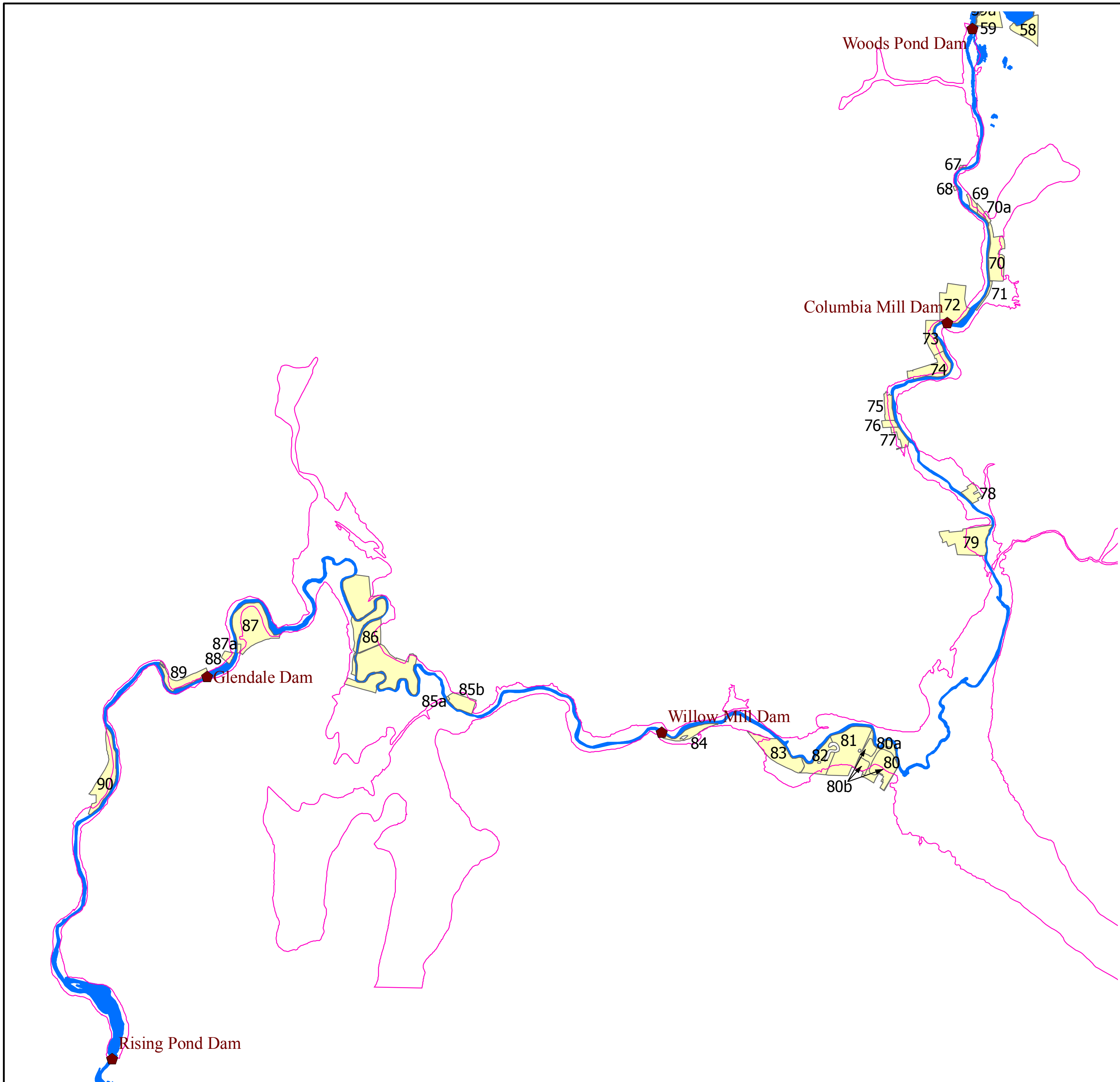

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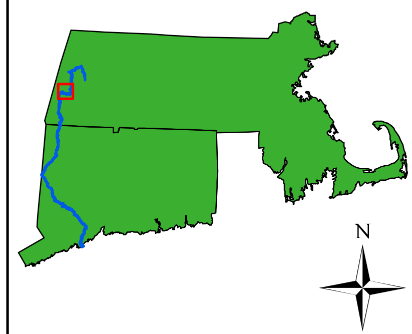

SCALE

0.5 0.25 0 0.5 Miles

LEGEND

Exposure Areas

100-year Floodplain

Housatonic River

Dams

Figure 5-1b.
Map of exposure areas (EAs) for direct contact assessment in Reaches 7 & 8.

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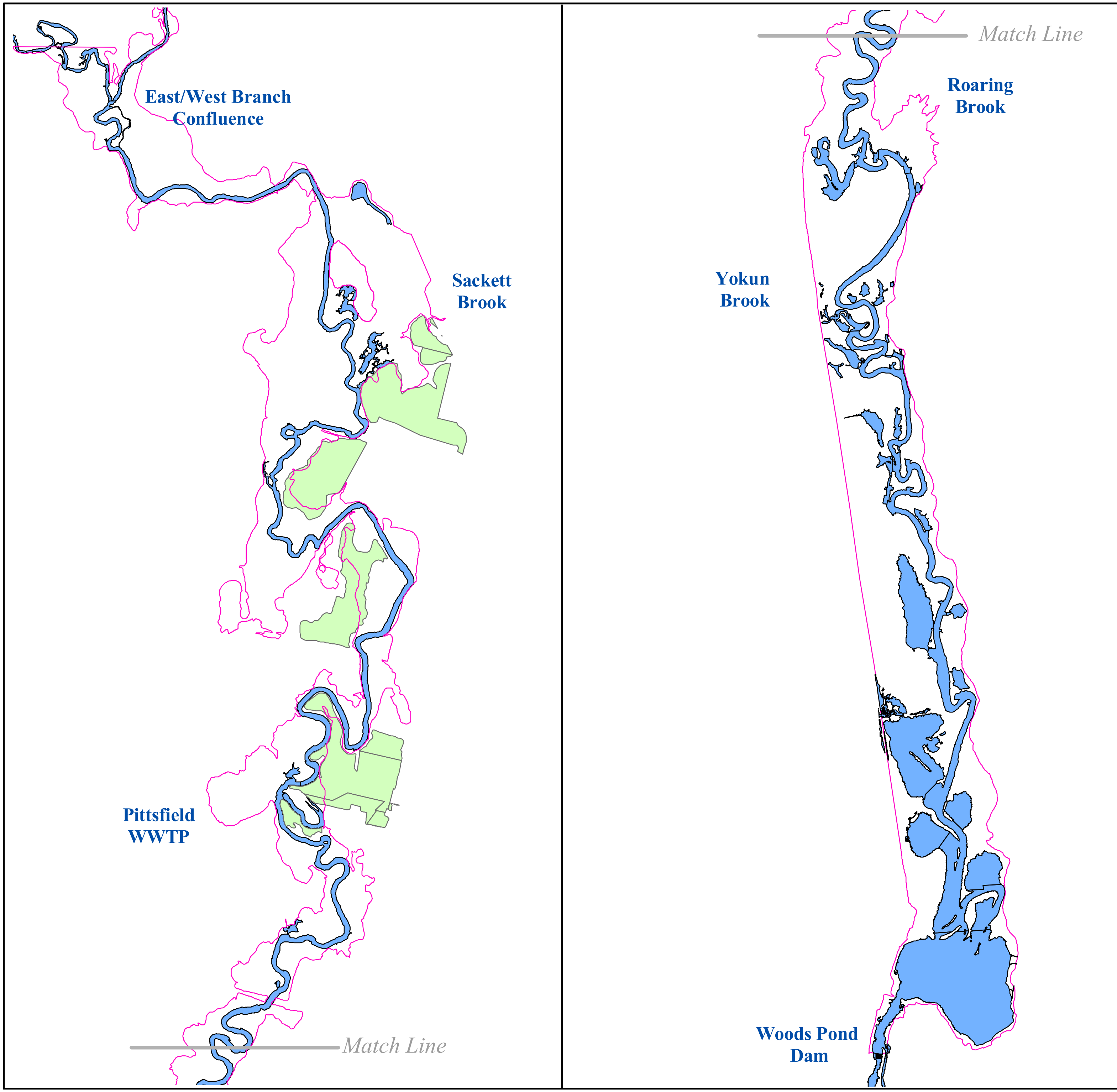

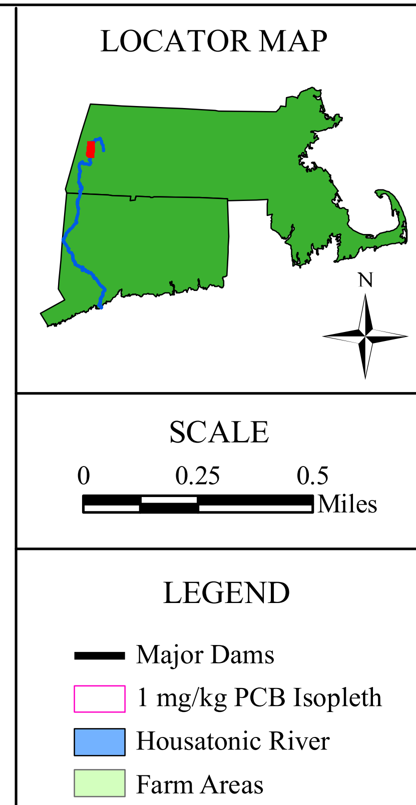

Figure 5-2a.
Map of farm areas for agricultural products consumption in Reaches 5&6.

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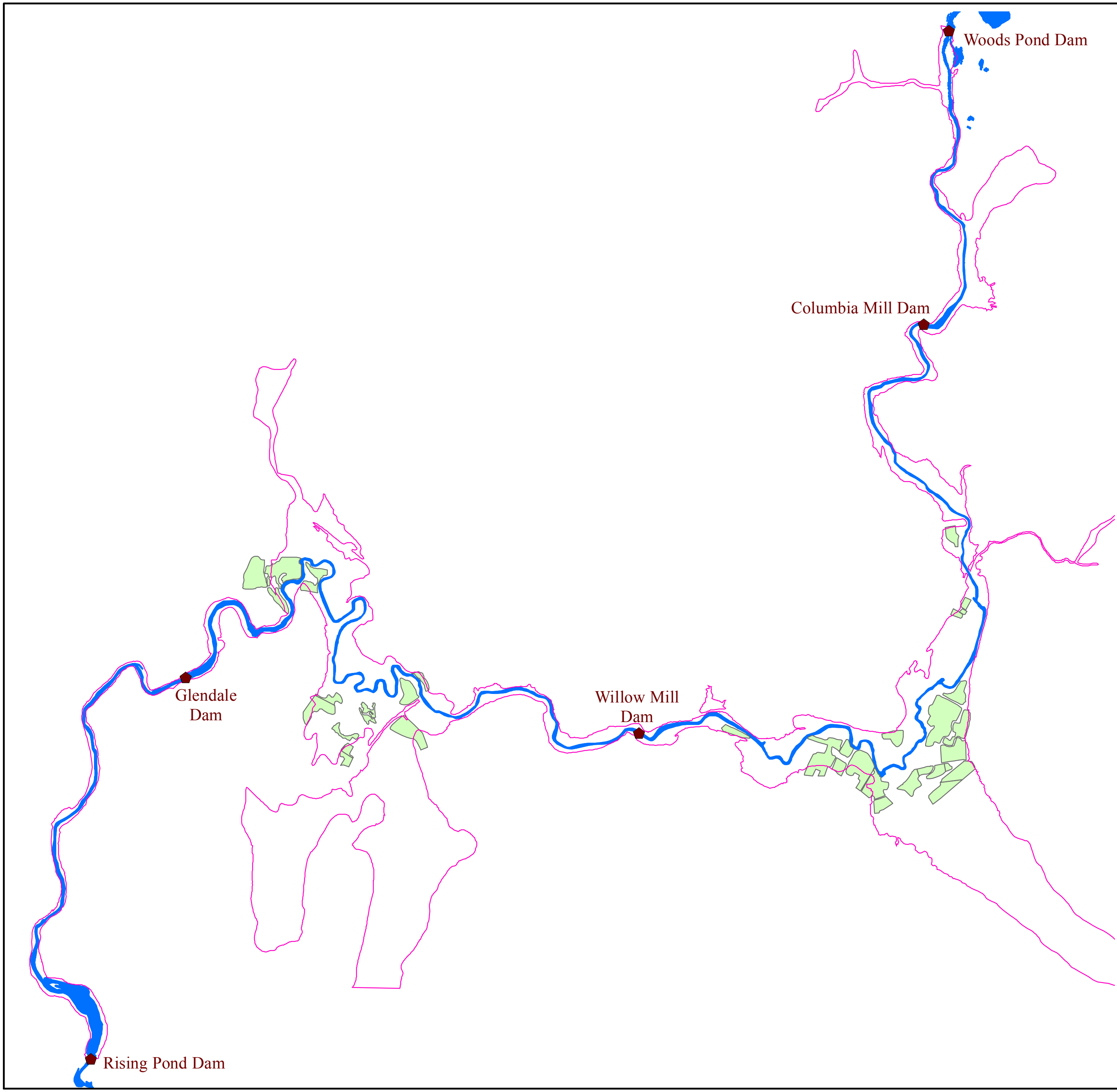

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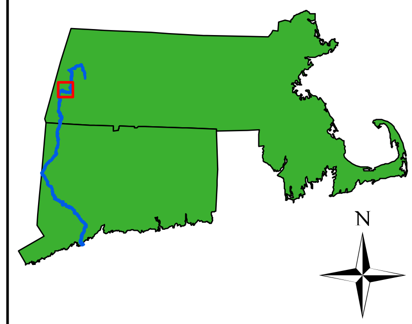

SCALE

0.5 0.25 0 0.5 Miles

LEGEND

Dams

100-year Floodplain

Housatonic River

Farm Areas

Figure 5-2b.
Map of farm areas for agricultural products consumption in Reaches 7&8.

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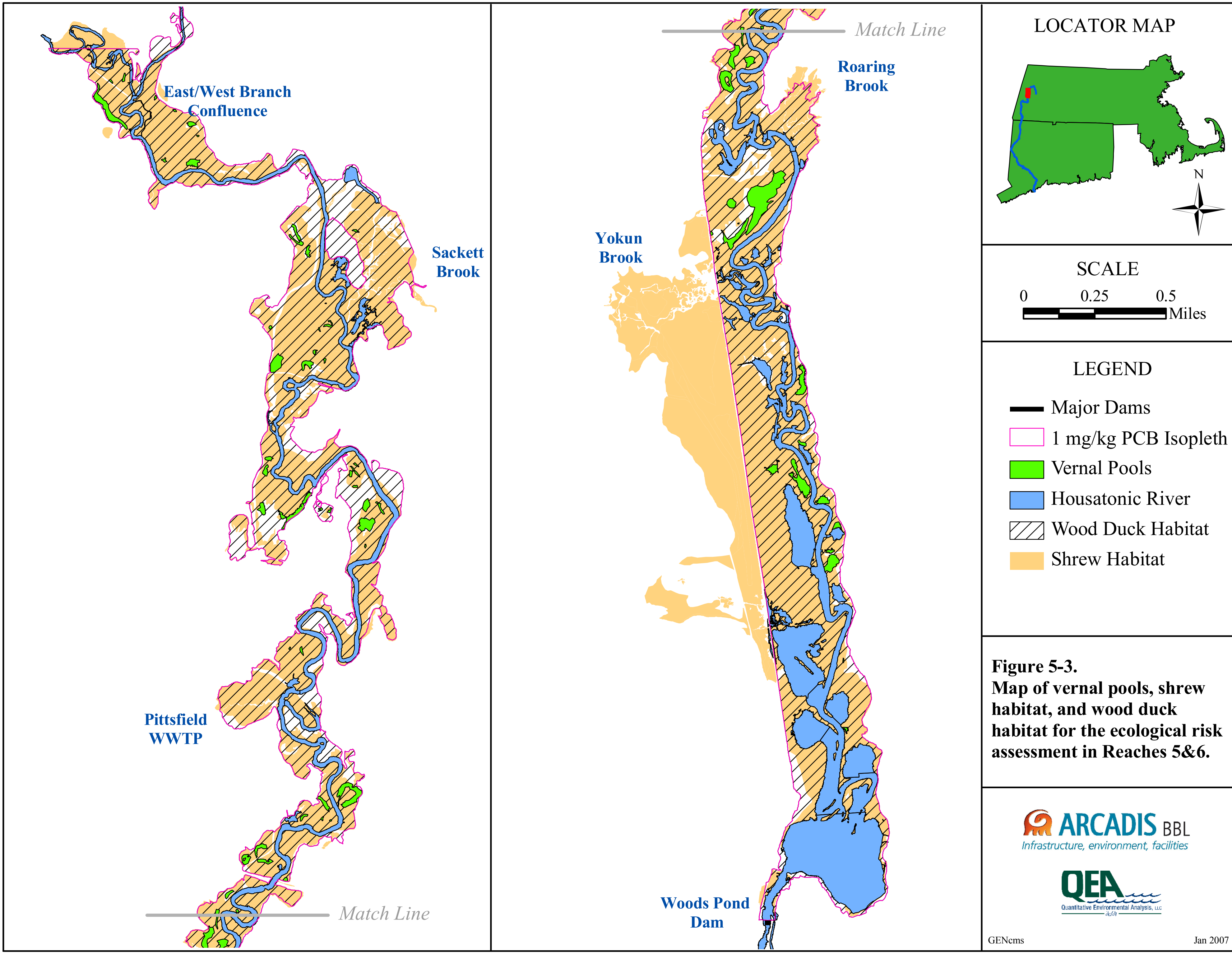

Figure 5-3.
Map of vernal pools, shrew habitat, and wood duck habitat for the ecological risk assessment in Reaches 5&6.

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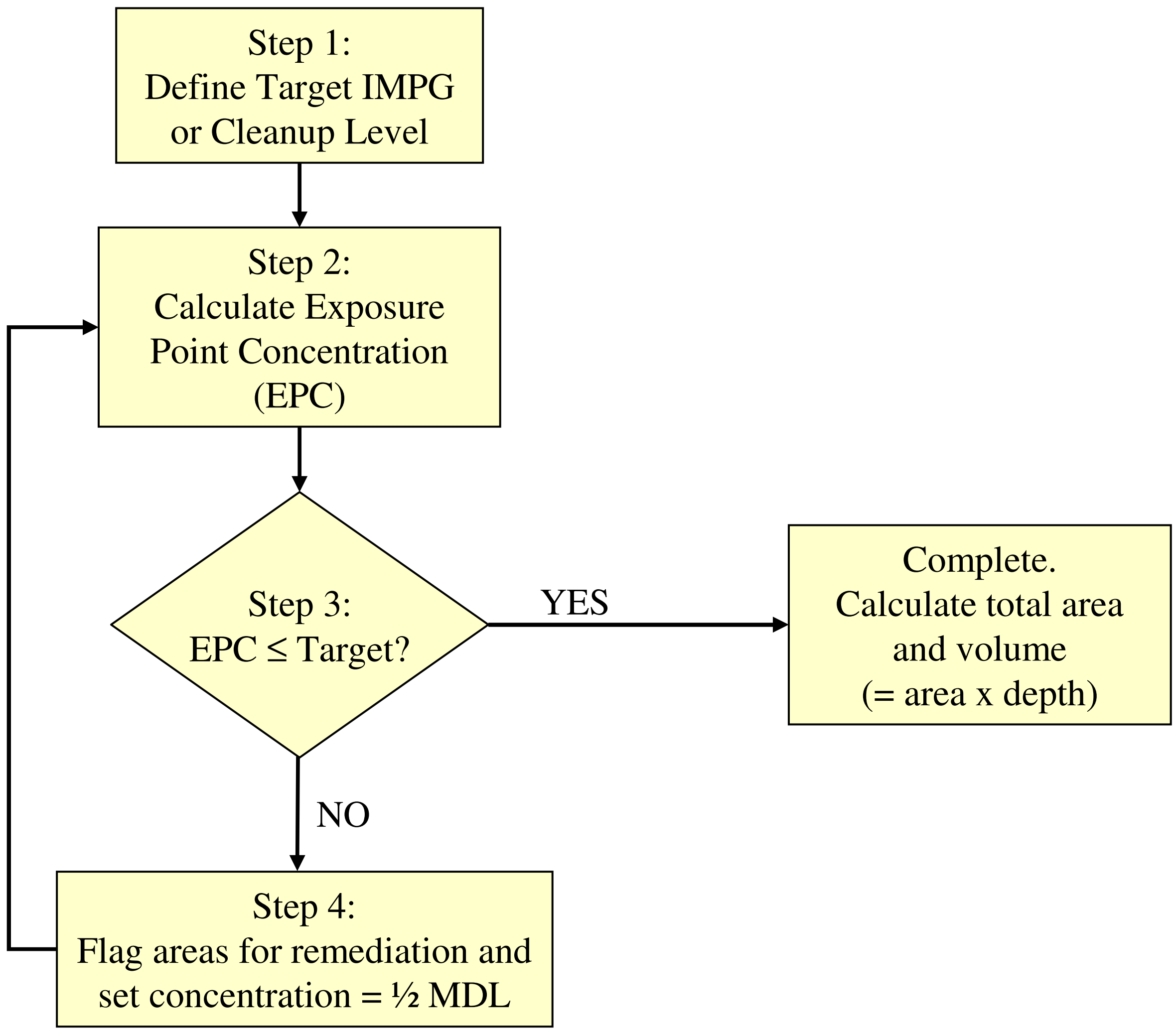

Figure 5-4.
Flow chart of the determination of areal extent and volume of floodplain soil remediation for alternatives based on achieving specified target average PCB concentrations.

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Appendices

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Appendix A

Assessment of Feasibility of Evaluating Dioxin TEQs in CMS

Appendix A. Assessment of Feasibility of Evaluating Dioxin TEQs in CMS

1. Introduction

In EPA's Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA), EPA quantitatively assessed potential risks associated with dioxin Toxicity Equivalency Quotients (TEQs) for certain exposure pathways and receptors. Dioxin TEQs are a measure of toxicity of different combinations of dioxins and dioxin-like compounds relative to the most potent dioxin congener, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Toxicity equivalency factors (TEFs) have been developed by the World Health Organization (WHO) to weight the toxicity of each dioxin and dioxin-like compound relative to 2,3,7,8-TCDD (van den Berg et al., 1998). Such TEFs have been developed for seven dioxin polychlorinated dibenzo-*p*-dioxin compounds, 10 polychlorinated dibenzofuran compounds, and 12 so-called "dioxin-like" PCB congeners. Under the approach used by EPA in its risk assessments, total TEQ concentrations were calculated by multiplying the concentration of each dioxin and furan compound and each dioxin-like PCB congener by its corresponding TEF developed by the WHO and published by van den Berg et al. (1998), and then summing those concentrations.

In addition, as required by EPA, Interim Media Protection Goals (IMPGs) for TEQs have been developed for the exposure pathways and receptors for which EPA quantitatively evaluated potential TEQ risks. Specifically, as described in Sections 3.2.3.2 and 3.2.4 of this CMS Proposal, IMPGs have been developed for TEQs in fish and waterfowl tissue based on human consumption, in fish tissue based on potential risks to fish, and in prey items of insectivorous birds and piscivorous mammals.[1]

However, the existing data available to support the calculation of TEQs in Rest of River media are limited. The same data sets that characterize PCBs in river sediment, floodplain soils, and fish tissue also contain measurements of congener-specific PCBs and dioxins/furans, but only for a subset of the samples. Of the samples used to quantify total PCBs, approximately 2% of floodplain soil samples, 5% of river sediment samples, and 90% of fish samples were analyzed for both congener-specific PCBs and dioxins/furans.

Given this more limited data set, GE has conducted an assessment of the feasibility of evaluating TEQs in the CMS, and specifically the feasibility of evaluating the ability of remedial alternatives under study to achieve the IMPGs for TEQs. The findings of this assessment are presented below.

2. Lack of Direct Means of Evaluating TEQs

There is no direct means to assess the ability of remedial alternatives to achieve specific TEQ concentrations, including the TEQ IMPGs. The EPA fate, transport, and bioaccumulation model that GE is required to use in the CMS under the Reissued RCRA Permit (see Section 5.2.2 of this Proposal) is limited to total PCBs and does not predict TEQ concentrations in water, sediment, or fish tissue. As a result, for the TEQ IMPGs that would apply to any of those media, there is no direct method for assessing an alternative's ability to achieve the IMPGs. Quantification of the short- and long-term effectiveness of potential remedial alternatives for sediments requires a mechanistic understanding of the various sources and sinks impacting TEQ distribution in the system.

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[1] In prior submissions to EPA, GE made clear its position that the current scientific evidence does not support the inclusion of "dioxin-like" PCB congeners in the TEQ approach, at least for human health assessment (e.g., GE, 2001, 2003; AMEC and BBL Sciences, 2003, 2005). Nevertheless, to be consistent with EPA's HHRA and ERA, as directed by EPA, GE developed these IMPGs for TEQs.

Lack of a TEQ modeling framework precludes any realistic projection of future TEQ distribution in water, sediment, and biota.

For floodplain soil, the available TEQ data are too limited to allow an evaluation of the ability of various floodplain soil remedial alternatives to achieve specific TEQ concentrations in soil, using the method described for PCBs in Section 5.3.3 and Appendix D of this Proposal. In any event, the only TEQ IMPGs that could potentially apply to a land-based medium are the IMPGs for insectivorous birds, which would apply to terrestrial as well as aquatic invertebrates. As discussed in Appendix B to this Proposal, target floodplain soil concentrations for TEQs could not be derived from these IMPGs due to TEQ-related data limitations.

3. Relationship Between TEQ and PCB Concentrations

Given the lack of any direct means to assess TEQs, the relationship between total PCB concentrations and total TEQ concentrations has been evaluated to assess the extent to which total PCB concentrations could serve as a possible surrogate for TEQ concentrations in the CMS. To do so, TEQ concentrations were calculated from the available data using the EPA approach described above and the mammalian TEF values published by van den Berg et al. (1998).[2] In calculating these TEQs, dioxin-like PCB congeners were conservatively assumed to account for 100% of the concentration when they were reported as coeluting with non-dioxin-like congeners. The TEQ concentrations were then plotted against the total PCB data from the same samples. Plots of TEQ concentrations versus total PCB concentrations are shown on Figures A-1 through A-4 for floodplain soil, sediment, fish fillets, and fish offal (the remaining carcass after fillets are removed from a fish sample), respectively. The extent to which non-detect data affects the TEQ-PCB relationships was evaluated in the analysis by preparing the plots with non-detects set to both zero and the method detection limit.

The relationship between TEQ and PCB concentrations in Rest of River floodplain soils (Figure A-1) exhibits a positive correlation, with a moderate level of variability (e.g., regression r^2 values of 0.7 to 0.8). However, the treatment of non-detects significantly affects the relationship, as the regression slopes differ by nearly a factor of two and differences of approximately an order of magnitude occur at the lower range of total PCB concentrations.

The same plot for sediment samples, which is shown on Figure A-2, indicates a weaker relationship between TEQ and PCBs in sediment (i.e., regression r^2 values of 0.4 to 0.6). Similar to the floodplain data, the treatment of non-detects has a large impact on the slope of the regression line and significantly impacts the TEQ-PCB relationship at lower concentrations.

The relationship between TEQ concentrations and PCB concentrations is plotted for the major fish species sampled from the Rest of River on Figures A-3 and A-4, for fillet and offal samples, respectively. Relative to floodplain soil and sediment, the TEQ-PCB relationships for fish tissue are much stronger (e.g., regression r^2 values greater than 0.95). For both fillets and offal, the relationship is stronger at higher concentrations, but weakens at the lower concentrations (e.g., 1 mg/kg or less). The amount of variability and impact that treatment of non-detects has on the relationship can be seen clearly at the lower concentration range. Furthermore, additional uncertainty in the relationship between TEQ and PCB for fillet-based concentrations is caused by the apparent presence of two populations of data at concentrations above 1 mg/kg (Figure A-3).

[2] Despite GE's position that the scientific evidence does not support the inclusion of PCB congeners in the TEQ approach, the "dioxin-like" PCB congeners were included in the TEQ calculations in this analysis to be consistent with the method used by EPA to calculate TEQ concentrations in the risk assessments.

Based on these analysis, GE has considered whether reliance on PCB concentrations could serve as an indirect means of assessing the ability of remedial alternatives to achieve the TEQ IMPGs. Since the TEQ IMPGs for human fish consumption, fish protection, and piscivorous mammals apply to fish tissue concentrations, the potential use of this approach in assessing achievement of those IMPGs depends on the correlation between total PCB concentrations and total TEQ concentrations in fish tissue. As shown above, while there is a reasonable linear relationship between PCBs and TEQs in fish tissue at higher PCB concentrations, the relationship breaks down at the lower range of PCB concentrations. Indeed, the relationship at the lower end of the PCB range is dependent on the assumptions used for non-detect PCB, dioxin, and furan congeners and is, consequently, unreliable as a predictor of TEQs. Thus, while the linear relationship between PCBs and TEQs at the higher end of the concentration range suggests that achieving the PCB IMPGs for fish tissue will also reduce TEQs in fish tissue, there is no reliable means to assess achievement of the TEQ IMPGs at the lower end of the PCB concentration range.

With respect to the IMPGs for insectivorous birds, target sediment and floodplain soil concentrations could not be developed for TEQs due to data limitations, as discussed in Appendix B. Further, as shown above, the relationships between PCB and TEQ concentrations in floodplain soil and sediment are not sufficiently strong to support use of PCB concentrations as a quantitative measure of TEQ concentrations.

In summary, the above analyses indicate qualitatively that implementation of remedial alternatives that would reduce PCB concentrations in the Rest of River would likely also reduce TEQ concentrations. However, the relationships are not sufficiently robust to allow a reliable quantitative evaluation in the CMS of the ability of remedial alternatives to achieve TEQ IMPGs.

4. Unreliability of TEQ Calculation Method

In addition to the above factors, a recent report by the National Research Council of the National Academy of Sciences (NAS) reviewing EPA's draft Dioxin Reassessment indicates that the method used by EPA to calculate TEQs could produce inaccurate results, at least for human exposures. As described in the HHRA, TEQs were calculated from measured concentrations of dioxin and furan compounds as well as "dioxin-like" PCB congeners by applying TEFs developed by the WHO (HHRA, Vol. IV, pp. 3-7, 3-8). Those TEQ calculations in the HHRA included all 12 of the PCB congeners for which WHO has developed TEFs. However, the NAS report noted that only four of those 12 PCB congeners were included in the Dioxin Reassessment and thus were evaluated by the NAS reviewers (NRC, 2006, p. 53). The report explained that the other eight PCB congeners with TEFs "were not considered at this time because of concerns about the accuracy of previous in vivo and in vitro toxicological (relative potency) results," given that a recent study found that many preparations of those PCBs actually contained some more potent dioxin-like congeners (*id.*, p. 53 n.2). Accordingly, use of a method that includes all 12 of these PCB congeners in the TEQ calculations could produce inaccurate results due to the inclusion of the eight congeners with potentially unreliable TEFs.

Moreover, the NAS report pointed out a significant deficiency in the use of the WHO TEFs to calculate TEQ concentrations and resulting toxicity in humans. The report stated: "[I]t remains to be determined whether the current WHO TEFs, which were developed to assess the relative toxic potency of a mixture to which an animal is directly exposed by dietary intake, are appropriate for the assessment of internal TEQ concentrations and potential toxic effects. The issue was not well described or well justified in the Reassessment and might be incorrect" (NRC, 2006, p. 61). It noted that, unless corrected values based on body burden TEFs are developed, "the overall TEQs estimated by use of intake TEFs could be inaccurate" (*id*.).

Thus, use of the TEF approach described in the HHRA could produce unreliable TEQ results. In the absence of a proven method to calculate TEQ concentrations in humans, the TEQ IMPGs based on human consumption of fish and waterfowl could not be reliably applied.

Finally, the NAS report casts doubt on whether those IMPGs themselves are reliable. For example, it states that the NAS committee that reviewed the EPA Dioxin Reassessment unanimously concluded that the current weight of scientific evidence favors use of a non-linear model for extrapolating carcinogenic effects of dioxin-like compounds at low doses (NRC, 2006, p. 135). However, in accordance with current EPA policy and EPA's HHRA, the Cancer Slope Factor (CSF) that was used in deriving the IMPGs for TEQs based on human consumption was based on a linear non-threshold model. If the model is inaccurate, the resulting IMPGs would likewise be inaccurate.

5. Conclusion

For the foregoing reasons, GE does not plan in the CMS to make a separate quantitative evaluation of the ability of the remedial alternatives under study to achieve particular TEQ concentrations, including the TEQ IMPGs. Instead, the evaluations of remedial alternatives in the CMS will focus on their effectiveness to address PCBs and their ability to achieve the IMPGs that have been developed for PCBs.

6. References

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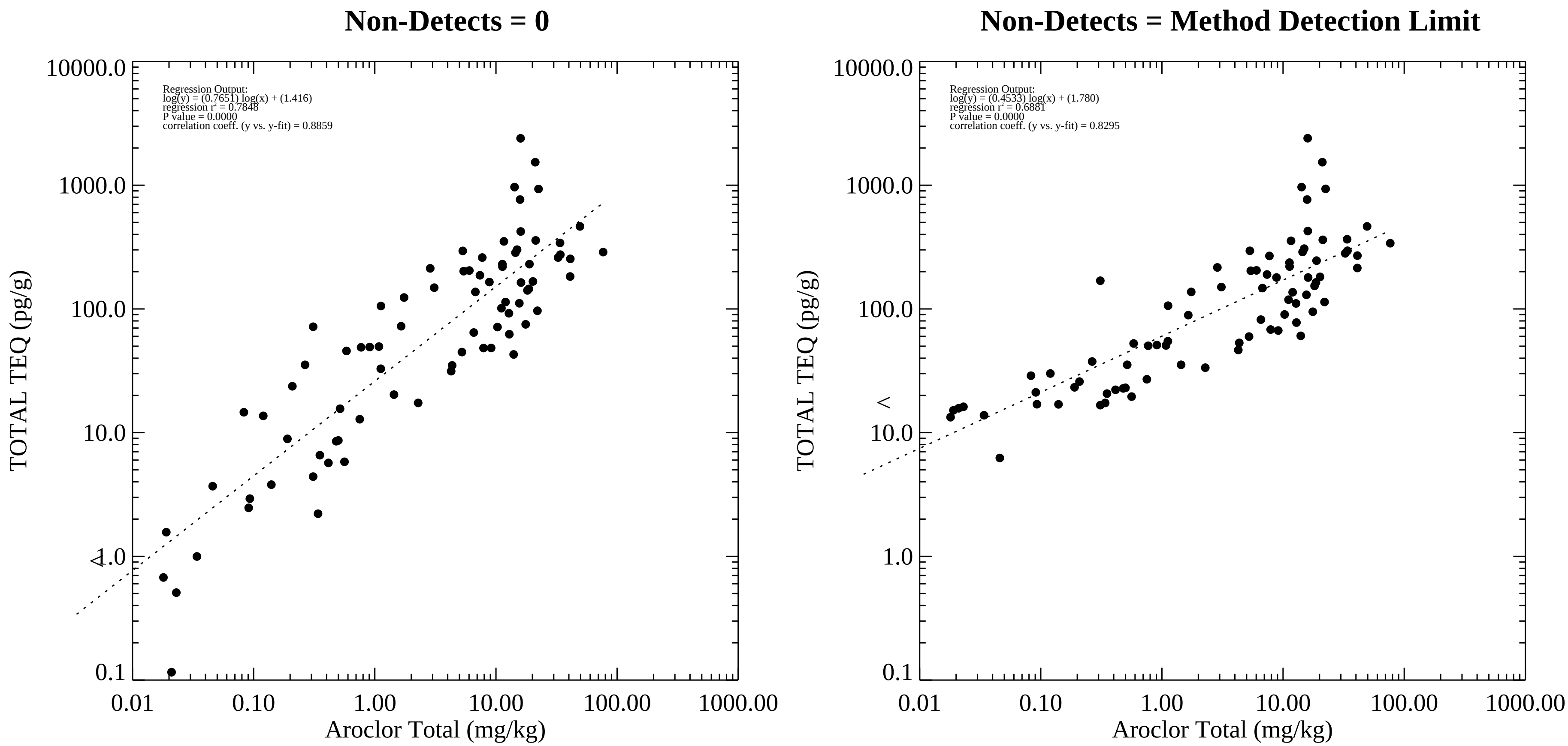

Figure A-1. Relationship between TEQ and Aroclor PCB concentrations in USEPA floodplain soil samples from the Housatonic River.

Notes: Assume PCB-123 and PCB-157 equal 100% of the coeluting congeners for 2001 samples. TEQ calculated for mammalian WHO TEF values.

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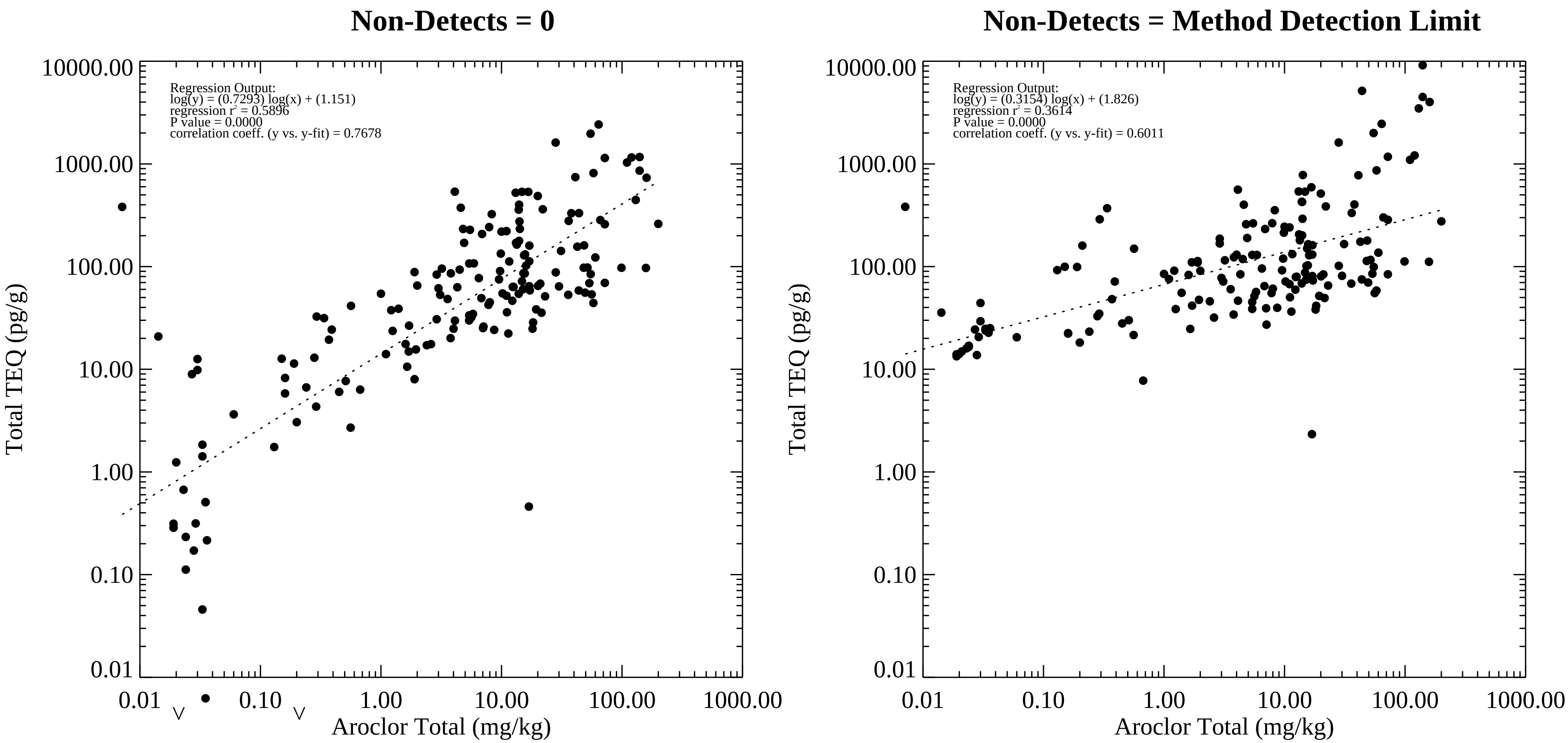

Figure A-2. Relationship between TEQ and Aroclor PCB concentrations in USEPA sediment samples from the Housatonic River.

Notes: Assume PCB-123 and PCB-157 equal 100% of the coeluting congeners. TEQ calculated for mammalian WHO TEF values.

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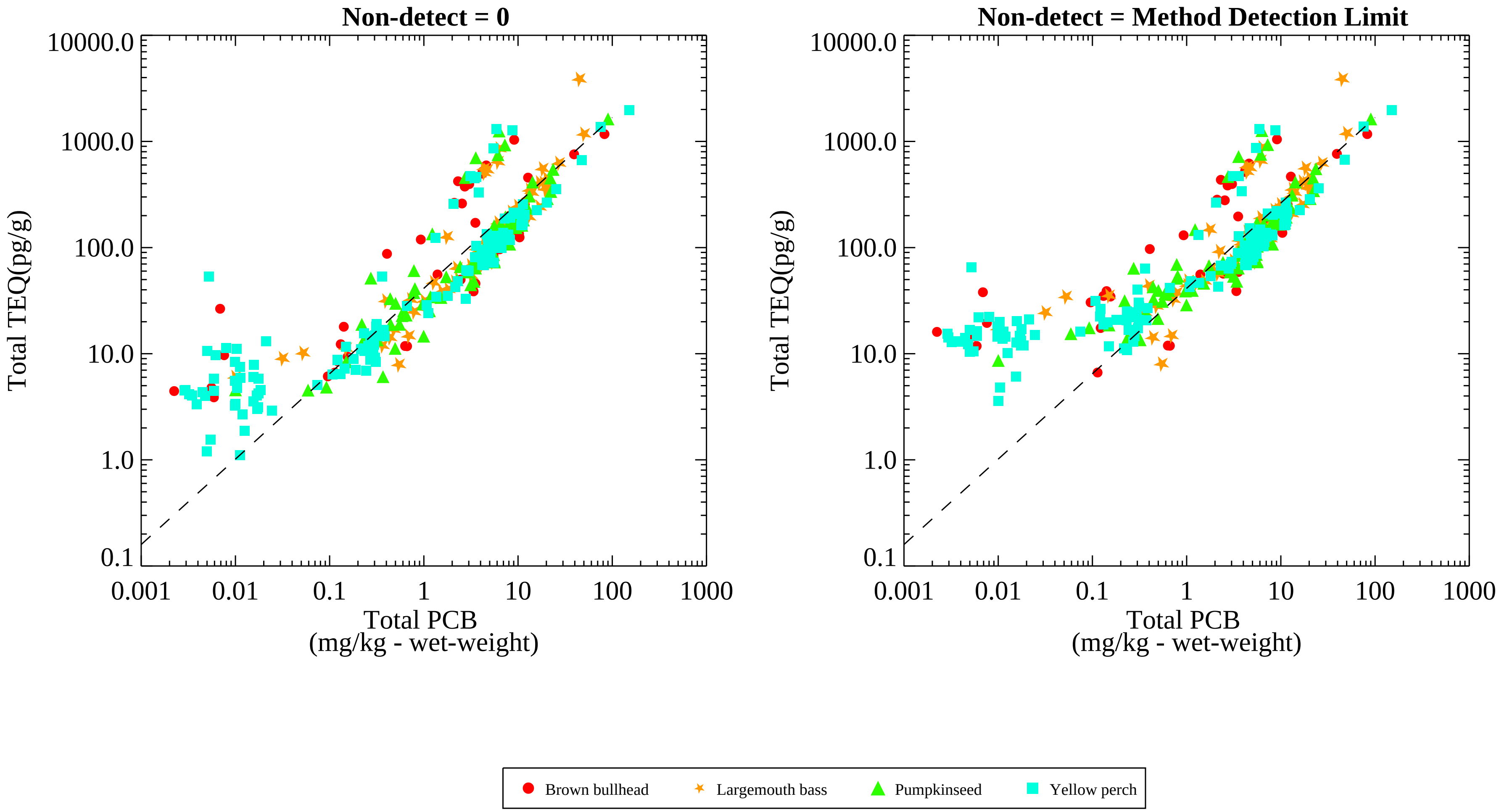

Figure A-3. Relationship between TEQ and total PCB concentration in fish fillet samples from the Housatonic River.

Notes: EPA fish tissue data (database release: January 2003). Total PCBs based on congener analysis.
Assume PCB-123 and PCB-157 equal 100% of the coeluting congeners. TEQ computed using mammalian WHO TEF values.
Dashed line is the regression line from offal tissue data

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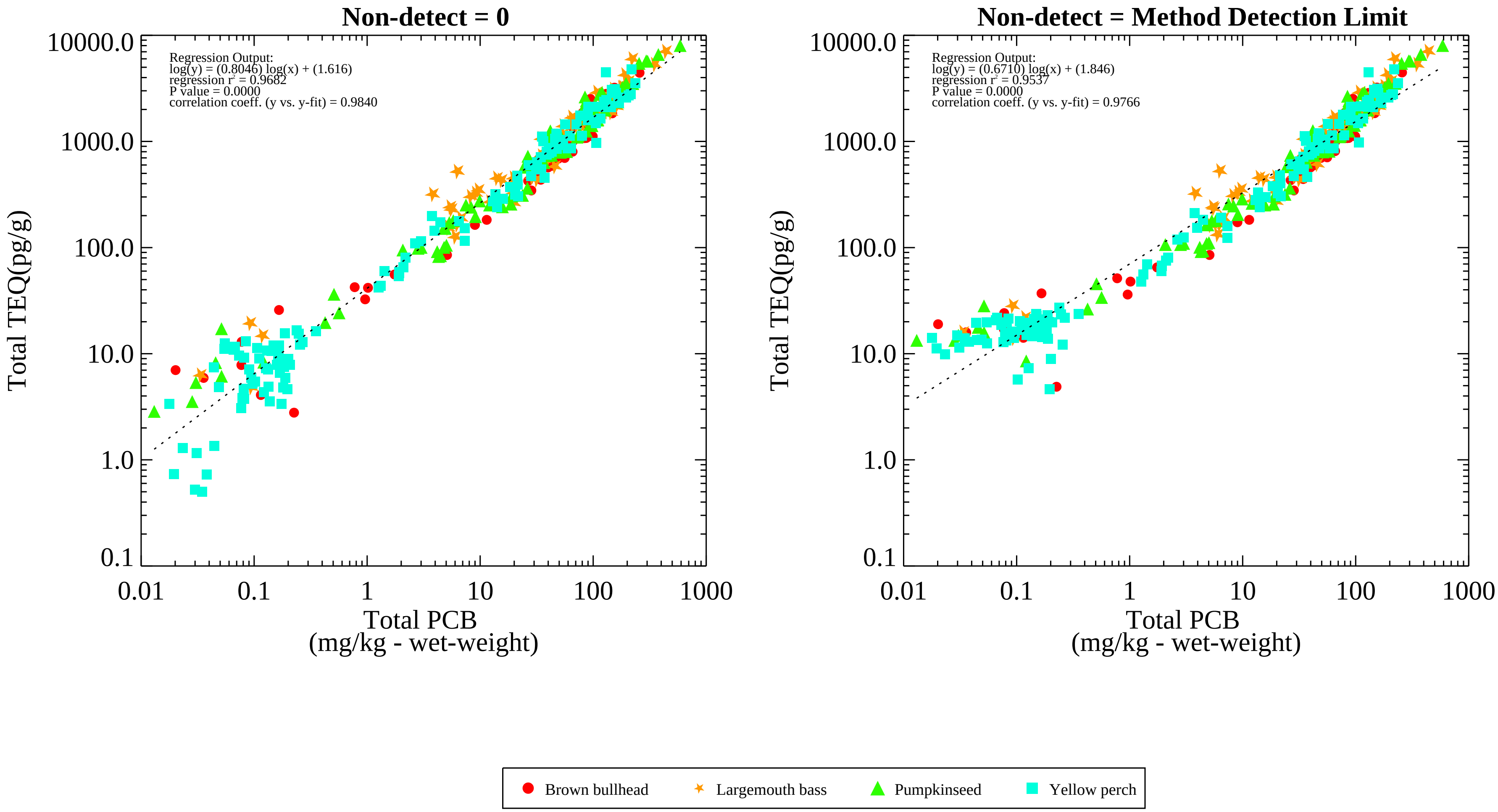

Figure A-4. Relationship between TEQ and total PCB concentration in fish offal samples from the Housatonic River.
Notes: EPA fish tissue data (database release: January 2003). Total PCBs based on congener analysis.
Assume PCB-123 and PCB-157 equal 100% of the coeluting congeners. TEQ computed using mammalian WHO TEF values.

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Appendix B

Development of Target Floodplain Soil Concentrations Associated with PCB IMPG for Insectivorous Birds

Appendix B. Development of Target Floodplain Soil Concentrations Associated with PCB IMPG for Insectivorous Birds

The Interim Media Protection Goals (IMPGs) specified in GE's revised IMPG Proposal (GE 2006) and approved by EPA for insectivorous birds were based on EPA's assessment of potential risks to the wood duck (which was selected as a representative species for the insectivorous birds that reside and breed in the Rest of River area), as described in EPA's Ecological Risk Assessment (ERA, EPA 2004). Those IMPGs apply to concentrations in wood duck invertebrate prey, which consists of both aquatic and terrestrial components. The IMPGs for wood duck invertebrate prey are 4.4 mg/kg for PCBs and 14 to 22 ng/kg for dioxin toxicity equivalents (TEQs).

These values cannot be applied directly in the Corrective Measures Study (CMS), which will evaluate the ability of various remedial alternatives to achieve certain target concentrations in media such as sediments and floodplain soils. Hence, GE has considered whether and how the IMPGs for insectivorous birds can be converted into sediment and/or floodplain soil concentrations for use in the CMS. This is complicated by the fact that the invertebrate portion of the wood duck's diet consists of both an aquatic invertebrate component (related to sediment) and a terrestrial invertebrate component (related to soil). In attempting to calculate target sediment and floodplain soil concentrations associated with the IMPGs, the concentration in one such component affects the allowable concentration in the other component – i.e., a higher concentration in sediments will require a lower concentration in soil in order to achieve the IMPG, and vice versa. Thus, it is not possible to derive a target concentration in one medium without knowing the concentration in the other.

In these circumstances, GE first selected a range of target sediment PCB concentrations that fall within the range of other sediment IMPGs (e.g., based on human direct contract and other ecological receptors). Those selected target PCB concentrations are 1, 3, 5, and 10 mg/kg. GE then calculated target floodplain soil concentrations associated with achieving the PCB IMPG of 4.4 mg/kg in wood duck invertebrate prey, assuming that the sediment PCB concentrations are equal to the selected target values. The underlying equation, assumptions and results of this analysis are summarized in Table B-1 and are detailed below. As also discussed below, target concentrations have not been proposed for TEQs in sediment or floodplain soil due to lack of adequate supporting information.

1. Derivation of Equation for Target Soil PCB Concentrations

As detailed in Attachment 29 of the revised IMPG Proposal, the prey-based IMPG is related to PCB concentrations in aquatic and terrestrial invertebrates as follows:

$$Ci = [(Pai \times Cai) + (Pti \times Cti)] / (Pai + Cai) \qquad \text{Eqn. 1}$$

Where:

Ci = concentration of PCBs in invertebrate prey of wood ducks (mg/kg)
Pai = proportion of wood duck diet comprised of aquatic invertebrates (unitless)
Cai = concentration of PCBs in aquatic invertebrates (mg/kg)
Pti = proportion of wood duck diet comprised of terrestrial invertebrates (unitless)
Cti = concentration of PCBs in terrestrial invertebrates (mg/kg).

By definition, the lipid-normalized concentration of PCBs in aquatic invertebrates is related to the organic carbon-normalized concentration of PCBs in sediment as follows (Ankley et al. 1992):

BSAF = (Cai / lipid) / (Csed / TOC) Eqn. 2

Where:

BSAF = biota-sediment accumulation factor (unitless)
Lipid = lipid content of aquatic invertebrates consumed by wood ducks (%)
Csed = concentration of PCBs in sediment (mg/kg)
TOC = total organic carbon content of sediment (%)

It follows that:

Cai = BSAF x Csed x 1/TOC x lipid Eqn. 3

By definition, the concentration of PCBs in terrestrial invertebrates is related to the concentration of PCBs in floodplain soil as follows:

Cti = BAF x Csoil Eqn. 4

Where:

BAF = soil-to-terrestrial invertebrate bioaccumulation factor (unitless)
Csoil = concentration of PCBs in floodplain soil (mg/kg)

Equations 3 and 4 may be substituted into Equation 1 to yield:

Ci = [(Pai x BSAF x Csed x 1/TOC x lipid) + (Pti x BAF x Csoil)] / (Pai + Pti) Eqn. 5

Solving Equation 5 for Csoil yields:

Csoil = [Ci x (Pai + Pti) – (Pai x BSAF x Csed x lipid x 1/TOC)] / Pti x BAF Eqn. 6

Equation 6 was then used to calculate the target soil concentration associated with the IMPG of 4.4 mg/kg for the invertebrate prey of wood ducks, based on the following assumptions regarding each of the equation's variables.

2. Assumptions

Input values for Equation 6 were preferentially selected based on site-specific data, as presented in the ERA and supporting studies and datasets. The bases for all input assumptions are detailed below.

Ci – The target PCB concentration in the wood duck invertebrate prey is set equal to the EPA-approved IMPG of 4.4 mg/kg, derived in the revised IMPG Proposal (GE 2006, Appendix D, Attachment 29).

Pai – The proportion of wood duck diet composed of aquatic invertebrates is set equal to 0.564, consistent with the ERA (Vol. 5, Table G.2-33) and based on the diet during the pre-laying period (Drobney and Fredrickson 1979, Drobney 1980).

Pti – The proportion of wood duck diet composed of terrestrial invertebrates is set equal to 0.196, consistent with the ERA (Vol. 5, Table G.2-33) and based on the diet during the pre-laying period (Drobney and Fredrickson 1979, Drobney 1980).

Csed - Given the inter-related but unknown values of Csed and Csoil, it is necessary to hold Csed at fixed target levels in order to generate the Csoil values that are associated with each sediment concentration. Values of 1, 3, 5 and 10 mg/kg were selected as example target sediment concentrations as discussed above.

BSAF – A biota-sediment accumulation factor of 1.8 is applied, based on the median BSAF derived from the 7-day bioaccumulation study on *Lumbriculus variegatus* (an aquatic invertebrate) conducted by EPA contractors (EVS 2003, Table 23) as part of the ERA (Vol. 4, p. D-39). The underlying data are reproduced in Table B-2.

Lipid – The lipid content of aquatic invertebrates was set equal to 0.80 percent, which is the median value calculated from EPA's 1999 data on shredders and predators collected from Reach 5, excluding three extreme values (ERA, Vol. 6, Appendix L). The underlying data are reproduced in Table B-3. Crayfish data were excluded from the calculation of lipid content because crayfish do not represent a significant proportion of wood duck's diet (ERA, Vol. 5, Table G.2-35).

TOC – The total organic carbon content of surface sediments (top 6 inches) was set equal to 6.9 percent, which is the spatially-weighted mean value for surface sediments in the Primary Study Area (PSA) including backwaters, calculated from EPA's monthly data exchange. The underlying data are reproduced in Table B-4, while the Theissen polygons used in the spatial weighting are shown in Figure B-1.

BAF – Bioaccumulation factors of 0.20 and 0.31 were calculated from EPA's dataset for concentrations of PCBs in co-located litter invertebrate and composite soil samples collected from three sampling stations (13, 14, and 15) within the PSA (ERA, Vol 6, Appendix L). The underlying data are reproduced in Table B-5. Although EPA contractors had sampled both earthworms and litter invertebrates from these three stations, earthworm data were excluded because they are not a component of wood ducks' pre-laying diet (ERA, Vol. 5, Table G.2-35). The BAF of 0.31 reflects the median of BAFs calculated from all litter invertebrate results, while the BAF of 0.20 is the median of BAFs calculated from only stations 13 and 14. In this case, exclusion of Station 15 results is based on the observation that concentrations of PCBs in soil at Station 15 are substantially lower than elsewhere in the PSA.

3. Results

As illustrated in Table B-1, based on the above assumptions, the target concentrations of PCBs in soil span a range from 36 mg/kg to 82 mg/kg, depending upon which target sediment concentration and BAF are applied. Ranges of target floodplain soil concentrations (based on use of BAFs of 0.31 to 0.20) associated with each of four target sediment concentrations are as follows:

Target Sediment PCB Concentration (mg/kg)	Target Soil PCB Concentration (mg/kg)
1	53 to 82
3	49 to 76
5	45 to 70
10	36 to 55

4. Discussion

Of the input variables used to generate the target soil concentrations, the most significant uncertainty and variability are associated with the BSAF and the BAFs. In order to verify the appropriateness of the BSAF and BAFs applied, we reviewed published papers on bioaccumulation of PCBs by aquatic and terrestrial invertebrates that form significant portions of the wood duck diet. As further detailed below, the literature review confirmed the appropriateness of the selected values.

As noted above, the BSAF used in the analysis (1.8) was derived from the 7-day *Lumbriculus variegatus* bioaccumulation study conducted as part of the ERA. Although 7 days is not likely a sufficient test duration to achieve steady state, the ERA (Vol. 4, p. D-39) noted that the values are consistent with equilibrium partitioning theory for PCBs, which yields a BSAF of approximately 2 (Parkerton 1993, McFarland 1994). The RFI Report for the Rest of River (QEA and BBL 2003, p. 8-51) reached a similar conclusion, noting that average or median BSAFs for benthic organisms generally lie between 1.5 and 3 for PCBs with logarithm of octanol-water partitioning coefficients (log Kow) in the range of 6 to 7 (Tracey and Hansen 1996; QEA 1999, Wong et al. 2001). Thus, the site-specific BSAFs are consistent with both equilibrium partitioning theory and literature-based field-derived BSAFs for species of aquatic invertebrates consumed by wood ducks.

The BAFs used in the analysis (0.20 and 0.31) were derived from co-located litter invertebrate and floodplain soil samples collected within the PSA as part of the ERA. The majority of published studies on bioaccumulation of PCBs by terrestrial invertebrates focus on earthworms. As previously discussed, because earthworms are not a significant portion of the wood duck's diet, they were excluded from the calculation of site-specific BAFs. Published earthworm bioaccumulation studies were excluded from the literature review for the same reason, which left two pertinent articles (Blankenship et al. 2005 and Paine et al. 1993).

Blankenship et al. (2005) reported total PCB concentrations for above-ground terrestrial invertebrates (excluding earthworms) and co-located soil samples collected from the Kalamazoo River Superfund Site. Arithmetic mean concentrations of total PCBs in terrestrial invertebrates and soil were reported to be 0.34 and 6.5 mg/kg, respectively, which yield a BAF of 0.05. Geometric mean concentrations in invertebrates and soil were 0.10 and 4.7 mg/kg, respectively, which yield a BAF of 0.02. In a 14-day bioaccumulation test on uptake of Aroclor 1254 in soil by house crickets, Paine et al. (1993) observed BAFs ranging from 0.07 to 0.19 for soil concentrations ranging from 100 to 2,000 mg/kg. The BAF associated with the lowest soil concentration (100 mg/kg) was 0.11. Relative to these two studies, the site-specific BAFs of 0.20 and 0.31 are conservative.[1]

Table B-6 presents alternative target soil concentrations, calculated using literature-derived BSAFs and BAFs, associated with each of the selected target sediment concentrations. Using these alternative assumptions, target soil concentrations range from 64 to 331 mg/kg. Thus, the target soil concentrations calculated using site-specific BSAF and BAFs are below or well within the range of target soil concentrations calculated using literature-derived BSAFs and BAFs, demonstrating the conservatism of the site-specific values.

In conclusion, target floodplain soil PCB concentrations that are associated with the four selected target sediment concentrations and based on the PCB IMPG of 4.4 mg/kg in the invertebrate prey of wood ducks range from 36 to 82 mg/kg. This analysis is based on site-specific data presented in the ERA and is conservative relative to available data published in the peer-reviewed literature.

[1] The BAF and the target soil concentration are inversely related, such that higher BAFs will yield lower target soils concentrations.

5. Evaluation of TEQs

This analysis does not propose target concentrations of TEQs in soil due to TEQ-related data limitations. Calculation of target soil concentrations for TEQs would require site-specific sediment-to-aquatic insect BSAFs and soil-to-terrestrial invertebrate BAFs. Calculation of site-specific BSAFs and BAFs would require evaluation of congener analyses of co-located sediment and aquatic invertebrate samples, as well as co-located floodplain soil and terrestrial invertebrate samples. The co-located sediment and aquatic invertebrate samples that support calculation of site-specific PCB BSAFs (discussed above) were analyzed for total PCBs, but not individual congeners. While terrestrial invertebrate samples were analyzed for congeners, the co-located soil samples were not.

In the absence of site-specific BSAFs and BAFs for TEQs, literature-derived BSAFs and BAFs might be considered. However, TEQs represent mixtures of congeners normalized to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) on a toxicological basis. The toxicity equivalency factors (TEFs) used to normalize mixtures are not relevant to bioaccumulation potential. That is, mixtures that are theoretically toxicologically equivalent are not necessarily equivalent with respect to bioaccumulation potential because different mixtures with the same TEQ concentration may be composed of congeners with quite different partitioning behaviors. Consequently, use of literature-derived BSAFs and BAFs for 2,3,7,8-TCDD was judged too uncertain for use in this application.

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Table B-1. Target Soil Concentrations Protective of Wood Ducks: Site-Specific BSAF and BAFs

Variable	Description	Value	Units	Basis
Ci	Target concentration of PCBs in invertebrate portion of diet	4.4	mg/kg	IMPG proposal
Pai	Proportion of diet comprised of aquatic invertebrates	0.564	unitless	ERA
Pti	Proportion of diet comprised of terrestrial invertebrates	0.196	unitless	ERA
Csed	Target concentration of PCBs in sediment	Range (see below)	mg/kg	Assumption
BSAF	Biota-sediment accumulation factor	1.8	unitless	Table B-2
Lipid	Lipid content of aquatic invertebrates	0.80	%	Table B-3
TOC	Total organic carbon in sediment	6.9	%	Table B-4
BAF	Soil bioaccumulation factor	Range (see below)	unitless	Table B-5
Csoil	Target concentration of PCBs in soil = [Ci x (Pai + Pti) - (Pai x BSAF x Csed x Lipid x 1/TOC)] / Pti x BAF		mg/kg	Calculated

Csed (mg/kg)	BSAF (unitless)	BAF (unitless)	Csoil (mg/kg)
1	1.8	0.31	53
		0.20	82
3	1.8	0.31	49
		0.20	76
5	1.8	0.31	45
		0.20	70
10	1.8	0.31	36
		0.20	55

Table B-2. Derivation of BSAF for Total PCBs

Station Identification Number	BSAF
011	2.39
398	NC
019	6.07
428	1.16
389	NC
031	0.80
Median	1.8

Notes:
Source: EVS 2003, Table 23. Based on 7-day in situ bioaccumulation test on *Lumbriculus variegatus*, using 7-day average total organic carbon
BSAF = biota-sediment accumulation factor
NC = not calculable because total organic carbon content was below detection limit

Table B-3. Lipid Fraction of Aquatic Invertebrate Prey of Wood Ducks

Sample Identification Number	Predator or Shredder	River Mile	Sampling Date	Lipids (%)
H3-TMI04001-P001	PR	133.07	07-Jul-99	0.50
H3-TMI04001-S001	SH	133.07	07-Jul-99	1.20
H3-TMI04002-S001	SH	133.07	08-Jul-99	0.10 a
H3-TMI04003-P001	PR	133.07	08-Jul-99	0.40
H3-TMI05001-P001	PR	132.07	01-Jul-99	0.80
H3-TMI05001-S001	SH	132.07	01-Jul-99	0.90
H3-TMI07001-S001	SH	130.07	30-Jun-99	1.30
H3-TMI09001-S001	SH	128.07	08-Jul-99	0.70
H3-TMI11001-P001	PR	126.07	30-Jun-99	11.70 a
H3-TMI11001-S001	SH	126.07	30-Jun-99	0.10 a
H3-TMI12001-P001	PR	125.07	30-Jun-99	0.40
H3-TMI12001-S001	SH	125.07	30-Jun-99	1.00
H3-TMI13001-P001	PR		09-Jul-99	0.90
H3-TMI13001-S001	SH		09-Jul-99	0.20
Median, excluding extreme values				0.80

Notes:

a. Extreme value, qualitatively designated as an outlier

Table B-4. Total Organic Carbon Content of Surface Sediment in the Primary Study Area

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
S1391204	3%	2,840	88
S1391205	15%	1,396	206
S1391206	27%	1,181	313
S1391207	29%	1,020	301
S1391208	7%	1,336	97
S1391209	17%	2,312	384
S1391210	14%	2,890	416
S1391211	14%	2,185	295
S1391212	13%	2,358	297
S1391213	9%	3,187	284
SE000337	5%	4,306	236
SE000802	36%	6,986	2,513
SE000871	3%	3,253	82
SE000872	5%	6,127	321
SE001000	17%	4,813	804
SE001001	20%	4,789	972
SE001002	21%	4,665	961
SE001015	12%	9,923	1,201
SE001016	5%	5,031	227
SE001004	8%	7,317	614
SE001005	2%	4,616	83
SE001006	2%	3,174	48
SE001007	3%	9,920	248
SE001008	1%	7,666	107
SE001491	24%	5,151	1,246
BH000532	5%	355	17
BH000533	0.0%	602	0
BH000534	0.2%	1,050	2
BH000535	1%	294	3
BH000536	1%	859	6
BH000537	0.0%	606	0
BH000538	3%	1,946	68
BH000539	6%	362	20
SD105501	1%	915	11
SD105502	0.1%	390	0
SD105601	2%	563	13
SD105602	1%	1,412	17
SD105603	0.5%	879	4
SD105701	0.2%	335	1
SE001025	0.4%	770	3
SE001026	3%	415	13
SE001054	2%	680	16
SE001056	1%	1,896	24

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SD105702	0.3%	2,390	7.9
SD105703	1%	2,144	12
SD105801	1%	411	2.2
SD105802	2%	156	2.5
SD105803	1%	347	3.5
SD109031	4%	421	15
SD109032	0.5%	550	2.6
SD109033	3%	1,716	44
SD109041	9%	314	28
SD109042	0.3%	147	0.48
SD109043	25%	140	35
SD109051	1%	1,940	13
SD109052	1%	657	3.3
SD109053	1%	516	5.6
SD109061	1%	118	0.90
SD109062	1%	162	1.1
SD109063	2%	1,389	21
SD115901	0.2%	96	0.22
SD115902	0.4%	418	1.8
SD115903	0.3%	552	1.5
SD116001	3%	342	9.4
SD116002	0.1%	427	0.51
SD116003	1%	1,032	7.6
SD116101	2%	205	3.7
SD116102	1%	473	2.6
SD116103	3%	328	10
SD119071	2%	873	16
SD119072	2%	548	8.3
SD119073	3%	537	19
SD119081	2%	1,327	28
SD119082	0.3%	619	2.1
SD119083	2%	718	17
SD119093	6%	736	46
SD126201	1%	66	0.81
SD126202	1%	602	4.7
SD126203	5%	702	36
SD126301	3%	413	12
SD126302	1%	371	3.7
SD126303	3%	688	21
SE001129	4%	410	17
SE001130	0.1%	495	0.37
SE001131	0.3%	382	1.2
SE001132	1%	1,137	5.9

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SD126401	6%	887	56
SD126402	3%	1,279	38
SD126403	1%	883	12
SD126501	2%	149	3.4
SD126502	0.3%	147	0.42
SD126503	2%	281	5.1
SD129101	2%	617	9.3
SD136601	3%	1,138	33
SD136602	1%	721	3.8
SD136603	7%	748	51
SD139114	2%	1,206	21
SD139115	1%	803	4.4
SD139116	2%	1,599	25
SE000120	3%	726	25
SE000121	4%	793	28
SE000122	3%	170	4.5
SE000123	2%	1,263	23
SE000124	2%	1,199	19
SE000128	2%	560	11
SE000129	1%	899	12
SE000130	6%	459	26
SE000131	2%	756	12
SE000132	9%	924	88
SE000133	2%	1,299	32
SE000134	0.3%	1,006	3.1
SE000135	0.4%	805	3.1
SE000136	5%	1,231	59
SE000137	6%	260	15
SE000138	1%	1,634	17
SE000139	8%	1,439	112
SE000140	5%	1,716	90
SE000141	7%	1,878	134
SE000142	4%	1,791	68
SE000143	2%	940	17
SE000145	10%	19	2.0
SE000146	1%	1,155	17
SE000147	3%	745	19
SE000148	1%	768	7.5
SE000149	2%	2,346	36
S1391217	8%	2,399	192
S1391218	0.1%	2,669	1.6
S1391219	6%	1,682	105
S1391220	8%	2,380	198

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000171	5%	2,356	109
SE000180	3%	253	8.1
SE000269	6%	15	0.94
SE000270	9%	9	0.85
SE000271	3%	70	2.1
SE000272	4%	621	25
SE000273	1%	54	0.69
SE000274	4%	783	33
SE000302	3%	126	3.8
SE000303	1%	21	0.23
SE000304	2%	853	15
SE000305	9%	77	6.8
SE000306	9%	9	0.86
SE000307	6%	52	3.3
SE000389	5%	27	1.2
SE000480	0.0%	128	0.0078
SE000481	0.3%	23	0.072
SE000487	8%	2	0.16
SE000726	1%	254	3.2
SE000727	1%	57	0.71
SE000728	1%	79	0.86
SE000729	1%	290	2.7
SE000732	6%	2,256	134
SE000733	3%	2,158	62
SE000734	2%	2,206	45
SE000770	1%	138	1.5
SE000809	5%	1,146	63
SE000814	7%	1,465	95
SE000844	5%	302	14
SE000859	1%	975	12
SE000868	5%	206	11
SE000886	5%	338	18
SE000887	13%	557	71
SE000888	3%	457	13
SE000897	1%	2,976	15
SE000906	3%	142	4.8
SE000907	1%	447	6.5
SE000915	2%	262	5.2
SE001024	0.5%	333	1.6
SE000762	5%	737	37
SE000763	8%	3,641	286
SE000764	0.2%	6,519	16
SE000765	11%	1,435	155

Table B-4. Total Organic Carbon Content of Surface Sediment in the Primary Study Area

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE001059	0.5%	2,072	10
SE001060	5%	715	33
SE001061	3%	1,060	30
SE001063	1%	1,189	8
SE001064	1%	975	7
SE001065	0.4%	853	4
SE001068	0.4%	3,135	11
SE001069	3%	1,556	53
SE001071	4%	3,137	138
SE001073	2%	921	15
SE001075	1%	1,455	12
SE001077	2%	2,678	47
SE001078	3%	744	21
SE001080	4%	2,314	102
SE001081	7%	743	53
SE001082	2%	3,231	54
SE001083	1%	2,570	14
SE001084	3%	2,333	80
SE001085	6%	600	34
SE001086	2%	1,021	17
SE001088	2%	946	20
SE001089	1%	1,155	15
SE001112	6%	858	49
SE001113	11%	847	94
SE001114	3%	1,331	36
SE001115	2%	921	21
SE001116	1%	378	3
SE001117	8%	282	21
SE001119	2%	2,411	36
SE001121	4%	501	20
SE001122	3%	932	25
SE001123	10%	954	94
SE001124	5%	2,348	118
SE001127	5%	579	30
SE001128	9%	1,269	108
FL000316	28%	121	34
FL000318	19%	221	42
FL000324	6%	2,570	150
FL000325	1%	2,666	21
FL000327	7%	418	30
FL000341	37%	134	49
FL000343	26%	204	54
FL000346	24%	197	47
SE001135	0.1%	849	0.64
SE001136	0.1%	575	0.43
SE001137	0.1%	1,475	1.1
SE001147	7%	3,421	237
SE001404	6%	10	0.59
SE001493	14%	492	67
SE001494	11%	1,167	126
SEEC0020	2%	63	1.4
SEEC0021	1%	32	0.44
SEEC0022	1%	1,053	14
SEEC0023	6%	28	1.6
SEEC0029	7%	69	4.8
SEEC0030	7%	30	2.1
BH000530	1%	773	4.4
BH000531	1%	1,139	14
SD095401	1%	1,303	11
SD095402	1%	398	2.7
SD095403	4%	306	12
SE000223	1%	976	6.9
SE000281	2%	678	15
SE000282	1%	16	0.21
SE000283	2%	1,947	35
SE000730	3%	1,978	56
SE000731	0.2%	2,672	4.3
SE000999	2%	1,383	26
SE001051	0.4%	318	1.4
SE001052	0.3%	2,112	6.5
SE001066	1%	894	9.4
SE001067	1%	1,270	16
SE001138	0.3%	1,797	5.1
SE001139	1%	594	5.9
SE001414	1%	204	1.1
S1391214	8%	3,332	270
S1391215	5%	3,644	196
S1391216	6%	2,795	164
SE000279	9%	18	1.5
SE000280	5%	456	24
SE000812	9%	1,706	150
SE000885	10%	410	42
SE001062	4%	2,776	123
SE001076	2%	1,598	26
SE001087	9%	1,110	103
SE001090	20%	22	4.3
S1391221	15%	2,772	417
S1391222	24%	1,975	472
SD136701	28%	1,860	529
SD136702	4%	460	20
SD136703	12%	1,288	148
SD136751	2%	678	13
SD136753	1%	619	5.2
SE000224	6%	1,537	99
SE000225	8%	1,183	89
SE000226	9%	2,017	174
SE000230	8%	1,298	110
SE000231	2%	913	21
SE000233	5%	1,281	58
SE000234	9%	1,584	137
SE000235	7%	3,511	240
SE000236	10%	2,733	273
SE000237	8%	4,860	404
SE000238	2%	1,840	29
SE000239	2%	1,403	34
SE000240	3%	1,289	38
SE000241	5%	1,400	63
SE000242	5%	707	35
SE000243	5%	1,117	61
SE000244	6%	1,778	99
SE000245	8%	1,008	83
SE000246	1%	1,280	16
SE000247	4%	1,059	42
SE000248	4%	1,841	66
SE000249	4%	981	37
SE000250	6%	3,376	217
SE000251	8%	5,295	423
SE000252	9%	2,437	218
SE000748	1%	679	9.3
SE000759	4%	458	18
SE000761	10%	1,210	115
SE000882	13%	2,741	347
SE000883	4%	1,753	72
SE000898	10%	3,458	337
SE000983	21%	3,484	718
SE000984	10%	3,396	343
SE000985	16%	2,969	485
SE000986	30%	2,762	828
SE000987	21%	2,723	570
SE000766	10%	1,992	200
SE000767	9%	1,670	144
SE000768	5%	1,228	58
SE000769	5%	272	14
SE000804	11%	4,779	524
SE000845	2%	671	15
SE000869	5%	2,267	115
SE000870	3%	7,861	198
SE000873	8%	4,778	399
SE000876	3%	478	17
SE000891	4%	1,450	64
SE000892	6%	1,214	76
SE001009	1%	15,222	135
SE001010	12%	1,354	156
SE001011	9%	5,530	498
SE001012	2%	1,345	26
SE001013	2%	4,777	91
SE001014	2%	8,366	167
SE001018	5%	3,703	190
SE001019	11%	3,879	427
SE001020	4%	1,459	61
SE001023	4%	530	24
SE001492	3%	6,190	196
F1263005	7%	211	14
FL000261	27%	54	14
FL000262	11%	389	42
FL000263	20%	520	105
FL000267	27%	96	26
FL000268	18%	146	26
FL000271	9%	7	0.70
FL000272	8%	0.33	0.025
FL000274	6%	82	5.2
FL000297	2%	235	5.8
FL000299	27%	32	8.5
FL000315	9%	158	13
FL000438	9%	1,035	89
FL000439	33%	1,693	565
FL000440	11%	1,987	228
FL000442	35%	1,605	556
SE000181	4%	574	23
SE000828	10%	841	82
SE000861	5%	1,501	78
SE001055	4%	2,539	95

General Electric Company
Housatonic River - Rest of River
CMS Proposal

Table B-4. Total Organic Carbon Content of Surface Sediment in the Primary Study Area

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
FL000361	15%	44	6
FL000362	24%	518	123
FL000363	19%	159	30
FL000364	13%	343	45
FL000525	6%	1,569	97
FL000527	5%	158	7
FL000538	6%	23	1
FL000550	6%	5,950	348
SD119091	7%	197	14
SD119092	1%	531	6
SD11RP08	7%	2,375	166
SD12RP04	6%	160	9
SD12RP06	4%	771	34
SE000144	9%	1,400	131
SE000150	4%	1,699	69
SE000174	6%	215	13
SE000175	1%	536	3
SE000176	3%	2,619	90
SE000177	4%	730	28
SE000178	6%	1,130	72
SE000179	3%	683	19
SE000259	12%	108	12
SE000260	5%	948	46
SE000261	7%	432	28
SE000262	7%	590	44
SE000263	9%	193	17
SE000264	8%	108	9
SE000275	2%	203	4
SE000276	6%	0	0
SE000277	1%	348	2
SE000278	2%	256	6
SD033003	1%	246	3
SD033101	1%	427	2
SD033102	0.0%	43	0
SD033103	4%	284	11
SD033201	0.0%	541	0
SD033202	0.1%	762	1
SD033203	1%	318	2
SD033301	1%	131	1
SD033302	0.1%	245	0
SD033303	1%	75	1
SD038951	0.4%	266	1
SD038952	0.1%	200	0

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE001098	2%	4,489	70
SE001099	9%	2,435	212
SE001100	2%	1,337	29
SE001101	6%	1,889	116
SE001106	3%	1,923	56
SE001107	8%	2,042	161
SE001118	7%	2,127	151
SE001120	3%	1,315	45
SE001125	7%	2,972	209
SE001126	7%	2,257	154
F1291042	50%	2,020	1,011
FL000328	13%	2,926	389
FL000528	13%	4,846	606
FL000529	11%	5,060	572
FL000530	7%	2,344	161
FL000531	12%	3,864	456
FL000534	5%	3,453	157
FL000535	20%	2,303	454
SD139111	14%	6,012	842
SD139112	1%	2,567	31
SD139113	8%	4,076	338
SE000172	5%	1,958	100
SE000256	22%	5,643	1,230
SE000257	20%	4,639	905
SE000258	7%	2,458	183
SE000808	29%	2,686	786
SE000856	1%	3,809	22
SE000877	3%	2,197	57
SE000878	1%	2,381	19
SE000880	18%	4,146	751
SE000881	13%	1,021	137
SD064101	3%	2,019	63
SD064201	1%	267	3.0
SD064202	0.3%	366	1.2
SD064203	10%	687	70
SD064301	3%	1,210	32
SD064302	0.1%	1,007	1.0
SD064303	13%	621	78
SD064401	0.4%	2,354	10
SD064402	0.4%	297	1.1
SD064403	6%	121	6.9
SD068981	4%	193	7.1
SD068982	0.1%	332	0.29

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000988	7%	2,743	194
SE000989	8%	2,677	205
SE000990	8%	2,389	198
SE000991	9%	3,003	271
SE000992	12%	2,066	255
SE000993	9%	3,951	344
SE000994	7%	5,376	364
SE000995	17%	8,096	1,344
SE000996	16%	8,808	1,418
SE000997	15%	2,764	420
SE000998	15%	2,813	409
SE001021	19%	2,361	453
SE001022	5%	3,091	166
SE001070	9%	3,038	280
SE001072	15%	4,018	595
SE001074	15%	5,198	754
SE001079	24%	18,129	4,429
SE001092	37%	5,501	2,049
SE001093	9%	3,050	288
SE001094	17%	3,866	651
SE001095	16%	4,383	709
SE001096	21%	6,323	1,306
SE001097	23%	3,779	854
SE001111	22%	3,988	861
SE001499	14%	2,094	293
F0890203	33%	688	227
FL000396	30%	939	284
FL000434	57%	1,392	798
FL000435	44%	658	289
FL000436	6%	520	32
FL000437	6%	638	37
SE000072	2%	1,005	18
SE000073	0.5%	644	3.1
SE000074	0.2%	609	1.2
SE000075	0.4%	890	3.9
SE000076	0.4%	284	1.1
SE000077	0.2%	221	0.42
SE000078	1%	246	2.2
SE000079	2%	1,023	17
SE000080	4%	2,184	83
SE000081	2%	1,830	39
SE000185	6%	147	9.5
SE000186	6%	154	9.9

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE001057	6%	2,555	158
SE001058	4%	1,819	65
SE000227	6%	1,877	116
SE000228	8%	2,425	190
SE000229	1%	1,156	6.0
SE000232	5%	3,271	178
SE000253	7%	4,687	344
SE000254	7%	3,647	256
SE000255	7%	3,358	236
SE000807	1%	1,612	16
SE000875	14%	1,181	171
SE000889	7%	1,896	137
SE000890	9%	2,909	273
SE000893	17%	2,700	450
SE000894	12%	2,998	363
SE000895	8%	3,557	274
SE000896	21%	2,459	511
SD105503	5%	770	39
BH000514	2%	138	2.3
BH000515	0.0%	92	0.018
BH000516	0.0%	3,317	0.19
BH000517	0.2%	277	0.53
BH000518	0.4%	227	0.91
BH000519	0.0%	424	0.025
BH000520	0.1%	204	0.16
BH000521	0.2%	56	0.089
BH000522	6%	120	6.9
BH000523	0.0%	329	0.021
BH000524	1%	417	3.3
BH000525	0.1%	1,074	1.5
SD033002	2%	183	3.7
SE000317	4%	110	4.4
SE000318	2%	488	10
SE000319	2%	481	7.8
SE000320	2%	203	3.1
SE000321	4%	864	36
SE000322	4%	661	25
SE000323	1%	311	3.4
SE000324	1%	116	0.74
SE000325	4%	644	26
SE000326	4%	757	27
SE000328	3%	22	0.64
SE000329	5%	2,327	111

Table B-4. Total Organic Carbon Content of Surface Sediment in the Primary Study Area

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SD038953	1%	119	2
SD043401	1%	156	2
SD043402	0.4%	189	1
SD043403	4%	43	2
SD043501	1%	75	1
SD043502	0.1%	196	0
SD043503	1%	1,032	14
SD043601	1%	172	1
SD043602	0.1%	676	1
SD043603	0.1%	46	0
SD043701	1%	954	5
SD043702	0.2%	450	1
SD043703	2%	450	9
SD048961	0.3%	633	2
SD048962	0.1%	32	0
SD048963	2%	279	6
SD048971	0.2%	228	0
SD048972	0.1%	237	0
SD048973	1%	591	4
SD053801	1%	186	1
SD053802	0.1%	92	0
SD053803	1%	142	1
SD053901	5%	75	4
SD053902	1%	1,647	17
SD053903	4%	368	17
SD054001	1%	1,145	17
SD054002	0.1%	640	1
SE000377	2%	637	15
SE000378	3%	251	7
SE000379	5%	238	13
SE000380	3%	5,951	153
SE000381	2%	557	9
SE000382	2%	166	3
SE000396	1%	286	2
SE000397	3%	251	7
SE000401	1%	546	3
SE000402	0.2%	1,204	2
SE000403	1%	217	1
SE000404	1%	350	2
SE000405	2%	893	18
SE000406	6%	436	25
SE000407	4%	33	1
SE000408	1%	386	3

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SD068983	3%	372	9.7
SD074501	0.1%	407	0.60
SD074502	0.1%	341	0.33
SD074503	0.2%	2,126	3.2
SD074601	0.4%	196	0.83
SD074602	1%	246	2.1
SD074603	21%	269	56
SE000049	0.1%	57	0.083
SE000050	0.1%	534	0.58
SE000052	0.1%	955	1.2
SE000053	0.3%	417	1.5
SE000055	0.1%	2,037	2.6
SE000056	0.3%	192	0.50
SE000058	2%	936	19
SE000059	0.2%	402	1.0
SE000060	4%	273	10
SE000061	0.1%	200	0.20
SE000062	0.1%	167	0.25
SE000063	3%	2,530	74
SE000064	0.1%	1,262	1.8
SE000065	2%	864	19
SE000066	0.2%	265	0.42
SE000067	1%	449	6.6
SE000068	0.1%	912	0.85
SE000069	0.3%	1,664	4.5
SE000070	1%	3,848	22
SE000071	1%	955	5.5
SE000437	1%	1,862	23
SE000438	2%	481	8.8
SE000449	1%	496	3.7
SE000450	3%	188	4.8
SE000467	2%	423	8.1
SE000478	2%	91	1.6
SE000479	5%	50	2.6
SE000484	0.0%	67	0.0044
SE000485	0.0%	7	0.00042
SE000495	1%	230	2.9
SE000652	1%	690	6.6
SE000710	1%	830	8.7
SE000718	3%	107	3.6
SE000719	3%	10	0.34
SE000720	5%	26	1.2
SE000721	6%	23	1.5

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000187	0.3%	2,908	8.4
SE000188	1%	287	2.5
SE000189	0.0%	295	0.019
SE000190	0.0%	246	0.014
SE000191	0.0%	18	0.0011
SE000192	0.0%	428	0.029
SE000193	1%	572	3.1
SE000287	0.3%	56	0.18
SE000288	0.4%	17	0.064
SE000289	0.2%	376	0.84
SE000290	0.4%	659	2.9
SE000291	0.2%	8	0.018
SE000292	2%	789	12
SE000295	0.1%	59	0.044
SE000298	1%	1	0.013
SE000299	1%	49	0.32
SE000300	0.4%	11	0.043
SE000301	0.2%	170	0.31
SE000308	5%	44	2.0
SE000309	2%	9	0.13
SE000310	1%	34	0.37
SE000311	4%	14	0.58
SE000312	1%	13	0.071
SE000313	4%	389	15
SE000314	4%	5,704	238
SE000315	3%	133	4.3
SE000316	3%	677	18
SE000920	0.2%	1,581	2.7
SE000922	0.1%	414	0.31
SE000924	1%	238	2.8
SE000925	1%	571	4.0
SE000926	0.2%	433	0.69
SE000927	2%	3,570	60
SE000929	0.1%	330	0.25
SE000930	0.1%	30	0.023
SE000931	0.1%	254	0.19
SE000932	0.1%	1,612	1.2
SE000934	0.1%	983	0.74
SE000935	0.1%	1,310	0.99
SE000936	1%	919	11
SE000937	0.1%	690	0.52
SE000938	1%	1,753	12
SE000939	0.2%	89	0.13

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000330	0.5%	28	0.14
SE000331	2%	82	1.3
SE000332	0.4%	2,295	8.9
SE000333	3%	1,087	32
SE000334	4%	318	11
SE000335	1%	1,070	14
SE000336	1%	755	8.8
SE000342	1%	178	2.5
SE000343	1%	310	2.4
SE000344	2%	191	2.9
SE000345	2%	77	1.7
SE000350	2%	487	7.6
SE000351	3%	217	5.7
SE000352	3%	54	1.4
SE000353	2%	132	2.1
SE000354	2%	64	1.6
SE000355	2%	102	1.8
SE000356	1%	64	0.90
SE000357	4%	2	0.066
SE000358	2%	208	4.0
SE000359	3%	717	20
SE000360	3%	740	22
SE000361	5%	492	22
SE000362	3%	4	0.12
SE000363	4%	429	18
SE000364	0.5%	1,075	5.3
SE000365	1%	93	1.0
SE001366	1%	970	12
SE001432	0.3%	435	1.2
SE001438	1%	366	4.9
SE001495	0.4%	1,691	6.4
SE001498	3%	492	14
SE001500	5%	1,078	49
SEEC0012	1%	248	1.9
SEEC0013	0.3%	141	0.42
SEEC0014	1%	11	0.066
SEEC0015	0.0%	9	0.00060
SEEC0018	2%	2	0.038
SEEC0019	0.3%	5	0.015
BH000526	1%	108	1.1
BH000527	0.2%	167	0.38
BH000528	5%	169	7.6
BH000529	0.4%	100	0.42

Table B-4. Total Organic Carbon Content of Surface Sediment in the Primary Study Area

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product ($TOC_i A_i$)
SE000409	1%	2,068	11
SE000410	1%	1,204	17
SE000411	2%	515	8
SE000412	2%	156	3
SE000418	3%	2,243	58
SE000419	2%	2,642	55
SE000420	0.4%	2,653	10
SE000421	1%	736	9
SE000422	1%	532	4
SE000423	0.4%	200	1
SE000424	0.4%	516	2
SE000425	0.3%	95	0
SE000426	0.2%	63	0
SE000427	0.2%	199	0
SE000428	1%	20	0
SE000429	1%	56	1
SE000430	1%	79	1
SE000431	0.3%	557	2
SE000432	0.2%	1,700	4
SE000433	0.1%	3,025	2
SE000434	0.3%	2,363	8
SE000435	2%	1,194	23
SE000436	1%	1,663	15
SD095303	1%	34	1
SD099001	3%	246	7
SD099002	1%	132	1
SD099003	0.5%	241	1
SE000082	1%	2,172	14
SE000083	1%	930	12
SE000084	1%	876	5
SE000085	3%	490	13
SE000086	1%	457	4
SE000087	2%	390	7
SE000088	2%	701	11
SE000089	2%	431	7
SE000090	2%	644	13
SE000091	0.1%	717	1
SE000092	0.3%	1,079	3
SE000093	4%	1,218	45
SE000094	1%	758	6
SE000095	0.3%	469	2
SE000096	1%	735	10
SE000097	1%	272	3

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product ($TOC_i A_i$)
SE000722	3%	73	2.2
SE000723	3%	2	0.066
SE000724	1%	116	1.1
SE000725	5%	14	0.65
SE000786	1%	876	9.2
SE000791	2%	268	5.5
SE000792	3%	314	9.0
SE000798	2%	1	0.012
SE000799	2%	345	6.9
SE000846	2%	1,046	22
SE000847	0.2%	161	0.36
SE000848	0.2%	487	0.92
SE000863	1%	1,489	22
SE000864	1%	1,745	18
SE000865	3%	1,069	31
SE000899	1%	404	2.4
SE000900	0.2%	455	0.75
SE000901	1%	253	1.4
SE000902	0.4%	594	2.2
SE000903	0.4%	186	0.69
SE000916	0.5%	449	2.1
SE000917	0.4%	362	1.3
SE000919	0.2%	595	1.1
SE000117	8%	806	68
SE000118	3%	927	32
SE000119	0.2%	292	0.50
SE000125	1%	976	8.8
SE000126	5%	867	44
SE000127	13%	665	84
SE000182	1%	295	1.6
SE000184	3%	1,386	36
SE000212	1%	1,249	9.4
SE000213	0.3%	363	1.1
SE000214	0.3%	1,038	3.6
SE000215	1%	748	4.0
SE000216	2%	906	17
SE000217	4%	985	36
SE000218	0.4%	732	2.8
SE000219	1%	1,452	16
SE000220	0.0%	1,189	0.080
SE000221	1%	532	7.5
SE000222	0.4%	1,338	5.3
SE000284	2%	247	5.2

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product ($TOC_i A_i$)
SE000940	0.1%	247	0.19
SE000941	0.4%	2,344	8.9
SE000942	2%	1,137	17
SE000943	0.4%	986	3.6
SE000944	3%	712	20
SE000945	0.3%	1,072	3.5
SE000946	1%	1,290	14
SE000947	0.3%	802	2.7
SE000948	1%	730	5.9
SE000949	3%	1,760	53
SE000950	0.4%	2,363	9.5
SE000951	0.1%	1,117	0.85
SE000952	1%	1,130	16
SE000953	2%	1,395	30
SE000954	0.2%	1,408	2.7
SE000955	2%	2,117	36
SE001049	0.3%	58	0.16
SE001050	1%	467	2.6
SE001133	1%	368	3.6
SE001134	0.2%	108	0.19
SE001149	2%	516	12
SE001150	1%	2,845	32
SE001151	1%	288	1.6
SE000961	1%	680	4.7
SE000962	0.4%	665	3.0
SE000963	1%	852	10
SE000965	1%	388	3.7
SE000966	2%	487	7.9
SE000967	2%	1,791	29
SE000969	1%	999	10
SE000970	0.3%	711	2.2
SE000971	2%	4,108	66
SE000972	1%	206	2.7
SE000976	1%	350	1.9
SE000977	1%	452	5.8
SE000978	1%	796	5.1
SE000979	1%	309	4.4
SE000980	1%	623	7.1
SE000982	4%	281	11
SE001027	2%	484	8.7
SE001048	0.2%	312	0.77
SE001053	1%	648	6.1
SE001140	0.1%	474	0.36

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product ($TOC_i A_i$)
SD074701	1%	126	1.3
SD074702	0.3%	177	0.54
SD074703	2%	1,845	41
SD078991	1%	246	1.9
SD078992	0.1%	463	0.64
SD078993	4%	508	19
SD084801	0.2%	2,794	5.9
SD084802	0.4%	664	2.8
SD084803	0.2%	431	0.86
SD084901	1%	1,049	8.7
SD084902	0.5%	647	3.1
SD084903	1%	557	3.3
SD085001	2%	70	1.7
SD085002	0.3%	106	0.32
SD085003	1%	301	4.1
SD085101	0.2%	314	0.62
SD085102	1%	271	1.8
SD085103	2%	197	3.0
SD095201	2%	224	4.1
SD095202	1%	203	2.1
SD095203	2%	134	3.1
SD095301	1%	595	6.5
SD095302	1%	114	1.4
SE000442	1%	2,049	17
SE000443	1%	818	4.4
SE000444	0.3%	2,414	6.3
SE000445	3%	997	31
SE000446	3%	499	16
SE000447	1%	282	4.1
SE000448	1%	542	7.4
SE000820	1%	423	4.4
SE000821	0.2%	285	0.54
SE000823	1%	449	3.0
SE000867	2%	814	16
SE000958	3%	501	13
SE000959	2%	1,635	37
SE000960	4%	430	16
FL000368	5%	49	2.6
FL000443	40%	326	130
FL000444	10%	1,270	133
SE000183	1%	2,755	17
SE000956	2%	5,388	88
SE000957	4%	4,251	184

Table B-4. Total Organic Carbon Content of Surface Sediment in the Primary Study Area

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000098	0.4%	255	1
SE000099	0.1%	620	1
SE000100	1%	665	6
SE000101	2%	736	14
SE000102	1%	757	8
SE000103	2%	190	3
SE000104	0.4%	635	2
SE000105	4%	635	25
SE000106	1%	471	2
SE000107	0.3%	689	2
SE000108	0.4%	528	2
SE000109	3%	444	13
SE000110	0.5%	768	4
SE000111	1%	566	3
SE000112	0.3%	564	2
SE000113	3%	500	14
Sum (S)		1,091,579	75,131
Spatially-weighted mean			6.9%

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000285	2%	9	0.16
SE000286	2%	952	14
SE000439	1%	49	0.27
SE000440	1%	731	7.9
SE000441	1%	917	8.8

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE001141	0.1%	345	0.26
SE001142	1%	591	3.6
SE001145	0.3%	417	1.4
SE001146	0.4%	769	2.8
FL000811	10%	1,861	192

Location Identification (i)	Total Organic Content (TOC_i)	Polygon Area (m^2) (A_i)	Product (TOC_i A_i)
SE000964	3%	608	16
SE000968	1%	307	3.9
SE000115	0.4%	676	3
SE000116	1%	581	8
SE000114	3%	484	12

Notes:
SWM = (S TOC_i A_i)/S A_i
where:
SWM = spatially weighted mean
TOC_i = total organic carbon measurement at station i
A_i = polygon area at station i
Non-detect TOC set to 1/2 of the measured detection limit.
Duplicate TOC data were averaged.
Fractionate samples, deep cores and sections less than 3" thick were not included in TOC Theissen polygons
Source: EPA monthly data exchange; samples collected from 1998 - 2002

Table B-5. Litter Invertebrate-Floodplain Soil PCB Bioaccumulation Factors

Sample Identification Number	Date Collected	Station	Litter Invert. PCB Conc. (mg/kg) (PCBli)	Soil PCB Conc. (mg/kg) (PCBsoil)[a]	BAF (PCBli / PCBsoil)
H3-TW13LI01-0-0G10	08/10/00	13	4.1	9.6	0.42
H3-TW13LI02-0-0G10	08/10/00	13	3.6	10.8	0.33
H3-TW13LI03-0-0G11	08/11/00	13	4.9	16.3	0.30
H3-TW14LI01-0-0G15	08/15/00	14	3.8	34.9	0.11
H3-TW14LI02-0-0G15	08/15/00	14	3.5	66.1	0.05
H3-TW14LI03-0-0G16	08/16/00	14	2.3	69.8	0.03
H3-TW15LI01-0-0G09	08/09/00	15	1.4	0.8	1.81
H3-TW15LI02-0-0G10	08/10/00	15	2.8	0.8	3.58
				Median BAF (all stations) [a]	0.31
				Median BAF (stations 13 and 14 only)	0.20

Notes:

BAF = bioaccumulation factor = PCBli / PCBsoil

PCBli = concentration of PCBs in litter invertebrates (mg/kg)

PCBsoil = concentration of PCBs in co-located surface soil (mg/kg)

a. Soil samples collected from stations co-located with litter invertebrate collections, from the upper 6 inches

Table B-6. Target Soil Concentrations Protective of Wood Ducks Based on Literature-Derived BSAFs and BAFs

Csed (mg/kg)	BSAF (unitless) [a]	BAF (unitless) [b]	Csoil (mg/kg) [c]	Csoil range (mg/kg)
1	1.5	0.05	331	146 - 331
		0.11	151	
	2.0	0.05	328	
		0.11	149	
	3.0	0.05	321	
		0.11	146	
3	1.5	0.05	311	128 - 311
		0.11	141	
	2.0	0.05	301	
		0.11	137	
	3.0	0.05	281	
		0.11	128	
5	1.5	0.05	291	110 - 291
		0.11	132	
	2.0	0.05	274	
		0.11	125	
	3.0	0.05	241	
		0.11	110	
10	1.5	0.05	241	64 - 241
		0.11	110	
	2.0	0.05	208	
		0.11	94	
	3.0	0.05	141	
		0.11	64	

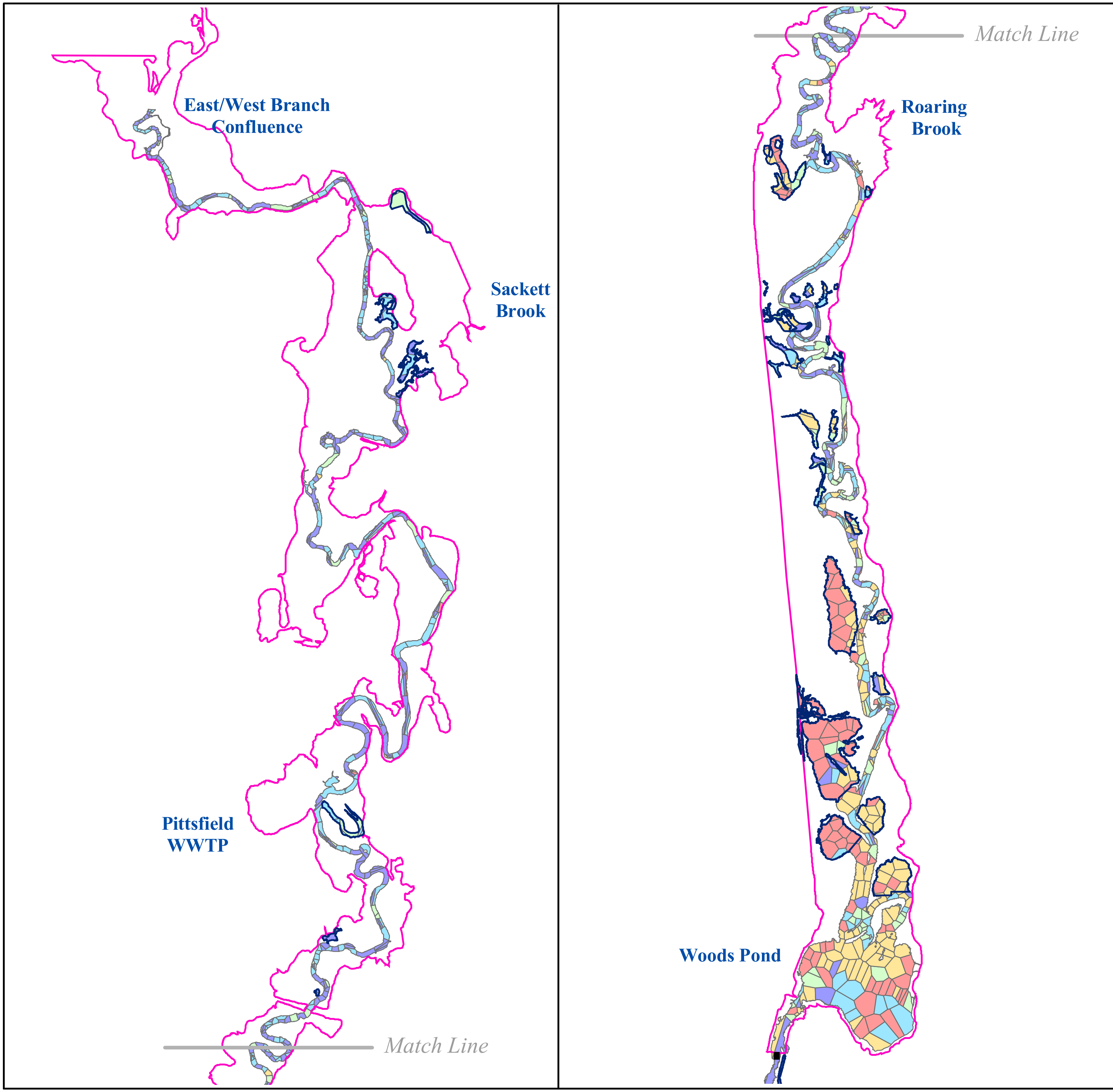
Notes:

a. Based on conclusions from ERA and RFI Report. The ERA cited Parkerton (1993) and McFarland (1994) as the basis for a BSAF of 2. The RFI Report cited Tracey and Hansen (1996), QEA (1999) and Wong et al. (2001) for a range of BSAFs of 1.5 to 3.

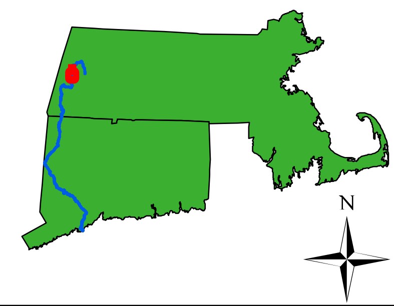
b. BAF of 0.05 from Blankenship et al. (2005); BAF of 0.11 from Paine et al. (1993).

c. Csoil = [Ci x (Pai + Pti) - (Pai x BSAF x Csed x Lipid x 1/TOC)]/ Pti x BAF
Where:

Ci =	Target PCB conc. in invertebrate portion of diet	4.4	mg/kg	(IMPG
Pai =	Proportion of diet composed of aquatic invertebrates	0.564	unitless	(ERA)
Pti =	Proportion of diet composed of terrestrial invertebrates	0.196	unitless	(ERA)
BSAF =	Biota-sediment accumulation factor	Range (see above)	unitless	see note a
Csed =	Target concentration of PCBs in sediment	Range (see above)	mg/kg	(Assumption)
Lipid =	Lipid content of aquatic invertebrates	0.80	%	(Table B-3)
TOC =	Total organic carbon in sediment	6.9	%	(Table B-4)
BAF =	Soil bioaccumulation factor	Range (see above)	unitless	see note b



LOCATOR MAP



SCALE

0 0.25 0.5 Miles

LEGEND

- Major Dams
- Backwaters
- 1-ppm PCB Isopleth

foc Theissen Polygon (%)

- < 1%
- 1 - 3%
- 3 - 5%
- 5 - 10 %
- > 10%

Notes:
foc data collected by USEPA.
Non-detect TOC set to 1/2 reported detection limit.

Figure B-1. Distribution of surface (0-6") organic carbon in Theissen Polygons from the Confluence to Woods Pond.

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Appendix C

Application of EPA's Wood Frog Population Model to the CMS

Appendix C. Application of EPA's Wood Frog Population Model to the CMS

1. Introduction

This appendix describes GE's proposed use of the frog population model developed by EPA for the Ecological Risk Assessment (ERA) (EPA, 2004) in the Corrective Measures Study (CMS). EPA used this model to evaluate the risk of extinction of wood frogs in the floodplain of the Primary Study Area (PSA) resulting from exposure to PCBs in vernal pool sediments. GE proposes to use this model, with minor adaptations as well as an extension to vernal pools that were not included in EPA's model, to evaluate various remedial alternatives for addressing the vernal pools in the PSA. Subsequent sections of this appendix provide: 1) background information on the EPA model; 2) a description of GE's duplication of the EPA model; 3) a description of the adjustments made to the EPA model for use in the CMS; 4) a description of how the results from the model will be applied to the additional vernal pools identified in the PSA; and 5) a hypothetical example of the use of this model for the evaluation of potential remedial alternatives for addressing vernal pools.

1.1 Background

The EPA wood frog model was developed by Applied Biomathematics Inc. and Woodlot Alternatives Inc., for use in the ERA. This model is based on the commercially available population modeling program - RAMAS Metapop 5.0 (Akçakaya, 2002). The EPA model and an interpretation of the model results are presented in Appendix E, Attachment E.4 of the ERA (EPA, 2004). The EPA model focuses on wood frogs (*Rana sylvatica*), which is a prominent species in the floodplain and is also used as a surrogate for other amphibian species.

The ERA defined the wood frog breeding population in the PSA as those frogs breeding within 27 vernal pools in the floodplain of the PSA that were identified as having suitable wood frog breeding habitat (EPA, 2004, Vol. 5, Appendix E, Attachment E.4, p. 2). As discussed in Attachment C-1, EPA's model treats the wood frog population in the PSA floodplain as a metapopulation, in which frogs are divided into subpopulations based on the vernal pools which they occupy for the reproductive phases of their life cycle. This is important in that these pools are highly variable environments that can be substantially impacted by natural events such as floods and droughts. Temporary loss of reproductive habitat (e.g., pools drying prematurely due to drought) is common and may eventually drive a subpopulation to extinction. Metapopulations persist in spite of these subpopulation extinctions because dispersal between local subpopulations permits rapid recolonization by immigrants from neighboring habitats (Hanski, 1999). The risk of metapopulation extinction (i.e., extinction of all local subpopulations) is a function of the number of occupied habitats, the distance between habitats, and the number of dispersing organisms. The EPA model takes all these factors into account.

This model was used in the ERA to evaluate the potential effects of PCB exposure on the wood frog population in the floodplain of the PSA. The EPA model evaluates the sustainability (viability) of the entire metapopulation. It incorporates estimates of reproduction, survival, and pool-carrying capacity as parameters for each subpopulation in the model. Interactions between subpopulations are accounted for through a dispersal algorithm that estimates the proportion of young frogs migrating to new pools. However, such parameters vary through time and across pools. The model accounts for this variability by randomly changing some parameters through time in a manner consistent with observed spatial and temporal variability in the parameters (called environmental stochasticity), based on site-specific data and information derived from the scientific literature.

Model output thus varies with each run, depending on which random estimate was selected (see Attachment C-1 for further explanation of stochasticity).

The EPA model provides estimates of the risk of extinction of the entire wood frog population and time to extinction based on "probabilities," calculated as the proportion of model runs (i.e., model is run 1000 times) in which the population went extinct after a specified period of years. Vital rates used in the model (e.g., rates of reproduction and survival) were taken from the scientific literature. These rates were adjusted to account for PCB-related effects based on site-specific exposure-response data.

Based on the results from this model, EPA concluded that exposure of wood frogs to PCBs at concentrations found in pools in the PSA increases the probability of wood frog population decline and extinction relative to a hypothetical population with no exposure to PCBs.

GE proposes to use this same population model to evaluate the impacts of alternative approaches to remediating the vernal pool sediments in the PSA on the long-term sustainability of the frog population, as measured by differences in the risk of extinction. The evaluation of the impact of different vernal pool remedial scenarios on the wood frog population required some minor modifications of EPA's 27-pool model, as well as an extension to the other vernal pools in the PSA, as will be explained in the discussion below.

1.2 Objective

The objective of using EPA's wood frog population model in the CMS is to compare the impact of different remedial alternatives on the local wood frog population in the PSA floodplain. Such alternatives would involve varying degrees of remediation of vernal pools in terms of achieving the Interim Media Protection Goals (IMPGs) that have been established for amphibians, which consist of a range of PCB concentrations from 3.27 to 5.6 mg/kg in vernal pool sediments. Potential remedial alternatives could range from no further action to remediating all pools with PCB concentrations above the lower IMPG, with various alternatives in between, such as remediating a certain portion of the pools exceeding the IMPG.

To accomplish this objective, first the appropriate model projection had to be selected for use in the CMS. The model proposed is based upon the EPA's "non-declining" projection presented in Appendix E, Attachment E.4 of the ERA (EPA, 2004). In EPA's non-declining projection, the reproduction and survival rates are set at a level large enough to sustain the population for at least 10 years (based on a studied population of wood frogs in Berven, 1990). The "non-declining" projection was chosen as the foundation for all GE models because EPA's other scenario, the "declining" projection, utilized reduced rates in survival and reproduction that caused the population to decline rapidly to extinction even without PCB effects. Such a rapid decline does not provide adequate resolution to evaluate the effects of various remedial scenarios over time. Use of EPA's "non-declining" projection, with additional modifications that permit long-term persistence of unexposed populations, provides a better foundation for evaluating the relative benefits of remediation and comparing alternatives. The duplication of the "non-declining" version of the EPA model is discussed in the following section.

2. Duplication of the EPA Model

The underlying code for the EPA population model was not available. Therefore, the EPA "non-declining" population model was duplicated using RAMAS Metapop 5.0 (Akçakaya, 2002) based on the documentation presented in Appendix E, Attachment E.4 of the ERA. The main model parameters provided by EPA in the ERA and incorporated in GE's duplicate model are outlined below:

Subpopulation size and PCB concentrations: The EPA model is based on the 27 vernal pools that were identified in the ERA as having suitable breeding habitat for wood frogs, based on field surveys and field collections of frogs for laboratory and other experimental studies. Frogs from these pools represent subpopulations of the metapopulation. Spatially weighted sediment total PCB concentrations and pool volume data for each of the 27 pools are provided in the ERA. Frog census data were available for only four pools. Starting subpopulation sizes in the remaining 23 pools were estimated using regressions developed from the PCB concentration and volume data. For the non-impacted scenario, PCB concentrations were set to zero to obtain initial subpopulation sizes.

Age classes and sex structure: Three female and three male age classes are included in the model for a total of six classes. Each age class is for one year and all frogs were assumed to be dead after they reached 3 years (based on Berven, 1990). It is assumed that one male frog can breed with up to 10 females.

Reproduction, survival, and stochasticity: Means and standard deviations for vital rates (fecundity and survival) of each age class were taken from the literature (Berven, 1990). The standard deviations were used to model environmental stochasticity. Demographic stochasticity was also included in the model.

Density dependence: All pools were given a ceiling in which the carrying capacity (K) was set equal to 10 times the initial subpopulation size without PCB effects. When the subpopulation size for a pool exceeded the carrying capacity, the size was reset to the carrying capacity for the next year.

Dispersal: Dispersal was based on a distance function (from Berven and Grudzien, 1990) that estimates the proportion of juveniles of each subpopulation that emigrates to another pool as a function of the distance between the two pools. Only juvenile frogs (age 0 class) were allowed to disperse. The proportions were scaled for each pool to ensure no more than 18.54% of each subpopulation emigrated (based on Berven and Grudzien, 1990).

PCB influence: EPA used data from wood frog reproduction and development studies conducted as part of the ERA (FEL, 2002) to develop exposure-response relationships between PCB concentrations and larval survival and malformation rates. In EPA's model, as described in Appendix E, Attachment E.4 of the ERA, PCBs are modeled as having a positive influence on survival of eggs to metamorphosis and a negative effect on survival of metamorphs in their first year of life. In EPA's model, metamorphs also show an increased rate of abnormalities (malformations) associated with PCB exposure. For gonadal abnormalities considered by EPA to be the result of PCB exposure, a fecundity coefficient (relative multiplier) that increased sterility was applied in the model. Fecundity is defined as the number of eggs produced per adult frog that hatch and survive through the first year. For all abnormalities considered by EPA to be the result of PCB exposure, a survival coefficient that increased juvenile mortality was applied in the model.

Time steps: The model was run over ten time steps with each time step lasting one year.

Iterations: Each model was run with 1000 iterations.

Using these parameters, the duplication of the EPA model was successful. As explained in the RAMAS program documentation, the sequence of random numbers used in Monte Carlo simulations is determined by an initial starting value termed the "seed." Changing the seed value changes the randomly selected values of the stochastic model parameters. Since the seed value used by EPA is unknown, it is not possible to exactly reproduce EPA's model outputs. However, by using the same set of assumptions and parameter distributions used by EPA, the distributions of outputs from GE's model runs were very similar to EPA's results. Figure 1 is taken directly from Figure 5 in Appendix E, Attachment E.4 of the ERA. That figure presents the output for the baseline model and three PCB impact variants of the "non-declining" population model in terms of the probabilities that the wood frog population in the floodplain will fall below a threshold number (with 0 representing terminal extinction) by the end of the modeled period. For comparison, Figure 2 presents GE's effort to duplicate this same set of four model variants. That figure is nearly identical to Figure 1.

3. Adjustments to the EPA Model for Use in the CMS

Once the model had been demonstrated to replicate the results of the original EPA model, GE made several minor adjustments to the model to allow it to be used in evaluating remedial alternatives. These adjustments are described below. These discussions are followed by an assessment of the behavior of the adjusted model, relative to that of the original EPA model, in evaluating the baseline (no PCBs) and current conditions (PCB-impacted) scenarios, to demonstrate that the adjustments do not alter the model's overall ability to estimate PCB impacts.

3.1 PCB Concentrations Below the Low Interim Media Protection Goal

EPA used separate regression models for males and females to quantify the relationship between PCB concentrations in vernal pool sediment and effects on malformation rates in exposed wood frogs (EPA, 2004, Appendix E, Attachment E.4, Figure 4). Each of these EPA regression models crosses the y–axis at malformation rates that are well above zero, thus indicating that the model would predict malformations even in the absence PCBs. If the EPA regression models are employed over the entire exposure-response range, they would indicate that PCB-related malformations would occur at PCB concentrations below the low IMPG (3.27 mg/kg), even at a PCB concentration of 0 ppm. Indeed, as shown in Table 13 of Attachment E.4, 7-10% of the female frogs were predicted to be malformed in the 8 ponds in which the PCB concentrations in sediments were below the low IMPG.

The lower bound of the IMPG range was established as a protective concentration below which risks to exposed wood frogs should be negligible. Thus, it appears that the levels of malformations observed or predicted below the low IMPG reflect ambient or baseline levels of malformations in the studies from which the exposure-response data were derived. GE recognizes that EPA's wood frog model was developed prior to the IMPGs. However, now that the IMPGs have been established, it seems reasonable to treat the lower IMPG as essentially an effects threshold below which no PCB-related adverse effects are expected to occur. Thus, remediating any pool to a spatially weighted average PCB concentration $\leq$ 3.27 mg/kg is considered to protect the frogs reproducing in that pool. For the purpose of evaluating remedial alternatives, therefore, the adjusted model truncates the exposure-response relationship in EPA's Figure 4 at a value of 3.27 mg/kg and assumes that no PCB-related effects occur at sediment concentrations below this value.

3.2 Assumptions Regarding Severity of PCB-Related Effects

The original EPA model evaluated four different scenarios regarding the relationship between PCB-related malformations and subsequent mortality or sterility. These are as follows:

- No effect (i.e., juvenile malformations do not result in increased larval mortality and gonadal malformations do not result in increased sterility);
- Assumption that 50% of juvenile malformations cause mortality and 50% of gonadal malformations cause sterility (least severe condition);
- Assumption that 50% of juvenile malformations cause mortality and 100% of gonadal malformations cause sterility; and

- Assumption that 100% of juvenile malformations (gonadal or otherwise) cause mortality (most severe condition).

For use in evaluating remedial alternatives, GE adopted only one scenario to facilitate comparison among alternatives. The scenario chosen was the fourth, most severe scenario, in which 100% of PCB-related juvenile malformations, gonadal or otherwise, are assumed to result in mortality. GE used EPA's relative multipliers (survival coefficients) to model this scenario. EPA's multipliers for this scenario incorporate both the assumed increase in survival of the larvae from exposure to PCBs and the assumption that all of the juvenile metamorphs that display any type and degree of PCB-related malformation will die (e.g., 100% mortality). Malformation rates were estimated by regressing malformation rates on PCB concentrations and using estimates from laboratory studies of the percent of malformations that were gonadal (see Attachment C-1 for further explanation of the development and application of the multipliers).

3.3 Duration of Simulations

The duration of the simulations was also modified. The duration of the simulation is determined by a set number of time steps. In the EPA model, one time step is equivalent to one year. The duration of the simulation is thus defined by the number of years simulated. The EPA model simulations ran for only 10 years. This time period is too short for evaluating remedial alternatives because remedy implementation may take longer than 10 years (potentially up to 20 years or more). To ensure adequate time to complete remediation and for the system to recover, the model run time was extended from 10 to 100 years. Another advantage of such an extended period is that the model is more sensitive to differences among scenarios than it would be with a run time of 10 or even 50 years (since the largest difference in extinction rates among scenarios occurs at > 100 years). Under this 100-year scenario, the frog population in EPA's "non-declining" model, which assumes no exposure to PCBs, still declines to extinction in approximately 70 years, as shown in Figure 3. To assess frog population viability over this 100-year period, adjustments in the vital rates in the age matrix were necessary, as described in the next section.

3.4 Adjustments of Vital Rates in the Age Matrix

As noted above, under the 100-year scenario, the frog population in EPA's "non-declining" model declines to extinction within approximately 70 years, even with no exposure to PCBs. Under EPA's approach, this decline did not affect use of the model, because the population was simulated for only ten years and the model was used only to compare relative differences in rates of decline over that time period. However, adjustments in vital rates in the age matrix were necessary to allow the population to persist, even in the absence of PCBs, throughout the 100-year period used in the adjusted model.

To reduce the likelihood of extinction not attributable to PCB exposure, GE increased the survival rates and fecundity in the age matrix to increase the growth rate of the subpopulations at densities below carrying capacity. A sensitivity analysis was performed to determine the smallest increase in these parameter values that would permit relatively high persistence of the wood frog population for 100 years in the absence of PCBs. Based on this analysis, it was determined that a 12% increase in survival and fecundity was sufficient to limit the likelihood that, under EPA's "non-declining" projection (with no PCB effects), the population would go extinct over the 100-year period (only 10% risk).

The modified vital rates are still well within one standard deviation of the mean of the values reported in Berven (1990), the source of vital rates used in the original EPA model. These modifications provide a realistic simulation of the long-term dynamics of the wood frog population because, under natural conditions without any chemical exposures, such a population would be expected to persist for at least 100 years. The change does not qualitatively affect the response of the model to simulated PCB exposures. When PCB effects are introduced using the same assumptions used by EPA, the risk of extinction of the population increases, just as in EPA's simulations (see results reported in Section 3.7 below). Thus, these modifications to the EPA model allow the adjusted model to be used to compare relative effects among remedial alternatives for a 100-year scenario.

3.5 Initial Subpopulation Sizes and Initial Age Class Abundances

To maximize comparability between the original EPA model and the adjusted model, the initial subpopulation sizes and age abundances were taken from the "non-declining" projection within the PCB-impacted scenario, as reported in Attachment E.4 of Appendix E to the ERA. These initial subpopulation sizes will be used for all evaluations of remedial alternatives to ensure that outputs from each scenario are comparable. This represents a slight modification of the approach used by EPA, in which the initial subpopulation sizes used in baseline (i.e., no PCB effects) simulations were different from the initial sizes used in the PCB-impacted simulations. Because extinction risk is in part a function of the initial subpopulation sizes, using the same initial sizes for all simulations facilitates comparisons between extinction risks calculated for remediation scenarios and those for the no further action and baseline (no PCB) scenarios. The initial subpopulation sizes for the PCB-impacted "non-declining" scenario were selected for this purpose because PCBs are present in the floodplain vernal pools.

3.6 Assumptions Regarding Temporary Habitat Loss During Remediation and Restoration

Remedial actions would temporarily destroy habitat in the subject vernal pools, eliminating the pools' ability to support frogs. These impacts need to be taken into account in the model if it is to be used for modeling alternatives that involve active remediation. Thus, GE adjusted EPA's survival multiplier that accounts for PCB impacts to further account for the temporary habitat destruction caused by remediation. In this adjustment, the timing of remediation for each pool during a model run and the duration of habitat loss are based on assumptions regarding the remediation. For alternatives involving remediation throughout the PSA floodplain, remedial actions are assumed to proceed in a sequential fashion down the floodplain, starting in the second year of the 100-year run for northern pools and starting with the sixteenth year for the most southern of the pools.

During the first year of the remediation period, relative survival and fecundity multipliers for all frogs (age class 0, 1 and 2) of a remediated pool are reduced to zero, assuming that pool habitat is destroyed during the remedial action and that all frogs in the pool are killed as a result. However, it is assumed that new migrants to the pool survive and are available to reproduce in the remediated pool in subsequent years. Even though these frogs may reproduce, it is assumed that the larvae they produce do not survive until the habitat recovers. During this post-remediation recovery period, relative survival multipliers for age class 0 (includes eggs and tadpoles) are set to zero to model the assumption that recovering habitat cannot support any tadpoles due to a lack of available food and cover. The period for habitat recovery has been set to five years. This 5-year assumption bounds the most severe end of a range of possible recovery periods, since the literature and restoration experience indicate that frog habitat in many pools may rebound more quickly than five years as long as the pool contours are recreated and canopy cover remains intact (DiMauro and Hunter, 2002). Nevertheless, a sensitivity analysis performed by GE showed that changing the recovery period from five to two years had little effect on the results (less than 2% difference in extinction risk), and thus the five-year habitat recovery period was used.

During the post-remediation period, relative survival multipliers of adult age classes (age classes 1 and 2) were set to one, based on the assumption that loss of pool habitat does not pose any risk to adult frogs that depend on the surrounding woodland for resources. Following recovery of the habitat, the positive effect of removing the PCBs during remediation is modeled by setting all multipliers for all age classes to one for the remainder of the 100-year run.

3.7 Model Outputs and Behavior Following Adjustments

The behavior of the model following the above adjustments was evaluated using two extreme scenarios. The first is a Baseline Scenario (BS), which assumes that PCBs were never present in the floodplain. This scenario thus provides a simulation of the risk of extinction of a hypothetical baseline population in the PSA that has not been exposed to PCBs. The second is a PCB Scenario (PCB), which represents current conditions in the PSA, with PCBs present in vernal pools at current concentrations. This scenario provides a simulation of the risk of extinction of the frog population (based on the most severe scenario of PCB-related mortality and other inputs described above) if no remedial actions were undertaken.

Sustainability of the frog population under these two scenarios was evaluated based on the predicted probabilities that the wood frog population in the floodplain of the PSA would fall below a given number or go extinct over the 100-year duration of the model run. Figure 4 compares these probabilities for the BS and PCB scenarios. This figure plots the probability of falling below a given threshold population size on the y-axis, against a range of population thresholds on the x axis. For example, the probability of dropping below 10,000 individuals over the 100-year model simulation can be obtained for each scenario by finding the point where the 10,000 threshold on the x-axis crosses the curve for each scenario and then finding the associated probability level on the y axis. As the threshold for terminal extinction is 0 individuals (i.e., all have died), the probability of reaching terminal extinction is determined by the point where each curve crosses the y-axis.

As shown in Figure 4, the model predicts about a 6-fold higher probability of extinction by the end of 100 years with existing concentrations of PCBs in the floodplain (63.6% probability) than under the BS, which assumes no exposure to PCBs (9.6% probability). When this plot is compared with the similar figure in the ERA for the "non-declining" population model by the end of 10 years (Figure 5 in ERA Attachment E.4, reproduced as Figure 1 herein), it can be seen that the adjusted model predicts a relatively large difference between the BS and PCB scenarios similar to the original EPA model. Thus, the adjustments made to the EPA model for use in the CMS have not significantly changed the model's behavior in predicting adverse impacts of PCBs on risk of extinction of the wood frog population.

4. Application of Model Results to 68 Vernal Pools

The EPA model, with the above modifications, can be used to evaluate the predicted effects of remedial alternatives on the long-term sustainability of the wood frog population inhabiting the 27 vernal pools used in the model. However, EPA's database identifies 68 vernal pools in the floodplain of the PSA (including some that may be characterized as backwaters). Although the 41 other pools were not identified in the ERA as having suitable wood frog breeding habitat, they may serve as habitat for other amphibians. Moreover, some of those 41 pools probably are used by breeding wood frogs in some years but not in others, depending on the dynamic colonization and extinction rates for the pool; for example, 7 of the 41 pools not included in the model have documented evidence of tadpoles or eggs in the pools. Accordingly, to be conservative and recognizing that the amphibian IMPGs apply to species other than wood frogs, GE is proposing to extend the model to all 68 vernal pools.

The simplest procedure for extending the model to all vernal pools in the PSA is to apply the results from the 27-pool model to all 68 pools. This would involve the following steps for a given remedial alternative (e.g., remediation of all pools or a specified proportion of pools with PCB concentrations above a certain threshold):

- Run the 27-pool model for that alternative to estimate the probabilities that the wood frog population would fall below a certain number or go extinct over the model period.

- Expand the list of pools considered to all 68 pools, ranked in order of PCB concentration, and apply the same remedial PCB threshold to that expanded list.
- Assume that the same probabilities estimated by the 27-pool model apply to the expanded list of 68 pools.

This extrapolation from 27 to 68 pools assumes that (a) the benefits to the wood frog population due to reductions in PCB exposure, (b) the potential deleterious effects of temporary habitat loss associated with remediation, and (c) the risk of extinction of the wood frog population, as demonstrated by the 27-pool EPA model, apply to all amphibian species in the 68 pools in the floodplain. This assumption is justified for the following reasons. The relationships used in the 27-pool EPA model to relate PCB exposure to impaired larval and metamorph development are based on the same data used by EPA in the ERA to develop the Maximum Acceptable Threshold Concentration for amphibians, which constitutes the low end of the IMPG range. Since that low IMPG developed from the wood frog data is considered by EPA to be protective of other amphibian species utilizing the PSA floodplain, the underlying exposure-response data should also be considered appropriate for evaluating the risk of terminal extinction for these additional amphibian species. By the same reasoning, vital rates and other life history characteristics incorporated in the adjusted 27-pool EPA model are assumed to be representative of other amphibian species utilizing the floodplain. Moreover, although the range of PCB concentrations in the 27-pool model is not as wide, when ranked from high to low PCB concentration, the relative distribution of PCB concentrations for the 27 pools evaluated in the EPA model is representative of that for the complete set of 68 pools (Figure 5), which further justifies extending the results to the 68 pools.

To evaluate the efficacy of the extension of the results from 27 to 68 pools, GE has developed an alternative approach for evaluating remedial options, which expands the EPA wood frog model itself from 27 to 68 vernal pools. This approach assumes that all 68 pools are suitable breeding habitat for wood frogs. Such an approach defines wood frog habitat liberally and probably overestimates frog habitat because it includes more permanent pools that may be avoided by wood frogs (Hopey and Petranka, 1994). Nevertheless, this approach is justified on the same theoretical basis described above – i.e., that since the wood frog was chosen as the representative amphibian species, the model results for wood frogs provide an appropriate surrogate for evaluating population-level impacts on all amphibian species. Use of the 68-pool model thus provides a second method to verify and assess the results of the extrapolation method discussed above. The same assumptions, parameters, and equations used to develop the modified 27-pool model were used in the 68-pool model. Details on the methods used to develop the expanded model are presented in Attachment C-2.

5. Application of the Model to Example Remedial Scenarios

GE proposes to use the EPA model, with the modifications described in Section 3 and the application to 68 pools described in Section 4, to evaluate and compare the predicted effects of remedial alternatives for vernal pools on the long-term sustainability of the amphibian population in the PSA. Sustainability is measured as the risk of extinction, quantified as the probability that the wood frog population in the PSA will go extinct over the 100-year duration of the model run.

To illustrate how the model will be used to evaluate remedial alternatives, this section describes the application of the model to three hypothetical remedial alternatives:

1. No Further Action Scenario (NFAS) – This scenario assumes that current concentrations of PCBs in the vernal pools will remain unchanged over the 100-year model run. It further assumes that there will be no temporary loss of frog habitat over this time period due to remediation. This scenario provides a simulation of the long-term risk of extinction and time to extinction of the wood frog population under existing PCB exposure conditions.

2. Remedial Scenario I (RS-I) – This scenario would involve remediation of all vernal pools with spatially weighted average PCBs concentrations greater than 20 mg/kg. Based on review of the PCB data from the 68 vernal pools in the PSA, there are 28 such pools, which amounts to approximately half of the vernal pools with spatially weighted average PCB concentrations exceeding the low IMPG of 3.27 mg/kg (57 pools). Under this scenario, the final spatially weighted average PCB concentration in each remediated pool would be equivalent to the low IMPG. This scenario assumes temporary loss of habitat in each of these ponds during the remediation and restoration periods.

3. Remedial Scenario II (RS-II) – This scenario would involve the remediation of all pools with spatially weighted average PCB concentrations in excess of the low IMPG of 3.27 mg/kg, so that the final spatially weighted average PCB concentration in each such pool is equivalent to the low IMPG. This scenario assumes temporary loss of habitat in each of these pools during the remediation and restoration periods.

The following subsections describe how these alternatives would be evaluated – first using the adjusted EPA 27-pool model, then by extending those model results to all 68 pools, and finally using the 68-pool model.

5.1 Model Results for 27 Pools

The three remedial alternatives described above were initially evaluated using the adjusted 27-pool model. The 27 vernal pools in this model are listed in Table 1. As shown in that table, 19 of those pools have spatially weighted average PCB concentrations exceeding the low IMPG of 3.27 mg/kg, and approximately half of them (11 pools) have spatially weighted average concentrations greater than 20 mg/kg. Thus, for this 27-pool example, the NFAS scenario would involve remediation of none of the pools, the RS-I scenario would involve remediation of the 11 pools with the highest PCB concentrations, and the RS-II scenario would involve remediation of the 19 pools exceeding the low IMPG. A complete description of the parameters used in these three scenarios, as well as the baseline scenario (BS) discussed in Section 3.7, is presented in Attachment C-3.

The results of the evaluation of the three remedial alternatives using the 27-pool model are presented graphically in Figure 6. That figure shows the predicted probability that the wood frog population in the floodplain of the PSA would fall below a given number or go extinct over the 100-year duration of each model run. (This figure is interpreted in the same way as Figure 4, as described above.) The resulting probability of terminal extinction for each of the three remedial alternatives is summarized in Table 2. As can be seen from these results, the probability of terminal extinction for the NFAS scenario (63.6%) is almost twice that of RS-I and RS-II (32.4% and 34.2%, respectively). This is not surprising given that the NFAS scenario does not involve any removal of PCBs while RS-I and RS-II each involves substantial remediation of pool sediments.

The similarity in the probability of terminal extinction for RS-I and RS-II is more striking. RS-I involves the remediation of about half of the vernal pools with PCB concentrations exceeding the low IMPG (11 pools), while RS-II involves the remediation of all pools with PCBs concentrations in excess of that level (19 pools). These patterns of extinction risk are not limited to the risk of terminal extinction. As can be seen in Figure 6, the plots for the RS-I and RS-II alternatives are very similar over the range of population size thresholds on the x-axis and both fall well below the curve for the NFAS alternative. Thus, the probability of falling below any specific threshold number on the x-axis is reduced for the RS-I and RS-II alternatives relative to the NFAS alternative. Moreover, the probability of falling below a given threshold is almost identical for RS-I and RS-II over the entire range of thresholds. These analyses demonstrate that, under the conditions specified in the 27-pool EPA model, remediation of all pools exceeding the low IMPG does not result in a significant incremental reduction in the risk of extinction beyond remediation of about half of those pools.

5.2 Extension of 27-Pool Model to All 68 Pools

To extend the model results to all 68 pools, all those pools were ranked in order of PCB concentration (Table 3). As can be seen from that table, 57 of the pools have spatially weighted average PCB concentrations exceeding the low IMPG of 3.27 mg/kg, and again approximately half of those pools – in this case 28 pools – have spatially weighted average concentrations greater than 20 mg/kg. Thus, for this extension, the NFAS scenario would involve remediation of none of the pools, the RS-I scenario would involve remediation of the 28 pools with PCB concentrations exceeding 20 mg/kg, and the RS-II scenario would involve remediation of the 57 pools exceeding the low IMPG. For this extrapolation, it is assumed that the same probabilities of extinction predicted by the 27-pool model for these alternatives would also apply to all 68 pools (63.6% for NFAS, 32.4% and 34.2% for RS-I and RS-II, respectively). Thus, under this approach, the probability of extinction for NFAS would be significantly higher than that for the other two scenarios, while the probabilities of extinction for RS-I and RS-II would remain very similar to one another.

5.3 Application of 68-Pool Model

As an additional method to evaluate the above scenarios, and to provide a check on the extrapolated results noted in Section 5.2, the expanded 68-pool model has been applied to the same alternatives described above. For this application, the remedial alternatives evaluated were the same as those described in Section 5.2 – i.e., NFAS, involving no remediation; RS-I, involving remediation of approximately half of the pools with PCB concentrations exceeding the low IMPG (i.e., the 28 pools exceeding 20 mg/kg); and RS-II, involving remediation of all pools with PCB concentrations exceeding that IMPG (i.e., 57 pools).

The results of the evaluation of the three remedial alternatives using the 68-pool model are presented graphically in Figure 7, which shows the predicted probability that the wood frog population in the floodplain of the PSA will fall below a given number or go extinct over the 100-year duration of each model run. The curves for RS-I and RS-II fall well below that for the NFAS. The resulting probability of terminal extinction for each of the three remedial alternatives is summarized in Table 4. As can be seen from these results, the probability of terminal extinction for the NFAS scenario using 68 pools (71.1%) is about twice that of RS-I and RS-II (33.9% and 28.3%, respectively), while the probabilities for RS-I and RS-II, while not quite as close as in the 27-pool model, are still generally similar to each other for terminal extinction.

These results from the 68-pool model generally confirm the pattern seen with the extrapolation of the 27-pool model results to the 68 pools. In both cases, the model indicates that remediation of all pools exceeding the low IMPG and remediation of about half of those pools (with the highest PCB concentrations) produce predicted terminal extinction risks that are relatively similar.

6. Conclusion

The EPA frog population model, with the adjustments and application of model results to 68 pools, provides a useful tool for evaluating and comparing the likely effects of various remedial alternatives on the sustainability of the local amphibian population in the PSA floodplain. Under this approach, instead of using the model (as EPA did) to quantify the increase in extinction risk caused by exposure of the wood frog population to PCBs present in vernal pool sediments, the model would be used to quantify the decrease in extinction risk caused by remediation of some fraction of the pools to sediment concentrations equal to or lower than the IMPG.

7. References

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Hopey, M.E., and J.W. Petranka. 1994. Restriction of wood frogs to fish-free habitats: How important is adult choice? *Copeia* 1994(4):1023-1025.

Figures

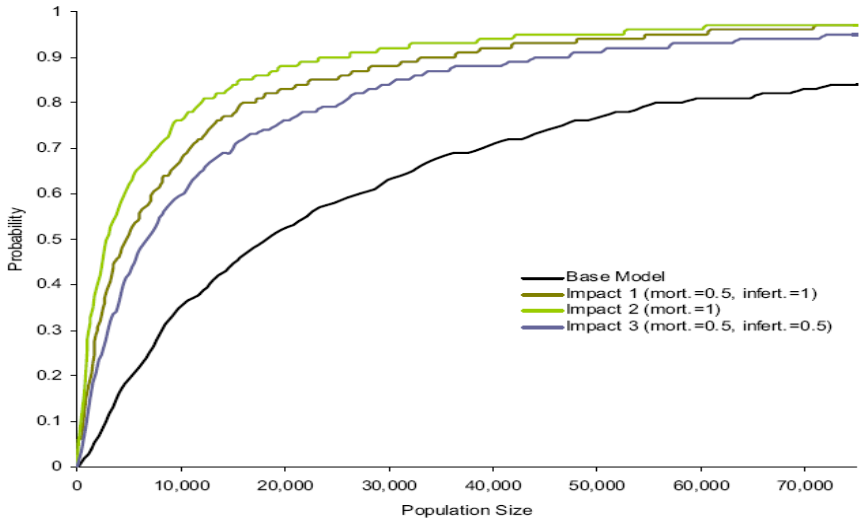

Figure 1. Output from the EPA "non-declining projection" model showing the probability of the wood frog population falling below a threshold number of individuals in 10 years by population threshold size for four scenarios: Base model (no PCB impacts), Impact 1 (malformed frogs have 50% mortality and 100% infertility), Impact 2 (malformed frogs have 100% mortality), Impact 3 (malformed frogs have 50% mortality and 50% infertility). Source: Figure 5 in Appendix E, Attachment E.4 in EPA (2004).

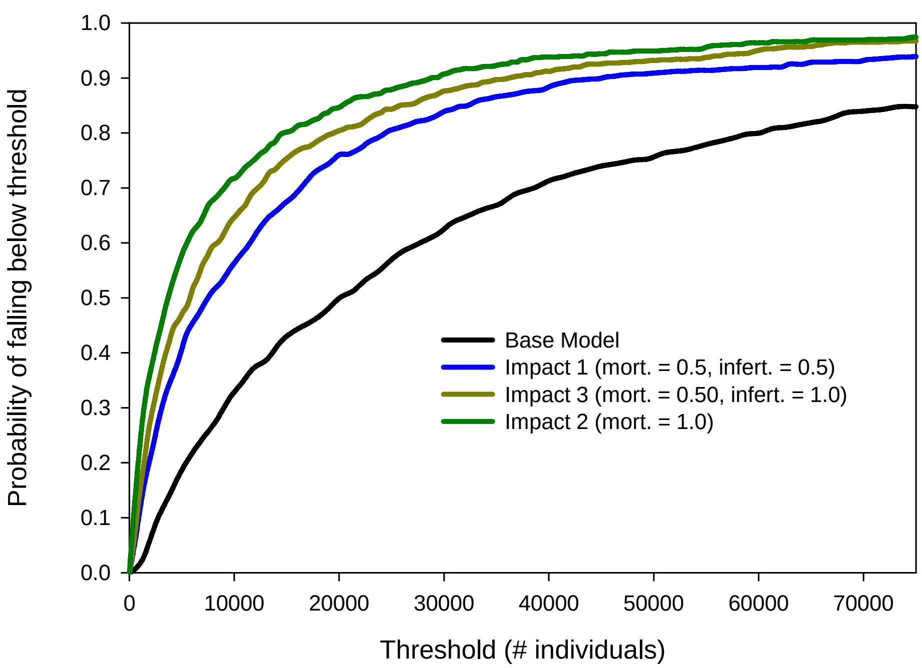

Figure 2. Output from GE model that closely duplicates the EPA model output shown in Figure 1.

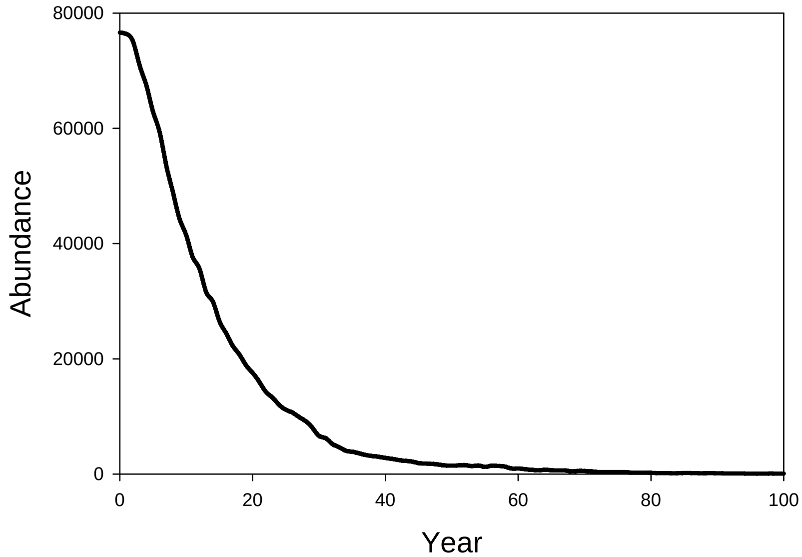

Figure 3. Trajectory of the population size predicted over time for the wood frog based on the EPA's non-declining projection scenario. Note that the population goes extinct (falls to zero) before 100 years.

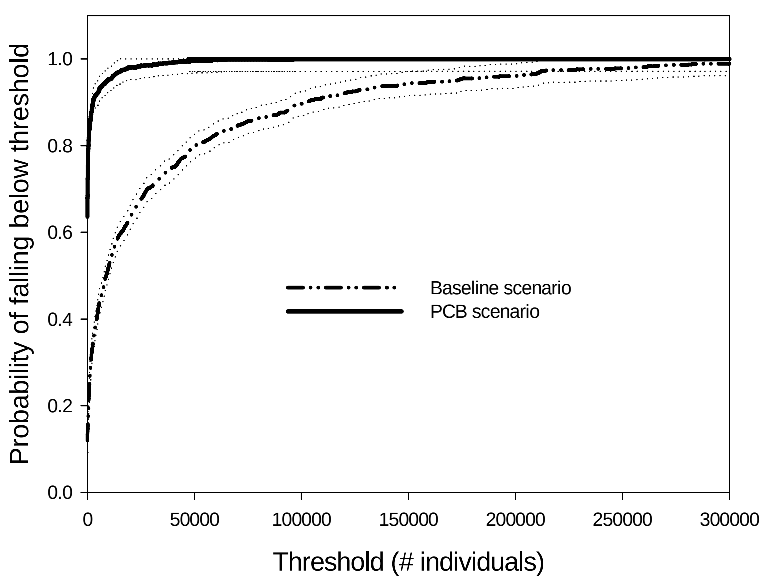

Figure 4. Based on the 27-pool wood frog model, probability of wood frog population falling below a threshold number of individuals (threshold = 0 for terminal extinction) in 100 years by population threshold for the two benchmark scenarios: baseline scenario (BS) which assumes no PCB impacts; and PCB scenario based on current conditions. The probability of reaching extinction (where risk curve intersects y-axis) for the PCB scenario is over 6 times higher (0.636) than the BS (0.096). Dotted lines bounding the probability curves are the upper and lower limits of the 95% confidence intervals.

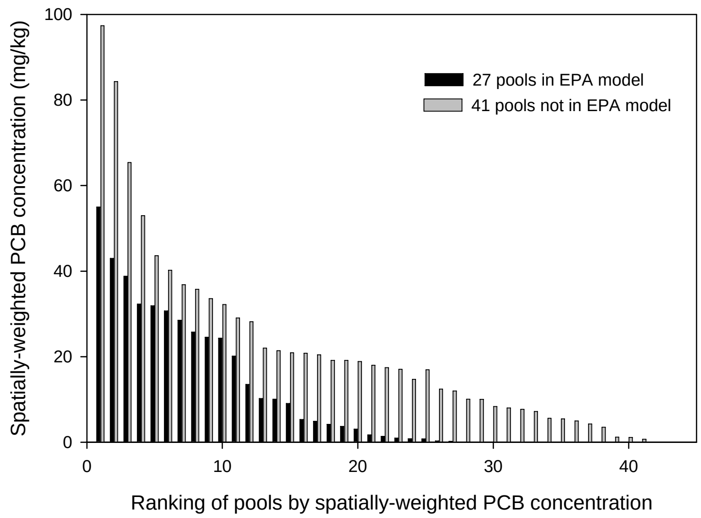

Figure 5. Distribution of PCB concentrations for 27 pools in EPA model compared to the 41 pools not in the EPA model.

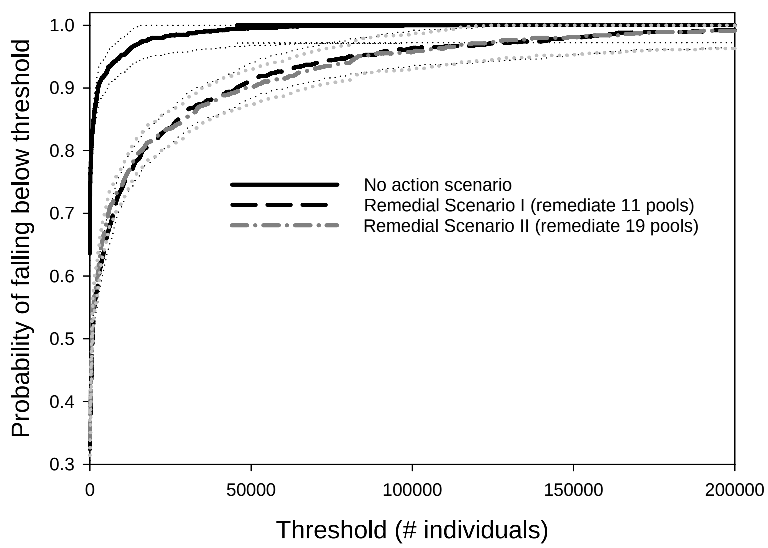

Figure 6. Based on the 27-pool wood frog model, probability of population falling below a threshold number of individuals (threshold = 0 for terminal extinction) in 100 years by population threshold for two remedial scenarios (RS-I and RS-II) and the no further action scenario (NFAS). The probabilities of reaching extinction (where curve intersects y-axis) for RS-I = 0.324 and for RS-II = 0.342 are well below that for the NFAS scenario with PCBs (0.636) and probabilities of the remedial scenarios are similar to each other. Dotted lines bounding the probability curves are the upper and lower limits of the 95% confidence intervals.

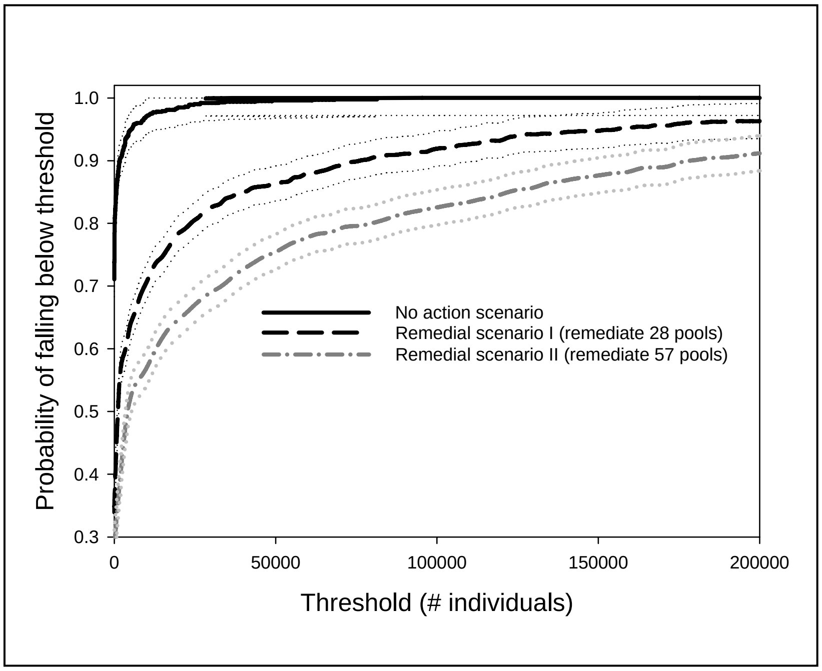

Figure 7. Based on the 68-pool wood frog model, probability of population falling below a threshold number of individuals (threshold = 0 for terminal extinction) in 100 years by population threshold for two remedial scenarios (RS-I and RS-II) and the no further action scenario (NFAS). The probabilities of reaching extinction (where curve intersects y-axis) for RS-I = 0.339 and for RS-II = 0.283 are well below that for the NFAS scenario with PCBs (0.711). Dotted lines bounding the probability curves are the upper and lower limits of the 95% confidence intervals.

Table 1. Housatonic PSA Pools that are Included in the Remedial Scenarios for 27 Pools[1]

Pool Name	Spatially Weighted Mean [tPCBs] (mg/kg)
8-VP-2	54.98
39-VP-1	42.96
26-VP-1	38.81
38-VP-2	32.31
8-VP-5	31.86
19-VP-1	30.67
38-VP-1	28.54
38a-VP-1	25.77
8-VP-1	24.56
49a-VP-1	24.34
42-VP-3	20.12
38-VP-3	13.49
27-VP-1	10.21
27b-VP-3	10.05
18-VP-1	9.03
66a-VP-1	5.31
18-VP-2	4.9
27b-VP-2	4.18
40-VP-1	3.69
23a-VP-1	3.04
12-VP-1	1.72
46-VP-5	1.36
8-VP-4	0.95
19-VP-7	0.82
46-VP-1	0.76
23b-VP-2	0.3
23b-VP-1	0.21

[1] Pool is included in the Remediation Scenario I (RS-I) if shaded gray

– – – Dashed line is the low IMPG cutoff. All pools listed above this cutoff are included in RS-II.

Table 2. Risk of Terminal Extinction for Remedial Scenarios for 27 Pools[1]

Remedial Scenario	Number of Pools Remediated	Risk of Terminal Extinction[1]
NFAS	**0**	**0.636**
RS-I	**11**	**0.324**
RS-II	**19**	**0.342**

[1] Risk of terminal extinction is from 27-pool model and represents the probability that the population will fall to zero individuals over the 100-year duration of the model run.

Table 3. Housatonic PSA Pools that are Included in the Remedial Scenarios for 68 pools.[1]

Pool Name	Spatially Weighted Mean [tPCBs] (mg/kg)
19-VP-8	**97.36**
33-VP-2	**84.31**
56A-VP-1	**65.40**
8-VP-2	54.98
23-VP-1	**52.95**
40A-VP-1	**43.59**
39-VP-1	42.96
19-VP-2	**40.19**
26-VP-1	38.81
42-VP-2	**36.80**
42-VP-4	**35.72**
19-VP-5	**33.60**
38-VP-2	32.31
40-VP-3	**32.19**
8-VP-5	31.86
19-VP-1	30.67
42-VP-5	**29.04**
38-VP-1	28.54
54-VP-1	**28.20**
38a-VP-1	25.77
8-VP-1	24.56
49a-VP-1	24.34
19-VP-6	**21.97**
49-VP-1	**21.40**
69-VP-1	**20.91**
42A-VP-1	**20.80**
27A-VP-1	**20.42**
42-VP-3	20.12
61A-VP-1	**19.10**
49B-VP-1	**19.10**
42-VP-1	**18.84**
55A-VP-1	**18.00**
8-VP-6	**17.43**
23-VP-2	**17.07**
46-VP-3	**14.70**
40-VP-2	**16.96**
38-VP-3	13.49
19-VP-3	**12.42**
61A-VP-2	**12.00**
27-VP-1	10.21
27-VP-2	**10.06**

Table 3 Continued	
27b-VP-3	10.05
33-VP-1	**10.00**
18-VP-1	9.03
19-VP-4	**8.34**
46-VP-2	**8.00**
5-VP-3	**7.70**
23-VP-3	**7.20**
8-VP-3	**5.57**
27B-VP-1	**5.46**
66a-VP-1	5.31
58A-VP-1	**5.00**
18-VP-2	4.90
5-VP-1	**4.27**
27b-VP-2	4.18
40-VP-1	3.69
67A-VP-1	**3.50**
- - - - - - - - -	- - - - - - - - -
23a-VP-1	3.04
12-VP-1	1.72
46-VP-5	1.36
55-VP-1	**1.20**
5-VP-2	**1.13**
8-VP-4	0.95
19-VP-7	0.82
46-VP-1	**0.76**
46-VP-4	**0.69**
23b-VP-2	0.30
23b-VP-1	0.21

, [1] Forty-one of the pools (bold) are not included in the 27-pool model but they would be remediated if their PCB concentration falls above the threshold of 20 mg/kg, as in the 27-pool model (shaded region). A pool is included for remediation in the Remediation Scenario I (RS-I) if in shaded region.

– – – Dashed line is the IMPG cutoff. All pools listed above this cutoff are included for remediation in RS-II.

Table 4. Risk of Terminal Extinction for Remedial Scenarios for 68 Pools.

Remedial Scenario	Number of Pools Remediated	Risk of Terminal Extinction[1]
NFAS	0	0.711
RS-I	28	0.339
RS-II	57	0.283

[1] Risk of terminal extinction is from 68-pool model and represents the probability that the population will fall to zero individuals over the 100-year duration of the model run.

Attachment C-1: Selected Aspects of Modeling

This attachment is designed to provide supplemental descriptions on select aspects of the modeling proposed by GE. The intent is to provide additional background on some of the more technical aspects of population modeling. The descriptions relate specifically to using RAMAS Metapop 5.0. to model the wood frog population within the Primary Study Area (PSA) of the Housatonic River floodplain, with the adjustments to the EPA model described in the main text of Appendix C. The topics of this attachment are as follows.

1. **Metapopulations –** Theory and explanation
2. **RAMAS Metapop 5.0 –** An overview of the RAMAS metapopulation viability model
3. **Vital Rates –** Measures of wood frog survival and reproduction
4. **Age Matrix –** Incorporating vital rates into RAMAS models
5. **Dispersal –** Incorporating dispersal between pools
6. **Relative Multipliers –** Use of relative multipliers to model PCB exposure effects

1. Metapopulations – Theory and Explanation

A metapopulation is a set of partially isolated subpopulations belonging to the same species. The subpopulations are able to exchange individuals and recolonize sites in which the species has recently become extinct. Metapopulation theory holds that the subpopulations will act independently of one another in resource use, and that most of the breeding is localized within specific subpopulations. However, individuals will at times disperse to and from other subpopulations, facilitating gene flow. The dynamics of metapopulations that are frequently modeled include subpopulation and regional extinction, rescue effects, and the dynamic components of recolonization (Hanski, 1999).

Metapopulation theory states that the size and isolation of a habitat patch containing a subpopulation are important determinants of patch occupancy (Hanski, 1999). If the subpopulations become too isolated and fragmented, the entire metapopulation could become extinct. Conversely, a subpopulation in a patch in close proximity to another patch that recently went extinct may recolonize the extinct patch. The metapopulation structure can reduce the likelihood of extinction for subpopulations. However, some patches may be of poor quality with limited reproduction and survival and are population "sinks" (net importer of individuals into the subpopulation), while patches of high quality are "sources" (net exporter of individuals out of the subpopulation). A good metapopulation model structure can account for such differences in quality among patches, whether natural or caused by PCBs or remediation activities.

The wood frog population in the PSA of the Housatonic River floodplain is an example of a metapopulation. Each vernal pool represents a habitat patch occupied by a subpopulation of frogs, where breeding and juvenile development occur. The pools are isolated by land, but when frogs mature and leave the pools, some disperse to new pools, although the majority (about 80%, Berven and Grudzien, 1990) return to the same pool to reproduce. If a pool dries up before all eggs hatch, few or no juveniles will be produced that year. However, the following year juvenile frogs from a nearby pool that successfully immigrate can recolonize the pool, returning the pool to productive habitat during later wetter years that sustain the required water levels. To capture sink/source and dispersal dynamics, the EPA model treats the PSA wood frog population as a metapopulation using the software program, RAMAS Metapop 5.0. A detailed description of the software's functionality as it pertains to the model is provided in the next section.

2. RAMAS Metapop 5.0 – An Overview of the RAMAS Metapopulation Viability Model

RAMAS Metapop version 5.0 is a computer software program developed by Applied Biomathematics Inc. that is used to stochastically model metapopulation viability. Stochasticity means randomness or the lack of any predictable order or plan and is generally measured in terms of probability. Models without stochasticity are deterministic, with one predicted outcome. Models with stochasticity have many possible outcomes due to random variation around the mean for a parameter, whether it be survival, fecundity, dispersal, or carrying capacity Stochastic population models often take the random variability of a natural environmental setting into account (e.g., climatic fluctuations or changes in predation) by randomly selecting a rate from the expected distribution of the rates around the vital rate mean (distributions such as normal or lognormal around survival or fecundity, see Section 4 for definition of vital rate). This is a very important consideration when attempting to predict population viability because in a natural setting there are significantly more variables acting upon a population beyond just the parameters that are entered into a model. Theoretically, the possible combinations of environmental pressures acting on a population could be considered infinite.

When major environmental factors affect population growth in all subpopulations similarly (e.g., drought year dries up most vernal pools), the population growth rate should be synchronized among subpopulations. The growth rates can be synchronized by correlating the stochastic parameters that determine the growth rate of subpopulations. The degree of correlation is specified by the modeler (0 = uncorrelated and 1 = perfect correlation).

In the wood frog model, only the survival and fecundity rates are stochastic. Stochasticity of these rates is composed of environmental and demographic stochasticity. Environmental stochasticity is described above as the variation caused by the natural changes occurring in the environment over time. In contrast, demographic stochasticity is not an estimate of the variability through time but rather accounts for variation around the mean vital rates due to chance, particularly in small subpopulations where death of a single individual may have a strong effect on subpopulation growth. To model demographic stochasticity, survival rates are randomly selected from a binomial distribution and fecundity is selected from a poisson distribution around the mean. The vital rates selected each year in the frog model were set to be perfectly correlated (r = 1.0) among the age classes and between survival and fecundity within a subpopulation, given no other information to suggest otherwise. These initial vital rates are modified by random selection of a rate from a normal or lognormal distribution around the initial rates that models the environmental stochasticity. The environmental stochasticity was best modeled using a lognormal distribution in the wood frog model because standard deviations of the vital rates are high relative to the mean. The correlation of the final vital rates selected among subpopulations across years was relatively high at 0.5, which accounts for all pools in the PSA being subjected to similar climatic conditions, yet allows some variation to be caused by changes in more local factors such as predation or competition.

RAMAS runs the model repeatedly in an iterative process, in which each iteration randomly draws a value from the distribution of each stochastic parameter. The modeler selects the number of iterations (set to 1000 in frog model). The more times the model is run, the more robust the conclusion, because the results are generated as probability estimates, and variability around probabilities decreases as sample size increases.

3. Vital Rates – Measures of Wood Frog Survival and Reproduction

Vital rates in RAMAS describe parameters that control the ability of a population to survive from one year to the next, and to reproduce a new generation. The following two subsections describe each of these parameters.

Survival

A survival rate specific to each age group is entered as a fraction that modifies the number of individuals in each age group in a subpopulation for each time step. For example, if the survival estimate for all one-year old frogs in a pool is 0.6, by the end of the year 60% live to 2 years old and 40% die.

Fecundity (Reproductive Capability)

Fecundity of each age class can provide a measure of the reproductive capacity of a subpopulation. In a model based on a pre-breeding count (number in each age class surveyed immediately before animals breed), it is calculated by multiplying the maternity of each age class by survival of the young (0 age class) over the year. The maternities in the frog model are the average number of eggs produced per year per adult frog of a given age class (including non-breeders). Such an estimate can be divided by two to estimate the number of one sex produced by females (e.g., number of females produced per female), which is entered into the age matrix (see below). The population dynamics in the wood frog model were based on a pre-breeding census (Berven, 1990), and thus fecundity in the model depicts the quantity of juvenile frogs that a mature frog of a given age produces and that survive to the next pre-breeding census.

4. Age Matrix – Incorporating Vital Rates into RAMAS Model

The age matrix, or, as it is often called, the Leslie Matrix, is the means by which RAMAS incorporates the vital rates (survival and fecundity) into the model computations. The table below provides an example of a section of the age matrix for female fecundity (number of females produced per female) and female survival for each age class.

			From	
		Age 0	Age 1	Age 2
	Age 0	0.0560	3.248	3.248
To	Age 1	0.3248	0	0
	Age 2	0	0.1456	0

The 1st row is composed of fecundity values

The remaining rows are composed of survival values

For a pre-breeding census, Age 0 individuals are almost one year old and, for species such as wood frogs, are able to breed. The example provided above is a one-sex female section of the larger two-sex age matrix used in the Housatonic frog model.

5. Dispersal – Incorporating Migration between Pools

Dispersal is the movement of organisms from one subpopulation to another. Dispersal allows for recolonization of subpopulations that went extinct. The proportion dispersing is used in the

RAMAS model and is the ratio of the number of dispersers to the number of individuals in the subpopulation just before the dispersal. Dispersal rates may be a function of subpopulation abundance or carrying capacity (density-dependent dispersal) and distance. In the frog model, only young frogs disperse, and dispersal is modeled as the proportion of frogs of each subpopulation dispersing to each of the other subpopulations based on distance. Density-dependent dispersal is not modeled. While it is conceivable that in addition to distance, density dependence may also be encouraging or discouraging dispersal among subpopulations, GE retained this assumption in the adjusted model to match EPA's approach. Therefore, the adjusted model used the dispersal matrix presented in Appendix E, Attachment E.4 of the ERA (EPA, 2004). One pool was missing from the matrix in the ERA. The dispersal values for that pool were obtained using pool distances estimated in Arc/Info.

6. Relative Multipliers – Use of Relative Multipliers to Model PCB Exposure Effects

Relative multipliers are the means in which impacts from PCB exposure are incorporated in the RAMAS model. These multipliers are applied to the vital rates in the age matrix. The relative multipliers used in the adjusted model, with its assumptions of 100% mortality of metamorphs, are less than one and thus model the deleterious impacts from PCB exposure, reducing the vital rate. For example, a relative multiplier of 0.78 applied to a survival rate of 0.8 produces a new survival rate of 0.624 that incorporates PCB exposure. These multipliers vary based on the PCB concentration found in a given pool. In the frog model, the higher the concentration, the more severe the impact, and therefore the smaller the fraction used as a relative multiplier in the model. Relative multipliers vary by age class ("Age 0" can have a different multiplier than "Age 2"). In the frog model, only juvenile frogs are affected by PCB exposure and have relative survival multipliers less than 1.0. Fecundity multipliers also are less than 1.0 to model the effect of gonadal malformations. A pool unaffected by PCBs (below the lower IMPG in the adjusted model) or remediated has a survival or fecundity multiplier of 1.0 (no effect).

7. References

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EPA (United States Environmental Protection Agency). 2004. *Ecological Risk Assessment for General Electric (GE)/Housatonic River Site, Rest of River.* Prepared by Weston Solutions, Inc. for U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. Attachment E.4 in Appendix E: "A Stochastic Population Model Incorporating PCB Effects for Wood Frogs (*Rana sylvatica*) Breeding in Vernal Pools Associated with the Housatonic River Pittsfield to Lenoxdale, Massachusetts." Prepared by Applied Biomathematics and Woodlot Alternatives.

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Attachment C-2: Development of 68-Pool Model

This attachment describes the development of the 68-pool wood frog model. The 68-pool model was run using the same general parameters in the 27-pool model. The values of parameters that were identical to the 27-pool model were mating ratios, age matrix, standard deviations of the age matrix, correlation among populations and within age groups and demographic parameters, duration of runs, number of simulations, designation of dispersing age classes, and demographic stochasticity. However, new values were estimated for the additional new pools for many parameters, using the same general assumptions and equations used in EPA's model and the 27-pool model. Similar to the 27-pool model, the 68-pool model assumes 100% mortality of all malformed metamorphs. The approach to developing new values for parameters is described below.

Dispersal: The dispersal matrix predicts the proportion of juvenile frogs emigrating from a pool to each of the other pools based on the distance between pools. The matrix for the 68-pool model was developed based on the methods employed in the EPA model. Distances from the center of each pool (centroid of the pool polygon) to the other 68 pools was calculated in GIS. The negative exponential equation in Berven and Grudzien's (1990) study was then used to predict proportion emigrating from a pool to each of the other pools based on the distance between pools. The proportions for each pool were summed and all values were adjusted proportionally to obtain a value of 18.54% leaving each pond, based on Berven and Grudzien's estimate of proportion emigrating.

Initial Population Estimates: Initial population estimates for the 25 new pools were calculated from estimates of volume, spatially-weighted PCB concentrations, and initial adult frog densities using the same method EPA used. Volumes for the new pools were estimated based on a regression of volume on pool area using the original 27 pools with a power function, which provided the best fit (Figure 1). The spatially-weighted PCB concentrations of the new pools were based on the method in the ERA of using inverse-distance weighting of the PCB concentrations of the top six inches of pool sediment.

Initial adult frog densities were estimated using EPA's regression of adult frog density on spatially-weighted PCB concentrations to establish initial densities for the No Further Action Scenario for the new pools. Some populations in pools with the highest PCB concentrations had negative estimates and were set to 0. Densities were multiplied by volume to obtain the initial population estimates. As was done for the 27-pool model, these population sizes were used for all scenarios to make them comparable.

Carrying Capacity for New Ponds: Carrying capacity for each of the new pools was set at ten times the baseline population size estimates. Baseline population size was estimated by setting the PCB concentration to 0 in the regression relating PCB concentration to adult density mentioned above and multiplying by pool volume.

Survival and Fecundity Multipliers: Survival and fecundity multipliers were developed for each pool using the equations apparently used in the EPA model. The equations derived and used produced multiplier values identical to the values that EPA used for the 27 pools in the ERA. Mortality multipliers for Age class 0 were calculated using EPA's regressions of larval mortality and metamorph malformation rate on spatially-weighted PCB concentration, assuming 100%

mortality and sterility of malformed metamorphs. The y-intercept of the larval mortality regression produced the reference mortality rate for the larval survival multiplier. The larval survival multiplier for the 68 pools then was calculated using the following equation:

$$\text{Larval survival multiplier} = 1 + \frac{(\text{reference mortality} - \text{PCB-exposed mortality})}{100 * 2}$$

The sex-specific mortality multiplier (equal to the malformation rate) was subtracted from the larval survival multiplier to obtain the Age class 0 survival multiplier. Survival multipliers for Ages 1 and 2 were set to 1.0.

Female gonadal malformation rate was calculated as 0.57 of all female malformations. The proportion of females without gonadal malformations (x) was input into the equation below to obtain the fecundity multiplier (y) for 100% sterility:

$$y = (x - 2.09)(x - 0.19) \quad * \quad -1.125$$

This equation was obtained by regressing y against x using the 27 pools that had such data to obtain a quadratic equation ($R^2 = 1.0$) and then factoring out the quadratic equation.

Timing of remediation: For scenarios involving remediation, timing of remediation is based on the same assumptions used in the model runs with the original 27 pools. The PSA was divided into 15 reaches, each with an assigned expected time for remediation, assuming remediation progresses downstream over time with the final pool remediated after 16 years. The number of years expected until remediation for each of the new pools is based on their location in these reaches.

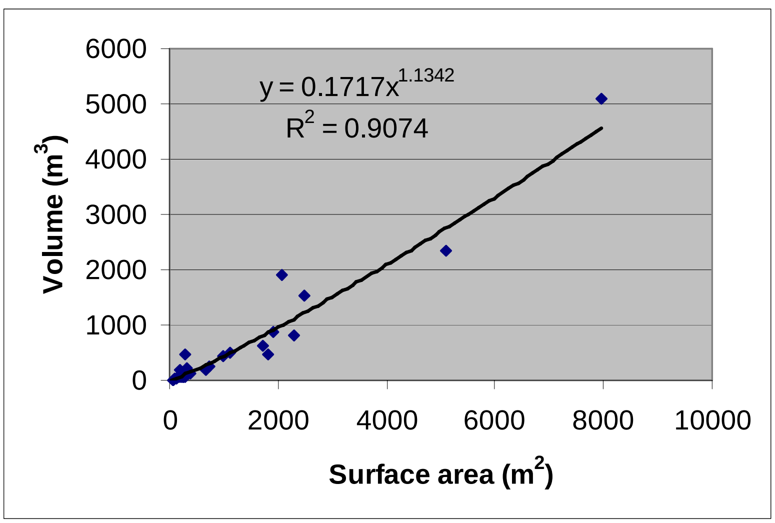

Figure 1. Regression predicting pool volume based on pool surface area developed using data from the 27 pools in the original EPA model.

Attachment C-3:
Parameter Inputs for 27-Pool Model Runs

This attachment provides the numerical values of the parameters for each of the four model scenarios discussed in the text of Appendix C for the 27-pool model – the Baseline Scenario (BS), the PCB Scenario (which is the same as the No Further Action Scenario [NFAS]), Remedial Scenario I (RS-I), and Remedial Scenario II (RS-II). This attachment also presents model flow charts for the Baseline, PCB, and Remedial Scenarios (Figures 1, 2, and 3, respectively). Values were from Appendix E, Attachment E.4 of the ERA (EPA, 2004) except for the modifications specified in Appendix C.

Model Parameter Inputs for Baseline Scenario (BS)

Replications: 1000

Replications: 1000
Duration: 100 time steps (100.0 years)

Stage structure
There are 6 stages

Stage-specific parameters

Stage	***Relative Dispersal***
Fem Age 0	1
Fem Age 1	0
Fem Age 2	0
Male Age 0	1
Male Age 1	0
Male Age 2	0

Sex structure
Both females and males
3 female stages
Mating system: polygynous, 1 male breeds with up to10 females

Age matrix

default	Fem Age 0	Fem Age 1	Fem Age 2	Male Age 0	Male Age 1	Male Age 2
Fem Age 0	0.056	3.248	3.248	0.0	0.0	0.0
Fem Age 1	0.3248	0.0	0.0	0.0	0.0	0.0
Fem Age 2	0.0	0.1456	0.0	0.0	0.0	0.0
Male Age 0	0.056	3.248	3.248	0.0	0.0	0.0
Male Age 1	0.0	0.0	0.0	0.3248	0.0	0.0
Male Age 2	0.0	0.0	0.0	0.0	0.1456	0.0

Constraints

Identification of cell in age matrix as survival (=1) or fecundity (=0).

	Fem Age 0	Fem Age 1	Fem Age 2	Male Age 0	Male Age 1	Male Age 2
Fem Age 0	0.0	0.0	0.0	1.0	1.0	1.0
Fem Age 1	1.0	1.0	1.0	1.0	1.0	1.0
Fem Age 2	1.0	1.0	1.0	1.0	1.0	1.0
Male Age 0	0.0	0.0	0.0	1.0	1.0	1.0
Male Age 1	0.0	0.0	0.0	1.0	1.0	1.0
Male Age 2	0.0	0.0	0.0	1.0	1.0	1.0

Stochasticity

Demographic stochasticity is used
Environmental stochasticity distribution: Lognormal
Extinction threshold for metapopulation = 0
Explosion threshold for metapopulation = 0
When abundance is below local threshold: count in total
Within-population correlation: All correlated (F, S, K)
(F = fecundity, S = survival, K = carrying capacity)

Standard deviations matrix

default	Fem Age 0	Fem Age 1	Fem Age 2	Male Age 0	Male Age 1	Male Age 2
Fem Age 0	0.06	2.21	2.1	0.0	0.0	0.0
Fem Age 1	0.22	0.0	0.0	0.0	0.0	0.0
Fem Age 2	0.0	0.07	0.0	0.0	0.0	0.0
Male Age 0	0.06	2.21	2.1	0.0	0.0	0.0
Male Age 1	0.0	0.0	0.0	0.22	0.0	0.0
Male Age 2	0.0	0.0	0.0	0.0	0.07	0.0

Catastrophes

There are no catastrophes.

Initial abundances

	Fem Age 0	Fem Age 1	Fem Age 2	Male Age 0	Male Age 1	Male Age 2
12-VP-1	335	96	13	334	101	14
18-VP-1	721	209	29	721	227	31
18-VP-2	2308	664	91	2309	706	97
19-VP-1	214	67	10	215	81	13
19-VP-7	91	26	3	90	27	4
23a-VP-1	721	206	28	721	217	30
23b-VP-1	211	60	8	210	63	8
23b-VP-2	184	52	7	182	54	7
26-VP-1	31	10	2	31	13	2
27b-VP-2	725	208	29	724	221	30
27b-VP-3	105	30	4	104	33	5
27-VP-1	3231	938	131	3231	1029	144
38a-VP-1	19	6	1	19	7	1
38-VP-1	539	165	26	540	199	31
38-VP-2	156	48	8	155	59	9
38-VP-3	86	25	4	86	28	4
39-VP-1	2484	829	144	2484	1051	183
40-VP-1	1359	393	54	1358	413	56
42-VP-3	204	61	9	204	70	10
46-VP-1	3107	885	120	3108	932	126
46-VP-5	110	31	4	109	33	4
49a-VP-1	15	4	1	15	5	1
66a-VP-1	49	14	2	49	15	2
8-VP-1	71	21	3	71	25	4
8-VP-2	156	57	11	155	74	15
8-VP-4	730	208	28	731	219	30
8-VP-5	41	13	2	40	15	2

Spatial structure

There are 27 populations

Characteristics of each local population:

Population	Initial abundance	Relative survival and Relative fecundity	Carrying capacity (K)	Density-dependent dispersal as a function of source pop. size (slope)
12-VP-1	893	1	8930	0.0
18-VP-1	1938	1	19380	0.0
18-VP-2	6175	1	61750	0.0
19-VP-1	600	1	6000	0.0
19-VP-7	241	1	2410	0.0
23a-VP-1	1923	1	19230	0.0
23b-VP-1	560	1	5600	0.0
23b-VP-2	486	1	4860	0.0
26-VP-1	89	1	890	0.0
27b-VP-2	1937	1	19370	0.0
27b-VP-3	281	1	2810	0.0
27-VP-1	8704	1	87040	0.0
38a-VP-1	53	1	530	0.0
38-VP-1	1500	1	15000	0.0
38-VP-2	435	1	4350	0.0
38-VP-3	233	1	2330	0.0
39-VP-1	7175	1	71750	0.0
40-VP-1	3633	1	36330	0.0
42-VP-3	558	1	5580	0.0
46-VP-1	8278	1	82780	0.0
46-VP-5	291	1	2910	0.0
49a-VP-1	41	1	410	0.0
66a-VP-1	131	1	1310	0.0
8-VP-1	195	1	1950	0.0
8-VP-2	468	1	4680	0.0
8-VP-4	1946	1	19460	0.0
8-VP-5	113	1	1130	
Total	48877	1	488770	

Correlation
Environmental fluctuations between years among populations are correlated, with correlation coefficients among populations all set to 0.500 to 0.500

Populations

General
Local threshold is 0.0
All populations are included in the summation

Density dependence
Density dependence is based on the abundances of all stages
Density dependence affects all vital rates
Density dependence type is Ceiling

Standard deviation of K is 0.0

Population management
Population management is not used

Dispersal

The dispersal matrix of proportion migrating from one pool to another is shown below:

LocationID	8-VP-1	8-VP-2	8-VP-4	8-VP-5	12-VP-1	18-VP-1	18-VP-2	19-VP-1	19-VP-7	23A-VP-1	23B-VP-1	23B-VP-2	26-VP-1	27B-VP-2	27B-VP-3	27-VP-1	38A-VP-1	38-VP-1	38-VP-2	38-VP-3	39-VP-1	40-VP-1	42-VP-3	46-VP-1	46-VP-5	49A-VP-1	66A-VP-1
8-VP-1	0.0000	0.0257	0.0307	0.0397	0.0079	0.0071	0.0084	0.0047	0.0063	0.0019	0.0013	0.0012	0.0009	0.0014	0.0016	0.0010	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000
8-VP-2	0.0325	0.0000	0.0366	0.0334	0.0128	0.0124	0.0144	0.0082	0.0110	0.0033	0.0023	0.0020	0.0016	0.0024	0.0027	0.0018	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000
8-VP-4	0.0383	0.0360	0.0000	0.0407	0.0117	0.0106	0.0126	0.0068	0.0089	0.0026	0.0018	0.0017	0.0013	0.0020	0.0022	0.0014	0.0002	0.0003	0.0002	0.0002	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000
8-VP-5	0.0460	0.0306	0.0379	0.0000	0.0098	0.0088	0.0104	0.0057	0.0075	0.0022	0.0015	0.0014	0.0011	0.0017	0.0019	0.0012	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000
12-VP-1	0.0097	0.0125	0.0116	0.0104	0.0000	0.0227	0.0252	0.0164	0.0136	0.0045	0.0038	0.0036	0.0032	0.0047	0.0055	0.0035	0.0004	0.0005	0.0004	0.0004	0.0006	0.0004	0.0003	0.0001	0.0001	0.0000	0.0000
18-VP-1	0.0111	0.0152	0.0132	0.0117	0.0287	0.0000	0.0322	0.0227	0.0218	0.0067	0.0053	0.0049	0.0041	0.0062	0.0071	0.0045	0.0006	0.0007	0.0006	0.0006	0.0008	0.0006	0.0005	0.0002	0.0002	0.0001	0.0001
18-VP-2	0.0126	0.0170	0.0151	0.0134	0.0306	0.0310	0.0000	0.0191	0.0191	0.0057	0.0045	0.0041	0.0035	0.0052	0.0060	0.0038	0.0005	0.0006	0.0005	0.0005	0.0007	0.0005	0.0004	0.0002	0.0001	0.0001	0.0001
19-VP-1	0.0072	0.0100	0.0085	0.0076	0.0208	0.0227	0.0199	0.0000	0.0243	0.0101	0.0084	0.0079	0.0067	0.0100	0.0115	0.0072	0.0010	0.0011	0.0010	0.0009	0.0013	0.0009	0.0007	0.0003	0.0003	0.0002	0.0001
19-VP-7	0.0094	0.0130	0.0107	0.0097	0.0166	0.0210	0.0191	0.0234	0.0000	0.0108	0.0078	0.0071	0.0057	0.0085	0.0093	0.0061	0.0010	0.0011	0.0009	0.0009	0.0012	0.0009	0.0007	0.0003	0.0003	0.0002	0.0001
23A-VP-1	0.0030	0.0041	0.0033	0.0030	0.0057	0.0067	0.0059	0.0101	0.0112	0.0000	0.0201	0.0179	0.0141	0.0159	0.0151	0.0140	0.0033	0.0036	0.0032	0.0030	0.0039	0.0030	0.0025	0.0011	0.0010	0.0007	0.0004
23B-VP-1	0.0025	0.0034	0.0028	0.0025	0.0059	0.0064	0.0056	0.0102	0.0099	0.0244	0.0000	0.0267	0.0206	0.0224	0.0207	0.0209	0.0037	0.0040	0.0035	0.0034	0.0046	0.0032	0.0026	0.0011	0.0010	0.0007	0.0004
23B-VP-2	0.0022	0.0031	0.0025	0.0023	0.0056	0.0060	0.0053	0.0096	0.0090	0.0219	0.0269	0.0000	0.0230	0.0227	0.0209	0.0234	0.0039	0.0043	0.0037	0.0036	0.0049	0.0033	0.0027	0.0011	0.0010	0.0008	0.0004
26-VP-1	0.0016	0.0022	0.0018	0.0016	0.0045	0.0045	0.0040	0.0073	0.0064	0.0153	0.0184	0.0204	0.0000	0.0180	0.0173	0.0286	0.0048	0.0053	0.0045	0.0045	0.0064	0.0039	0.0032	0.0013	0.0012	0.0010	0.0005
27B-VP-2	0.0026	0.0037	0.0030	0.0027	0.0073	0.0075	0.0066	0.0122	0.0107	0.0192	0.0224	0.0225	0.0201	0.0000	0.0278	0.0216	0.0030	0.0033	0.0028	0.0028	0.0039	0.0026	0.0021	0.0009	0.0008	0.0006	0.0003
27B-VP-3	0.0028	0.0039	0.0032	0.0029	0.0081	0.0082	0.0072	0.0134	0.0113	0.0175	0.0198	0.0198	0.0184	0.0265	0.0000	0.0199	0.0027	0.0030	0.0025	0.0025	0.0035	0.0023	0.0018	0.0008	0.0007	0.0005	0.0003
27-VP-1	0.0018	0.0024	0.0020	0.0018	0.0050	0.0051	0.0045	0.0082	0.0072	0.0159	0.0196	0.0217	0.0298	0.0202	0.0194	0.0000	0.0043	0.0047	0.0040	0.0039	0.0056	0.0035	0.0028	0.0012	0.0010	0.0009	0.0005
38A-VP-1	0.0003	0.0004	0.0003	0.0003	0.0007	0.0007	0.0006	0.0011	0.0011	0.0037	0.0034	0.0035	0.0049	0.0028	0.0026	0.0041	0.0000	0.0307	0.0299	0.0302	0.0275	0.0256	0.0210	0.0092	0.0080	0.0066	0.0037
38-VP-1	0.0003	0.0004	0.0003	0.0003	0.0007	0.0008	0.0007	0.0012	0.0012	0.0038	0.0036	0.0038	0.0053	0.0030	0.0028	0.0045	0.0300	0.0000	0.0270	0.0284	0.0301	0.0231	0.0190	0.0084	0.0073	0.0062	0.0034
38-VP-2	0.0003	0.0004	0.0003	0.0003	0.0006	0.0007	0.0006	0.0010	0.0011	0.0034	0.0031	0.0032	0.0044	0.0025	0.0023	0.0037	0.0292	0.0270	0.0000	0.0293	0.0244	0.0291	0.0237	0.0103	0.0089	0.0073	0.0040
38-VP-3	0.0003	0.0004	0.0003	0.0003	0.0006	0.0006	0.0006	0.0010	0.0010	0.0033	0.0030	0.0032	0.0044	0.0025	0.0023	0.0037	0.0296	0.0285	0.0294	0.0000	0.0274	0.0263	0.0224	0.0100	0.0087	0.0074	0.0041
39-VP-1	0.0003	0.0004	0.0003	0.0003	0.0007	0.0008	0.0007	0.0012	0.0012	0.0036	0.0035	0.0038	0.0055	0.0030	0.0028	0.0047	0.0235	0.0263	0.0213	0.0239	0.0000	0.0185	0.0159	0.0075	0.0064	0.0058	0.0033
40-VP-1	0.0002	0.0003	0.0003	0.0002	0.0005	0.0005	0.0005	0.0008	0.0009	0.0028	0.0024	0.0025	0.0034	0.0020	0.0018	0.0029	0.0217	0.0200	0.0252	0.0227	0.0184	0.0000	0.0316	0.0134	0.0117	0.0091	0.0049
42-VP-3	0.0002	0.0002	0.0002	0.0001	0.0003	0.0003	0.0003	0.0005	0.0005	0.0017	0.0015	0.0015	0.0020	0.0012	0.0011	0.0017	0.0131	0.0121	0.0151	0.0142	0.0116	0.0233	0.0000	0.0225	0.0197	0.0148	0.0079
46-VP-1	0.0000	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005	0.0004	0.0004	0.0005	0.0003	0.0003	0.0005	0.0036	0.0034	0.0041	0.0040	0.0034	0.0062	0.0141	0.0000	0.0726	0.0510	0.0283
46-VP-5	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004	0.0003	0.0003	0.0004	0.0002	0.0002	0.0004	0.0029	0.0027	0.0033	0.0032	0.0027	0.0050	0.0114	0.0667	0.0000	0.0561	0.0328
49A-VP-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0001	0.0002	0.0001	0.0001	0.0002	0.0013	0.0013	0.0015	0.0015	0.0014	0.0022	0.0047	0.0261	0.0312	0.0000	0.0896
66A-VP-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0004	0.0024	0.0031	0.0150	0.0000
Sum	0.1854	0.1854	0.1854	0.1854	0.1854	0.1853	0.1854	0.1853	0.1853	0.1854	0.1853	0.1854	0.1853	0.1854	0.1854	0.1854	0.1853	0.1854	0.1854	0.1854	0.1854	0.1854	0.1854	0.1854	0.1854	0.1853	0.1853

Model Parameter Inputs for PCB/NFAS Scenario

Parameters in the PCB Scenario (same as No Further Action Scenario [NFAS]) are the same as for the Baseline Scenario (BS) except that relative multipliers for fecundity and survival in the age matrix are applied as shown below. GE used the same approach and multipliers that EPA used in Attachment E.4 of Appendix E in the ERA (EPA, 2004), except that pools with spatially-weighted mean PCB concentrations < 3.27 (lower Interim Media Protection Goal) had a fecundity and survival multiplier of 1 (no effect) for all age classes. The multipliers do not change over time.

Relative Fecundity:

Pool Name	Fecundity multiplier
23b-VP-1	0.98
23b-VP-2	0.98
46-VP-1	0.98
19-VP-7	0.98
8-VP-4	0.98
46-VP-5	0.98
12-VP-1	0.97
23a-VP-1	0.97
40-VP-1	0.97
27b-VP-2	0.97
18-VP-2	0.96
66a-VP-1	0.96
18-VP-1	0.94
27b-VP-3	0.93
27-VP-1	0.93
38-VP-3	0.91
42-VP-3	0.86
49a-VP-1	0.82
8-VP-1	0.81
38a-VP-1	0.8
38-VP-1	0.77
19-VP-1	0.74
8-VP-5	0.73
38-VP-2	0.72
26-VP-1	0.64
39-VP-1	0.58
8-VP-2	0.46

Relative Survival Files: Each pool has one file with one row with the 6 values shown below that modify the survival estimates in the 6 columns of the age matrix.

Pool Name		Female			Male	
	Age 0	Age 1	Age 2	Age 0	Age 1	Age 2
23b-VP-1	0.96	1	1	0.99	1	1
23b-VP-2	0.96	1	1	0.99	1	1
46-VP-1	0.96	1	1	0.99	1	1
19-VP-7	0.96	1	1	0.99	1	1
8-VP-4	0.96	1	1	0.99	1	1
46-VP-5	0.96	1	1	0.99	1	1
12-VP-1	0.97	1	1	1	1	1
23a-VP-1	0.96	1	1	0.99	1	1
40-VP-1	0.96	1	1	1	1	1
27b-VP-2	0.96	1	1	1	1	1
18-VP-2	0.96	1	1	1	1	1
66a-VP-1	0.96	1	1	1.01	1	1
18-VP-1	0.95	1	1	1.02	1	1
27b-VP-3	0.95	1	1	1.02	1	1
27-VP-1	0.94	1	1	1.02	1	1
38-VP-3	0.93	1	1	1.03	1	1
42-VP-3	0.91	1	1	1.05	1	1
49a-VP-1	0.9	1	1	1.06	1	1
8-VP-1	0.89	1	1	1.06	1	1
38a-VP-1	0.89	1	1	1.07	1	1
38-VP-1	0.87	1	1	1.06	1	1
19-VP-1	0.87	1	1	1.08	1	1
8-VP-5	0.86	1	1	1.07	1	1
38-VP-2	0.86	1	1	1.08	1	1
26-VP-1	0.84	1	1	1.09	1	1
39-VP-1	0.83	1	1	1.09	1	1
8-VP-2	0.82	1	1	1.09	1	1

Model Parameter Inputs for RS-I and RS-II

Parameters are the same as for the PCB/No Further Action Scenario (PCB/NFAS) except that multipliers for fecundity and survival are applied from a different file modified for remediation for every population. The files change the survival multipliers over time following timing of remedial actions and habitat recovery as indicated in the text of Appendix C. The only difference between RS-I and RS-II is the number of pools remediated. RS-I would involve remediation of the 11 most contaminated pools in the 27-pool model, whereas RS-II would involve remediation of all pools above the lower IMPG of 3.27 mg/kg (19 pools).

An example of a relative survival file for a remediated pool is given below for pool 39-VP-1:

0.41 1 1 0.93 1 1
0.41 1 1 0.93 1 1
0.41 1 1 0.93 1 1
0.41 1 1 0.93 1 1
0.41 1 1 0.93 1 1
0.41 1 1 0.93 1 1
0.41 1 1 0.93 1 1
0 0 0 0 0 0
0 1 1 0 1 1
0 1 1 0 1 1
0 1 1 0 1 1
0 1 1 0 1 1
1 1 1 1 1 1

In this file, remedial actions to clean the pool begin eight years after the simulation is begun (timing depends on location of pool) and thus the multipliers switch from those in the multiplier files of the PCB/NFAS scenario to all zeros (all breeding frogs and young die due to physical disturbance). The habitat is assumed to still be used by breeding frogs in the following years (water will be present due to contouring the pool), but habitat will be poor for tadpole survival (poor food and cover) for four more years and thus survival of age class 0 during those years should be set to 0. The fifth year after remedial action, good food and cover has been established and PCBs are reduced below the IMPG, resulting in no negative effects on the vital rates (set to 1.0).

Relative fecundity file example for pool 39-VP-1:

0.58 0.58 0.58
0.58 0.58 0.58
0.58 0.58 0.58
0.58 0.58 0.58
0.58 0.58 0.58
0.58 0.58 0.58
0.58 0.58 0.58
0 0 0
1 1 1

The fecundity file shows that fecundity will be modified for PCB exposure up until the pool is remediated in the eighth year. No reproduction occurs during the year of remediation and then fecundity will be restored to a condition unaffected by PCB exposures in the following years. The assumption is that frogs will be attracted to the remediated pool the year after PCBs are removed and continue to produce eggs. However, as shown in the survival files, the survival of the juveniles produced will be zero until the habitat recovers.

Figures

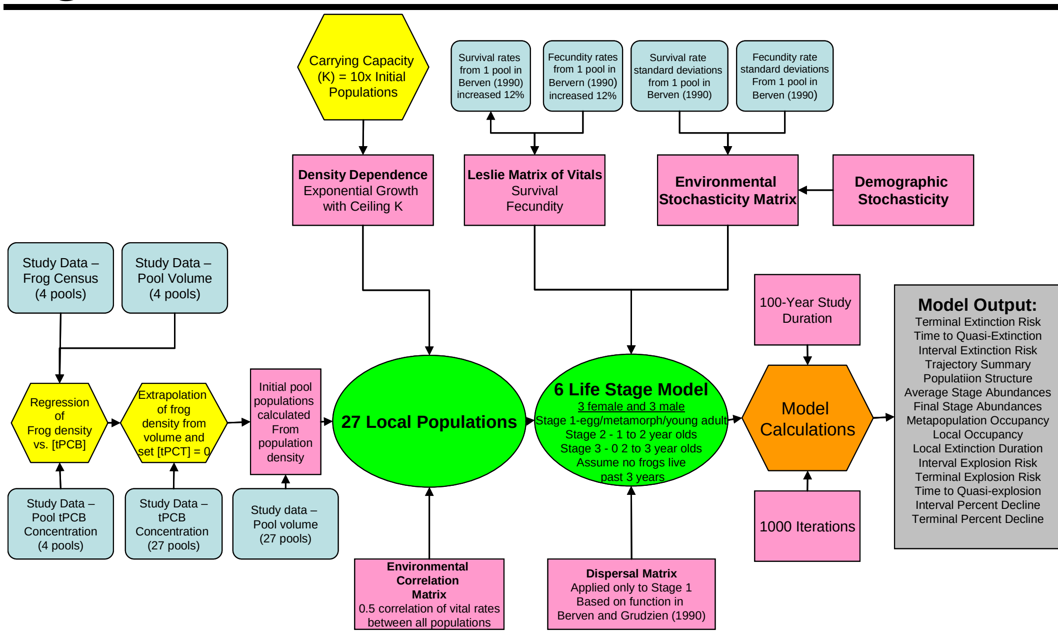

Figure 1. Flow chart of the Baseline Scenario (BS) of the adjusted EPA wood frog population model showing input parameters and output produced by RAMAS. Initial population sizes were based on estimated sizes in today's PCB-contaminated ponds for all three scenarios to facilitate comparisons. Frog census, pool volume, and PCB concentrations are from Woodlot Alternatives (2002).

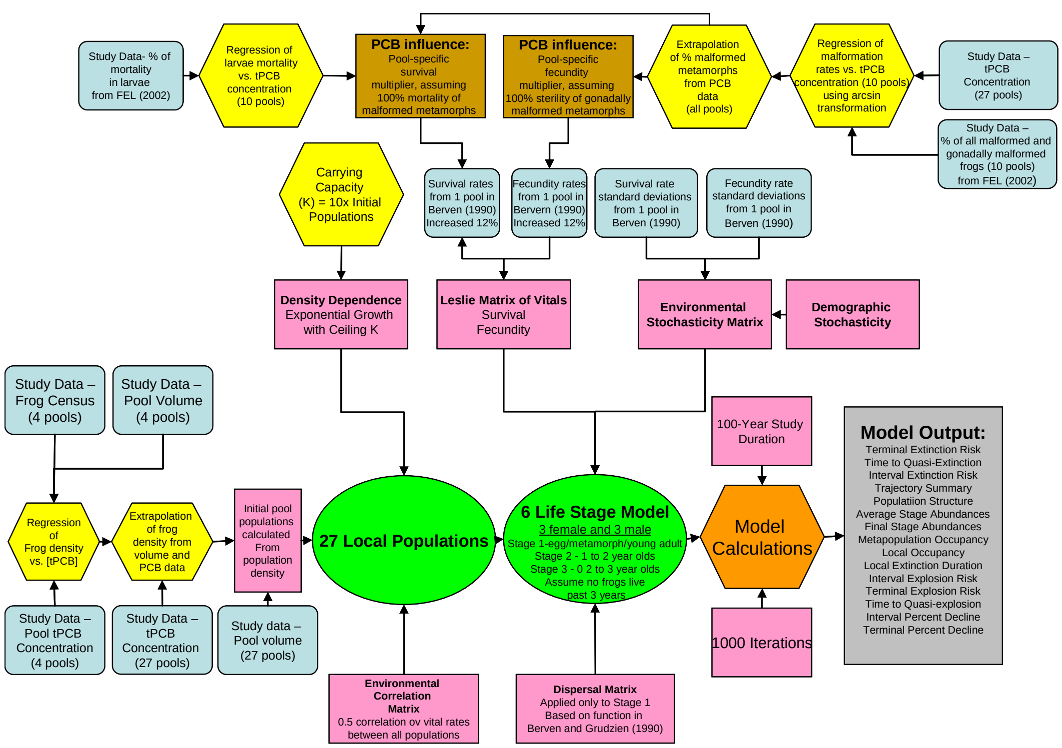

Figure 2. Flow chart of the Present Conditions Scenario of the adjusted EPA wood frog population model.

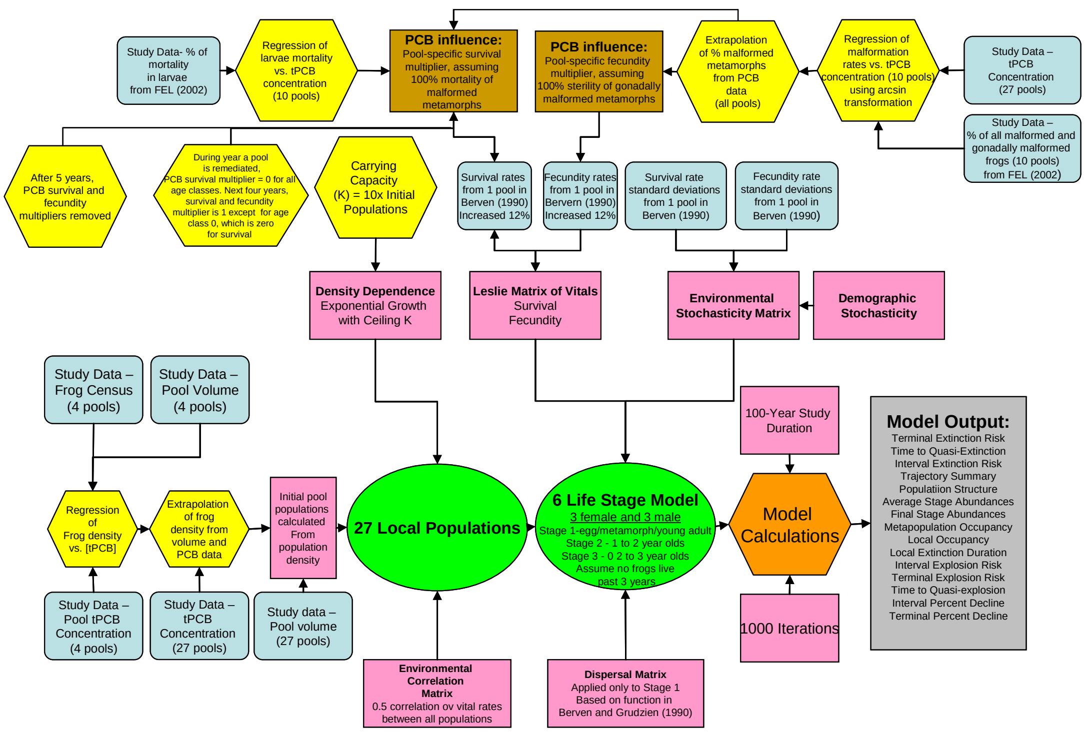

Figure 3. Flow chart of the Remedial Scenarios of the adjusted EPA wood frog population model.

References

EPA (United States Environmental Protection Agency). 2004. *Ecological Risk Assessment for General Electric (GE)/Housatonic River Site, Rest of River*. Prepared by Weston Solutions, Inc. for U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. Attachment E.4 in Appendix E: “A Stochastic Population Model Incorporating PCB Effects for Wood Frogs (*Rana sylvatica*) Breeding in Vernal Pools Associated with the Housatonic River Pittsfield to Lenoxdale, Massachusetts.” Prepared by Applied Biomathematics and Woodlot Alternatives.

FEL (Fort Environmental Laboratories, Inc.). 2002. *Final Report – Frog Reproduction and Development Study. 2000 Rana sylvatica Vernal Pool Study.* Study protocol no.: WESR01-RSTS03-1. Prepared by Fort Environmental Laboratories, Inc., Stillwater, OK.

Woodlot Alternatives, Inc. 2002. *Ecological Characterization of the Housatonic River.* Prepared for U.S. Environmental Protection Agency.

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Appendix D

Determination of Areal Extent and Volume of Floodplain Soil Remedial Alternatives

Appendix D. Determination of Areal Extent and Volume for Floodplain Soil Remedial Alternatives

1. Introduction

As described in Section 5.3.2 of this CMS Proposal, several remedial alternatives have been developed for evaluation in the CMS to address PCBs in floodplain soil. For human health protection, the alternatives are of two types (apart from the "no action" alternative). The first type involves soil removal/replacement as necessary to achieve specified average target PCB concentrations, based on certain sets of health-related IMPGs (or, for farm areas, target floodplain soil PCB concentrations derived from the IMPGs for agricultural products consumption) in the various averaging areas. The second type involves removal and replacement of all soils within a given depth having PCB concentrations exceeding certain concentration thresholds. In addition, for the latter alternatives, based on an evaluation of the average floodplain soil PCB concentrations that would result from the alternative, adjustments to the alternative (i.e., increases or decreases in the extent of removal) may be made for particular areas to meet certain target levels or ranges. Finally, Section 5.3.2 explains that, for each of the health-based alternatives, a supplemental evaluation will be made regarding the need for and extent of additional remediation to achieve certain average target PCB concentrations based on ecological considerations in various habitats. This section describes the procedures to be used in the CMS to estimate the areal extent and volume of floodplain soil to be remediated for a given floodplain alternative.

The method to be used to estimate the areal extent and volume of soil to be removed under a given alternative will depend on the type of alternative being evaluated, as summarized below:

- For alternatives based on achieving specified average PCB concentrations (e.g., IMPGs), an iterative method will be used to determine the areal extent and volume of soil to be removed to achieve target soil concentrations, calculated as spatially weighted means over the various averaging areas within the floodplain.
- For PCB threshold-based alternatives, the areal extent and volume of soil to be removed to achieve the specified "not-to-exceed" PCB concentration will utilize a GIS-based spatial data query method.
- For threshold-based alternatives that are subsequently adjusted to meet certain target PCB levels in certain areas, areal extent and volume will be determined using a combination of these two methods.

These procedures for estimating areal extent and volume in the CMS will utilize various GIS methods, a spatially interpolated PCB data coverage of the floodplain, and spatial averaging methods, which are described below in Sections D.2, D.3, and D.4, respectively. The methods for computing areal extent and removal volume for the floodplain remediation alternatives are described in Section D.5.

2. Representation of Spatial Information

The methodology used to determine areal extent and removal volume for floodplain remedial alternatives must incorporate several spatially-varying features within the floodplain. For example, evaluation of IMPG achievement for many portions of the floodplain will involve assessment of multiple receptors and exposure pathways (e.g., a single area of the floodplain may need to consider human direct contact, agricultural product consumption, and ecological risk), each having different applicable IMPGs, and each being applied as spatial averages over different geographical areas (see Section 3.2 and Figures 5-1, 5-2, and 5-3 of the main text).

Since this evaluation will require the incorporation of various spatial data sets, GIS-based analyses will be used to facilitate the areal extent and volume associated with each remedial alternative. The GIS analyses will employ a raster data model, whereby floodplain features (e.g., locations of EAs, agricultural areas, and vernal pools, mapping of human use accessibility, and the PCB concentration data) are translated to 3 x 3-meter grid cells[1] over the floodplain area covering Reaches 5 through 8 (i.e., the 1-mg/kg PCB isopleth in Reaches 5-6 and 100-year floodplain in Reaches 7-8). This approach allows multiple layers of information to be overlaid in a consistent manner, and facilitates the remediation calculations described below.

3. Spatial Distribution of Soil PCB Concentrations

To facilitate estimation of areal extent and volume for the floodplain remedial alternatives during the CMS, a spatially-interpolated PCB data set was developed to provide continuous coverage of soil concentrations over the floodplain within Reaches 5 through 8. The subsections below describe the general data processing approach and the method used to spatially interpolate the data.

a. Data Processing

Several PCB data sets were combined to provide a detailed representation of the current spatial distribution of PCB concentrations in floodplain soils (as discussed in Section 2.4 of the main text). Data treatment used in the development of the spatially interpolated floodplain data set was consistent with data treatment used for the analyses presented in GE's RFI Report. Non-detect (i.e., "U" qualified) concentrations were replaced with one half of the reported Method Detection Limit (MDL), and data sets that could not be used to reasonably construct 6-inch vertical averages were omitted for consistency. A more detailed description regarding data processing can be found in the RFI Report.

b. PCB Spatial Interpolation

In the HHRA (Vol. I, Attachment 3), EPA generated spatially-weighted 0- to 6-inch PCB concentrations in Reaches 5 and 6 of the floodplain using an Inverse Distance Weighting (IDW) method. IDW assumes that each data point has a local area of influence that diminishes with distance away from that point. For development of the spatially-interpolated PCB data coverage used for the CMS, a somewhat simpler method based on Thiessen Polygons (TP) was employed. As implemented in the HHRA, IDW requires cross validation to optimize the coefficients in the IDW used for each area of interpolation. Cross validation of this sort is computationally intensive. In contrast, the TP method employed here is an exact interpolator, whereby each data point has a local area of influence that does not diminish with distance. The TP method was selected for floodplain interpolation in the CMS for two primary reasons:

1) The IDW method used by EPA was only applied for Reach 5 and 6 floodplain concentrations for the top 6 inches. For the CMS, assessment of floodplain alternatives will include depths of 0-12 inches and will extend to areas in Reaches 7 and 8. The floodplain data coverage in the PSA for depths below the surface 0-6" and for all depths in Reaches 7 and 8 is limited compared to the 0-6" data in the PSA (see Section 5 of the RFI Report), and was considered insufficient for IDW.

[1] This approach is consistent with the representation of floodplain soil PCB concentrations of the PSA in the EPA HHRA.

2) The TP approach readily accommodates incorporation of new data as needed (e.g., future sampling efforts conducted in the floodplain).

The TP method was thus used to generate the spatially-interpolated PCB data coverage that will serve as the basis for determining the areal extent and volume for the floodplain remediation alternatives evaluated in the CMS. The method used to generate TPs in the floodplain for Reaches 5 and 6 was generally consistent with the method used by EPA during generation of its IDW (described in the HHRA) in that topographic and hydrologic information was incorporated into the interpolation process. Since PCBs are transported onto the floodplain during overbank flow conditions, the PCB distribution in floodplain soils is likely governed by the topographic and hydrologic features that also influence the distribution of wetland habitats (HHRA Vol. I, Attachment 3). In Reaches 5 and 6, six "super habitats" (i.e., grouped habitats having similar characteristics) were introduced by EPA in the HHRA to guide the spatial interpolation of PCBs in the floodplain (see Figure D-1). For generating the CMS spatially-interpolated PCB data coverage, TPs were generated for each individual "super habitat" using only the data from within that "super habitat" boundary. TPs generated for all six "super habitats" were then merged to form a single PCB TP raster coverage for the entire floodplain within Reaches 5 and 6. A few "super habitat" boundaries were modified from those presented in the HHRA to avoid excluding samples located just outside the 1-mg/kg PCB isopleth (but very near the "super habitat" boundary) from the PCB TP data coverage.

An alternative method was used to generate the PCB TPs in Reaches 7 and 8. This was because: 1) the data density in Reaches 7 and 8 is significantly less than in Reaches 5 and 6; 2) the majority of the available floodplain data are located near the river shoreline; and 3) detailed habitat delineation has not been performed downstream of Woods Pond Dam. Similar to the use of "super habitats" in Reaches 5 and 6, the floodplain area in Reaches 7 and 8 was divided into two areas that were selected to represent different flood inundation frequencies: proximal and distal floodplain (see Figure D-2). The boundary used to separate the proximal and distal floodplain was based on the approximate 1-mg/kg isopleth for Reach 7 and 8 developed by EPA, which is similar to the 10-year floodplain for those reaches (see Figure 6.4-1 of the MVR). TPs were then separately generated for the proximal and distal floodplain areas on opposite sides of the river channel (i.e., polygons were not allowed to cross the river). The resulting floodplain PCB TPs were then merged to form a single PCB TP raster coverage for Reaches 7 and 8.

To evaluate the spatial interpolation approach described above, 0-6" PCB TPs were compared to the EPA 0-6" IDW representation of floodplain soil PCBs used in the HHRA within Reaches 5 and 6. The objective of this comparison was to evaluate the differences in PCB spatial patterns resulting from the IDW and TP interpolation methods. PCB data provided in the HHRA (Vol. IIIA, Attachment B1) were used as the basis for this evaluation. Figures D-3a and D-3b show a side-by-side comparison of the PCB TP grid developed for the CMS (TPs converted to a 3 x 3-meter raster grid as described in Section D.2 above) with EPA's IDW grid in Reaches 5 and 6. This evaluation demonstrates that the interpolated PCBs generated by TP and IDW methods are generally comparable (i.e., the two methods show similar spatial patterns on a large scale, and generally result in similar spatial averages over large areas). Some of the observed differences are a result of the differences in the interpolation methods, while some are also due to the inclusion of data outside of the 1-mg/kg isopleth boundary for TP generation (these were not included by EPA in the IDW). Figure D-4 shows a one-to-one comparison of spatially averaged PCB concentrations interpolated using TP and IDW for the direct contact EAs in Reaches 5 and 6 (the subareas were excluded). In general, spatially-averaged PCB concentrations using the two methods are reasonably similar in most EAs, with the exception of a few EAs that have a relatively small area. The similarity of the IDW and TP results suggests that the spatial distribution of PCBs in the IDW method is driven more by the "super habitat" boundaries than by the IDW weighting parameters.[2] Given the observed similarity

[2] It is worth noting that IDW interpolation reduces exactly to the TP interpolation as IDW parameters values n (number of neighbors) and p (distance power) approach 1 and 0, respectively.

in PCB concentrations estimated using IDW and TPs, the TP approach described above was considered sufficient for developing the spatially-interpolated PCB data coverage to develop areal extent and volume estimates for floodplain remedial alternatives in the CMS.

c. Vertical PCB Distribution

The floodplain remedial alternatives described in Section 5.3.2.2 of the main text specify remediation of the top foot of soil. In general, the Housatonic River floodplain soil cores were processed in 6-inch intervals (see Section 2.4.2 of the main text). Thus, estimation of areal extent and volumes for these scenarios will require depth-averaged PCB concentrations over the top 1-foot interval.

The Housatonic River floodplain contains numerous samples at the surface (particularly in Reaches 5 and 6); however, sample density significantly decreases with depth (e.g., Table 5-7 of RFI Report). In some areas, the spatial coverage of samples beneath the surface is insufficient to develop a reasonable TP coverage (e.g., parts of Reach 7). To account for this, PCB TPs were generated for both the 0-6 and 6-12 inch layers, and the 0-1 ft average PCB concentration for a given location was computed by averaging the PCB TP raster grids from those layers. For areas lacking data in the 6-12" interval, relatively large TPs were generated, assigning the same concentration over a large area. The uncertainty associated with these values is offset by averaging them with TPs from the 0-6" surface layer (which are based on data collected at a much greater density).

4. Spatial Averaging

As discussed in Section 5.3.2 of the main text, floodplain remedial alternatives having specified target PCB levels will achieve those levels as spatial means. The spatial means will be computed over the applicable averaging areas, and the applicable average will be computed as the 95% UCL on the spatial mean (except for areas where data sufficient to support spatially-weighted arithmetic means are available). The averaging areas and method for computing UCLs for those alternatives are described below. For the alternatives based on a not-to-exceed PCB threshold, the spatial averaging methods described below are not applicable.

a. Averaging Areas

As discussed in Section 5.3.1 of the main text, several different evaluation areas in the floodplain were developed to support the HHRA and ERA (see Figures 5-1, 5-2, and 5-3). These include EAs for human direct contact; agricultural fields for agricultural products consumption; individual vernal pool areas for wood frog habitat; and the habitat areas that cover a majority of the floodplain area in Reaches 5 and 6 for the evaluations of shrew and wood duck. For the target level-based floodplain alternatives in the CMS, the PCB raster data coverage (i.e., developed based on the TPs, described above) will be spatially averaged over these areas when determining the areal extent and volume necessary to achieve the desired cleanup level (e.g., IMPG). During this spatial averaging of the PCB concentrations, two modifications will be applied:

1) In the direct contact risk assessment in the HHRA, EPA developed accessibility weighting factors in the PSA to account for the decreases in exposure frequency in areas of the floodplain difficult for humans to access. The PSA was mapped into four accessibility categories: walkable, wadable, difficult, and

boatable. Weighting factors, which were used as multipliers on the PCB concentrations, were specified to be 1.0, 0.2, 0.2, and 0.0 for each of these areas, respectively. This weighting approach will be used for computing spatial averages in the CMS: a raster grid representation of the use-weighting factors will be multiplied by the interpolated PCB raster grid data when conducting remediation assessment of the direct contact EAs, except for waterfowl hunter EAs, where use-categories were given a factor of 1.0 in the HHRA. Areas specified as boatable, which were assigned a use factor of 0.0 in the HHRA, will be excluded from the computation of spatial averages in the CMS to avoid artificial reductions of the averages (except for waterfowl hunting EAs).

2) For agricultural product consumption assessments, only the portions of agricultural fields within the floodplain boundary will be considered for spatial averaging. To account for the fraction of a given field that is located outside the floodplain area, a weighting factor will applied to the target floodplain soil concentration when determining the extent of remediation necessary in that area (see Section 3.3.1 of the main text). For example, for an agricultural field in which 80% of the total cultivated area is located within the floodplain, the initially calculated target soil level derived from the pertinent IMPG would be divided by a factor of 0.8 before it is compared to the spatial average of the agricultural field to estimate the extent of remediation.

b. UCL Calculation

The 95% UCL provides a conservative estimate of mean PCB concentration commonly applied in risk assessments (EPA, 1989, 1992, 2002). There are several different methods available for estimating the UCL, depending upon the distribution of PCB data for a given area. In the HHRA, EPA applied the Modified Halls Bootstrap Method to compute the UCL for spatially interpolated data (i.e., IDW results) in EAs within the PSA (HHRA Vol. I, Attachment 4). The Hall's Bootstrap method is non-parametric and can be used to estimate the UCL for data with any underlying distribution. The Halls Bootstrap method involves random sampling of the IDW grid values, with the modification being that the size of each random sampling is equal to the degrees of freedom for a given area, as defined by the number of samples in that area. Further description of the Modified Hall's Bootstrap Method, including computer source code, can be found in Attachment 4 of the HHRA. This method will be used for calculation of UCLs in the CMS.

Similar to the HHRA, once the UCL is calculated for a given averaging area, it will be compared to the maximum data value within the given area, and the lower of those two values will be used as the EPC (i.e., the EPC is not allowed to exceed the maximum interpolated value within a given area).

5. Areal Extent and Removal Volume Calculations

a. Target Level-Based Alternatives

Determination of areal extent and removal volume for the target level-based alternative described in Section 5.3.2.1 of the main text (Alternatives FP 2, FP 3, FP 4, and FP 7) will involve identifying the extent of remediation necessary to achieve the target level as a spatial average soil PCB concentration in a given area. The method will be based on the spatially-interpolated PCB data coverage described in Section D.3 and will proceed on an area-by-area basis. For a given averaging area (e.g., direct contact EA or subarea, or farm area), this method will be implemented in four steps:

1) The applicable target PCB value (i.e., an IMPG or other target floodplain soil concentration) for the averaging area of the floodplain being evaluated will be assigned based on the applicable human exposure scenario and the target level of risk reduction (e.g., cancer risk of 10^{-5}) specified for that alternative. For areas having multiple use types, the lowest IMPG value will be used for that given area. If the given averaging area is an agricultural field, the target PCB level will be adjusted based on the portion of the field that is located within the floodplain, as described in Section D.4.1 above.

2) The PCB exposure point concentration (EPC) for the given area will then be calculated using the methods described in Section D.4.2 – i.e., the EPC will be defined as the 95% UCL on the spatially-weighted mean of the data from that area or the maximum measured value, whichever is lower, unless the given area contains sampling data that are sufficiently dense, uniform, and representative, to support use of a spatially-weighted arithmetic mean. EPA's use accessibility factors will be applied in these calculations.

3) The EPC calculated for the area being evaluated will then be compared with the target PCB value to determine if remediation of soil would be necessary to achieve that value.

4) If remediation is required in a given averaging area to achieve the target PCB level, the approximate areal extent and volume will then be calculated using an iterative process. First, a portion of the given area will be "flagged" for remediation (starting with the highest concentrations) and the interpolated PCB values will be replaced with the applicable "clean" soil concentration – i.e. one-half the typical PCB MDL.[3] Then, the EPC will be recomputed based on the modified spatial PCB distribution within that area and compared against the target PCB level. This sequential replacement of concentrations with ½ MDL and recalculation of the EPC will be repeated until the amount of remediation is sufficient to reduce the EPC to a level that is at or below the target PCB level specified for that area.

These steps then will be repeated for all remaining discrete averaging areas of the floodplain (e.g., direct contact EAs, agricultural fields for agricultural products consumption), depending on the target PCB levels specified for the given remedial alternative. This method will account for overlapping of averaging areas such that remediation is not "double-counted."

For the supplemental ecological evaluations described in Section 5.3.2.3 of the main text, the same approach will be used to determine the areal extent and volume of soil removal that would be needed to achieve a given target ecologically based PCB levels in the relevant ecological habitat(s). In these applications, however, the approach will first take into account the removal associated with the health-based alternative. For example, when removal of a portion of a vernal pool located within a direct contact EA is necessary to reduce the spatial mean below the target risk level for the direct contact, that removal will be taken into account when the vernal pool is subsequently evaluated for the target PCB level for amphibians.

Similar to the method for threshold-based initial alternatives described above, the volume will be calculated based on the total area delineated for removal and the one-foot removal depth.

[3] This is consistent with the procedure specified in the *Statement of Work for Removal Actions Outside the River* (Appendix E to the Consent Decree) for post-remediation evaluations in areas outside the River.

b. Threshold-Based Alternatives

Determination of areal extent and removal volume for the threshold-based alternatives described in Section 5.3.2.1 of the main text (Alternatives FP 5 and FP 6) will be based on the spatially-interpolated PCB data coverage described in Section D.3. The method will consist of using GIS software to identify, from the continuous PCB concentration data coverage, the locations within the floodplain where soil PCB concentrations exceed the threshold concentration specified for the given alternative. The use accessibility factors developed by EPA for the HHRA will not be applied in this step. The total volume will then be calculated as the product of the total area of the identified locations and the one-foot removal depth.

c. Alternatives Containing Adjustments to Meet Target Levels

Estimation of areal extent and removal volume for floodplain alternatives in which adjustments are made to the threshold-based alternatives (as described in Section 5.3.2.2 of the main text) will consist of a combination of the two methods described above. For example, consider an alternative that consists of an initial threshold-based alternative that is then adjusted to achieve certain target IMPGs in various averaging areas. Once areas are identified for remediation based upon the not-to-exceed threshold method (described in Section D.5.1), the UCL method described above would be used to recalculate the spatially-weighted means for the relevant averaging areas. Then, the re-computed (i.e., post-threshold-based remediation) EPCs would be compared to the target IMPGs. If the EPC in a given area exceeds the target IMPG for that area, the iterative removal identification procedure described in Section D.5.2 would be used to determine the additional removal necessary to achieve the target IMPG. Likewise, if the threshold-based removal reduced the EPC to a level lower than the target IMPG in a given averaging area, the threshold-based removal would be set to zero, and the iterative method would be used to determine the removal necessary to achieve the target IMPG.

6. References

EPA. 1989. *Risk Assessment Guidance for Superfund, Volume 1 – Human Health Evaluation Manual (Part A).* Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002. December.

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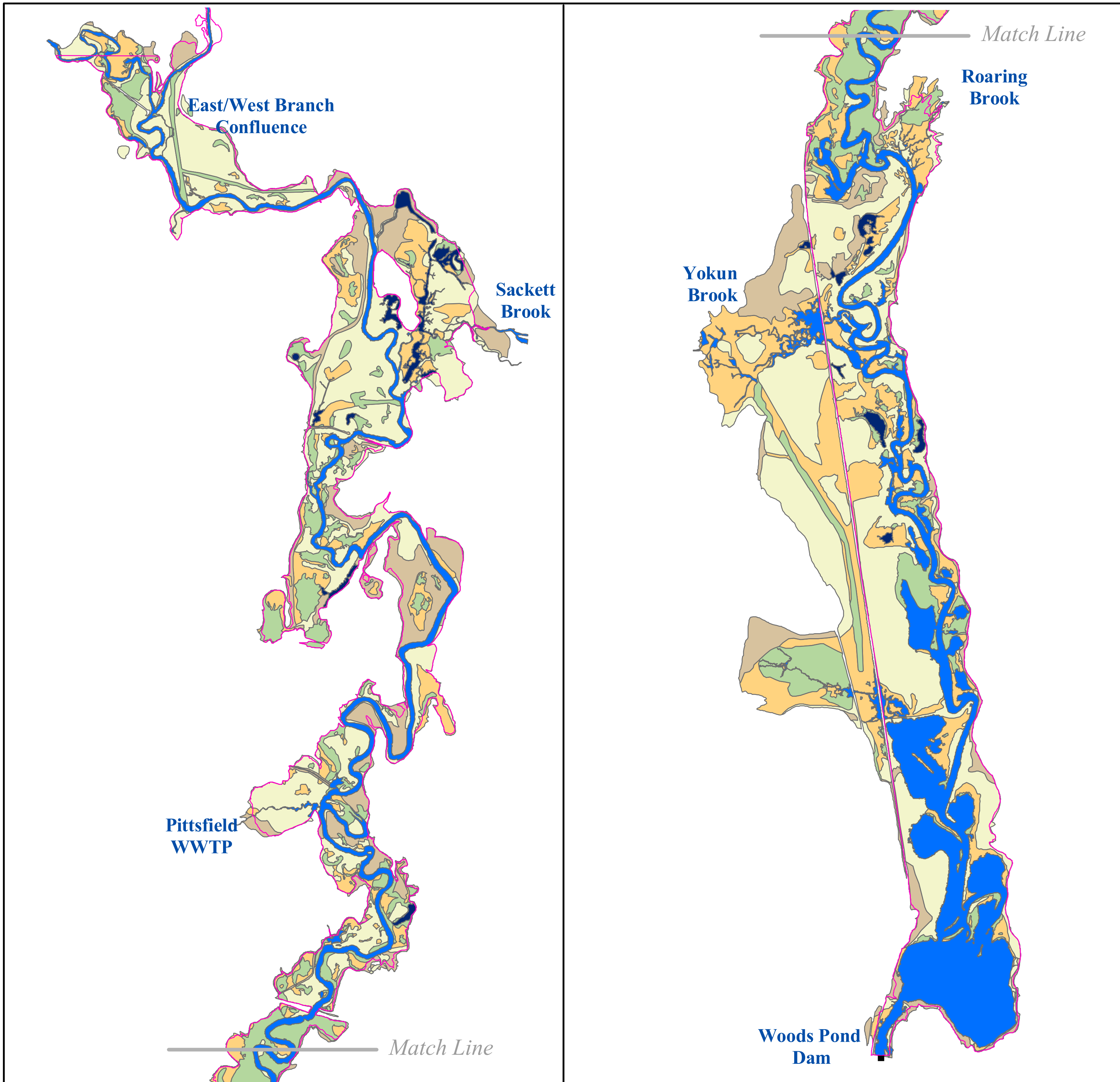
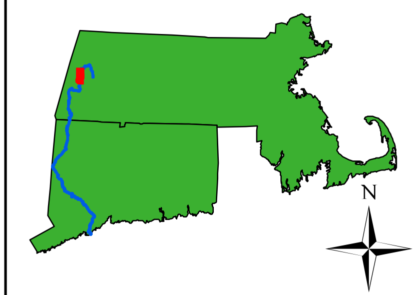


LOCATOR MAP



SCALE

0 0.25 0.5 Miles

LEGEND

- Major Dams
- 1 mg/kg PCB Isopleth
- Emergent marsh and wet meadow
- Transitional floodplain forest, black ash-red maple-tamarack calcareous seepage swamp, and red maple swamp
- High terrace fp forest, northern hardwoods-hemlock-white pine forest, red oak-sugar maple transition forest, rich mesic forest, successional northern hardwoods, cultural grassland, and agricultural field.
- Shrub swamp
- Stream
- Lake/Pond

Figure D-1.
Map of super habitats in Reaches 5 and 6.

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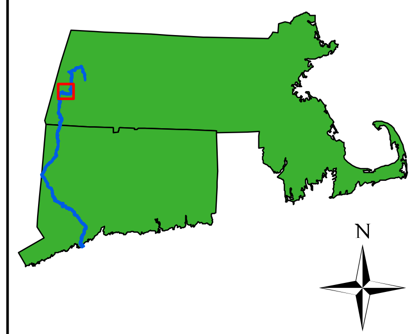

SCALE

0.5 0.25 0 0.5 Miles

LEGEND

Dams

100-Year Floodplain Boundary

Proximal

Distal

Housatonic River

Figure D-2.
Map of proximal and distal floodplain in Reaches 7 and 8.

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QEA
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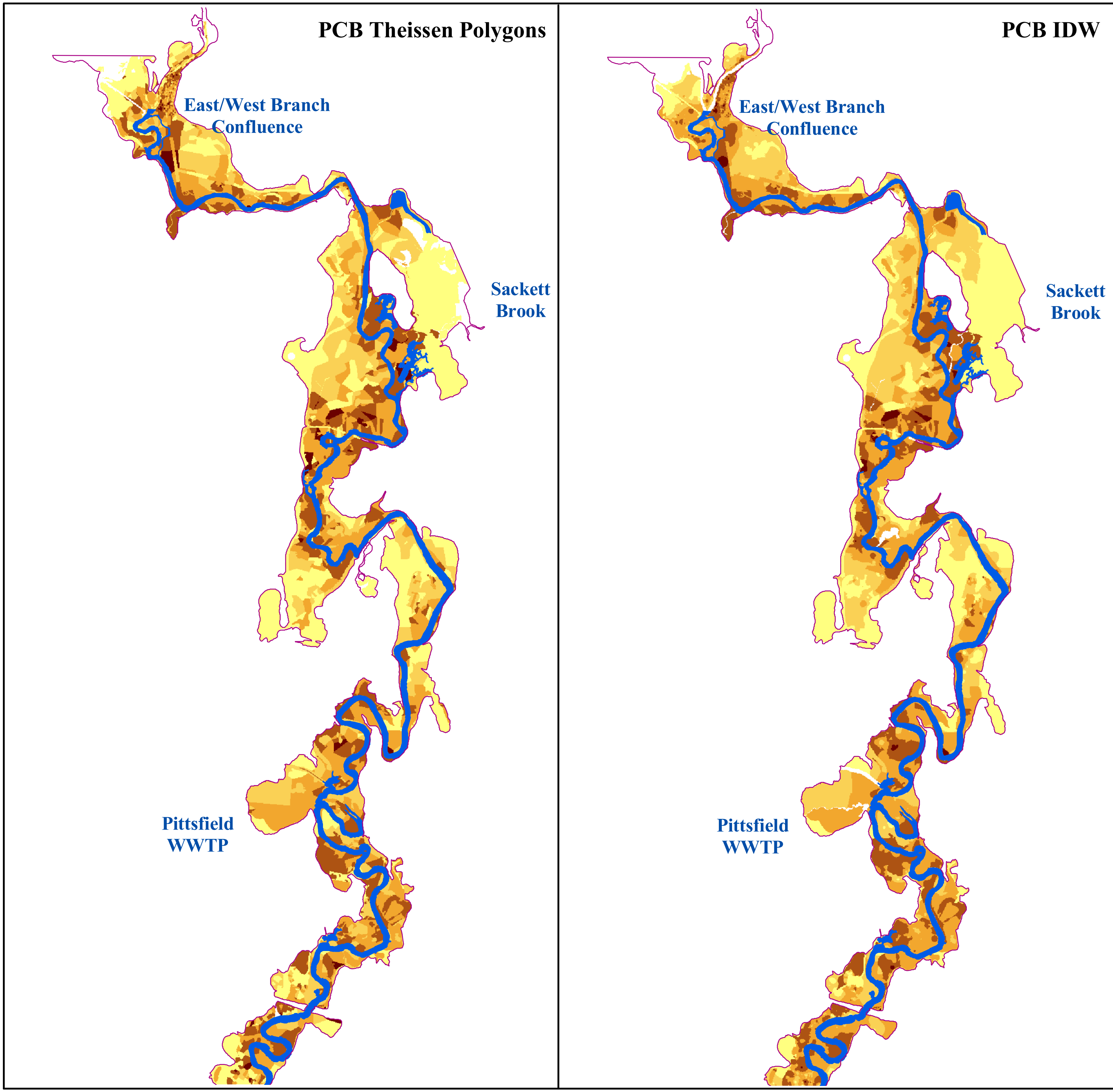

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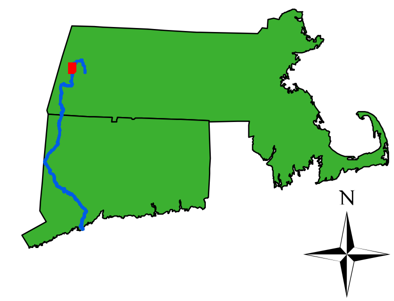

SCALE

0 0.25 0.5 Miles

LEGEND

1-ppm PCB Isopleth

Major Dams

Housatonic River

0-6" PCBs (ppm)

0 - 3

3 - 10

10 - 30

30 - 100

> 100

Figure D-3a.
Comparison of 0-6" PCB Theissen Polygons with EPA's IDW grid in from the Confluence to New Lenox Road.

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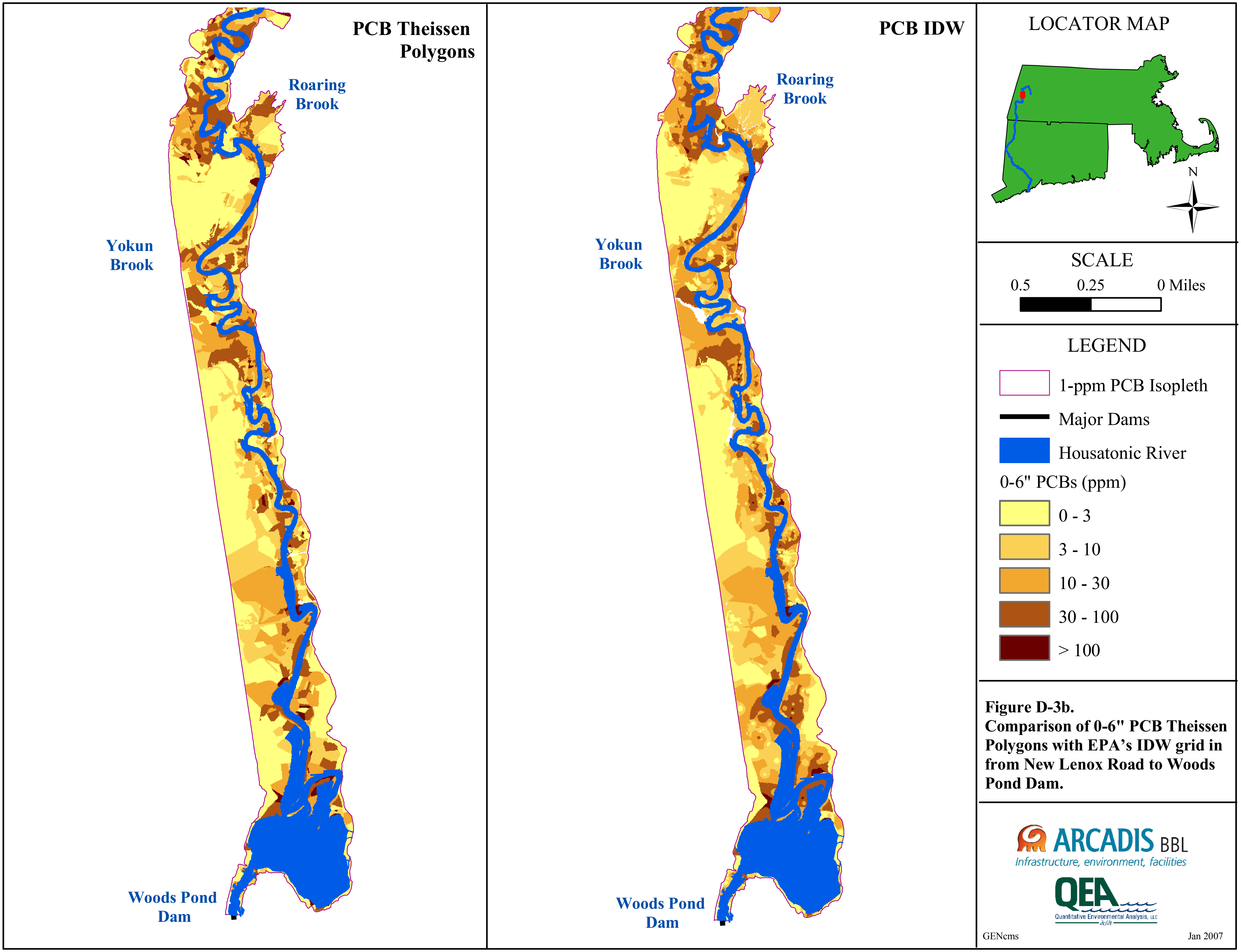

Figure D-3b.
Comparison of 0-6" PCB Theissen Polygons with EPA's IDW grid in from New Lenox Road to Woods Pond Dam.

Z:\GENcms\DOCUMENTS\reports\cms proposal\working\Figures\Appendix\figureD-3b_PCBcomparison_part2.mxd

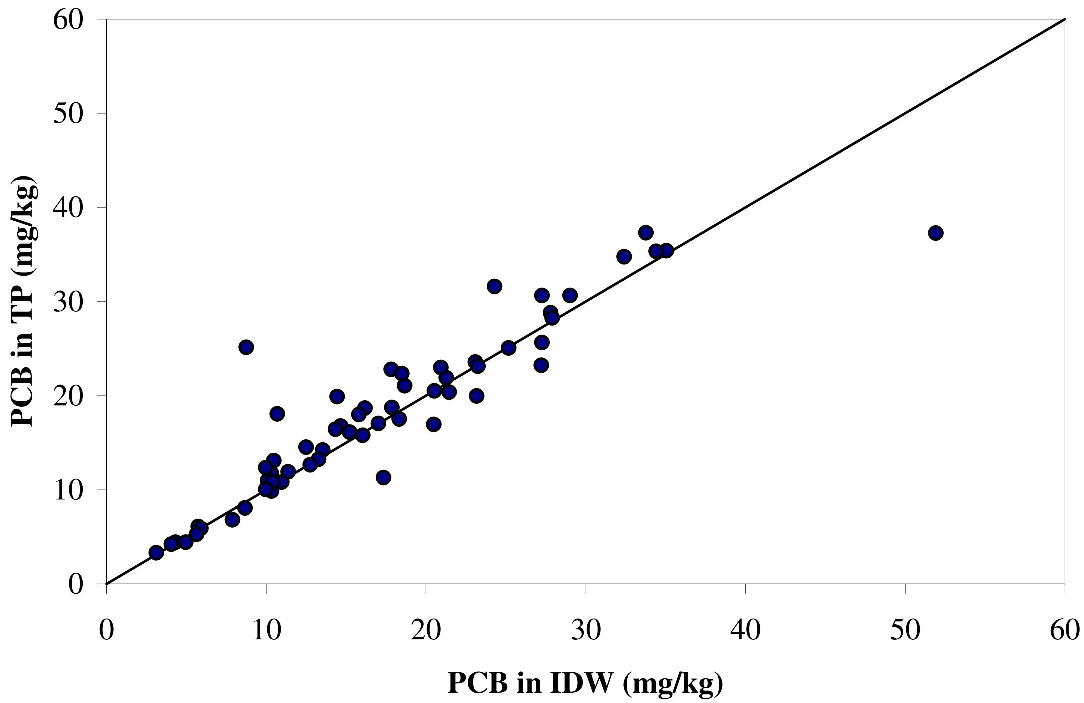

Figure D-4. Comparison of 0-6" spatial average of PCBs calculated using EPA's IDW grid with those calculated using PCB Theissen Polygons (TPs) for EAs in Reaches 5 and 6.

Note: Spatial averages calculated for main EAs; sub EAs, utility corridors, and trails (EAs 4 and 12) that overlapped with main EAs are not shown on the chart.