ATTACHMENT 10
EXCERPTS FROM COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR THE GE-PITTSFIELD/HOUSATONIC RIVER PROJECT REST OF RIVER
(MAY 2014)
(CA OR COMPARATIVE ANALYSIS)

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR THE GENERAL ELECTRIC (GE)-PITTSFIELD/HOUSATONIC RIVER PROJECT REST OF RIVER

DCN: HR-052014-AAYR
SDMS: 557091

U.S. ENVIRONMENTAL PROTECTION AGENCY
New England Region
Boston, Massachusetts

U.S. ARMY CORPS OF ENGINEERS
New England District
Concord, Massachusetts

May 2014

Contract No. W912WJ-08-D-0008
Task Order No. 0002

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LIST OF ACRONYMS

ACEC	Area of Critical Environmental Concern
ARAR	applicable or relevant and appropriate requirement
BEHI	Bank Erosion Hazard Index
BMPs	best management practices
Board	EPA National Remedy Review Board
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMR	Code of Massachusetts Regulations
CSTAG	EPA Contaminated Sediments Technical Advisory Group
cy	cubic yard
DFW	Massachusetts Division of Fisheries and Wildlife
EA	exposure area
EMNR	Enhanced Monitored Natural Recovery
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERE	environmental restrictions and easements
GE	General Electric Company
GHG	greenhouse gas
GWTP	groundwater treatment plant
HI	hazard index
IC	institutional control
IMPG	Interim Media Protection Goal
lb	pound
MESA	Massachusetts Endangered Species Act
MGL	Massachusetts General Laws
mg/kg	milligrams per kilogram
MNR	monitored natural recovery
NBS	Near Bank Stress
NCP	National Contingency Plan
NHESP	Natural Heritage and Endangered Species Program
NRWQC	National Recommended Water Quality Criteria
OMM	operation, maintenance, and monitoring
PCB	polychlorinated biphenyl
PSA	Primary Study Area
RCMS	Revised Corrective Measures Study
RCRA	Resource Conservation and Recovery Act
RME	reasonable maximum exposure
SA	sediment [exposure] area
TOC	total organic carbon
TMV	toxicity, mobility, or volume
tPCBs	total polychlorinated biphenyls
TSCA	Toxic Substances Control Act
WWTP	Wastewater Treatment Plant

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

MAY 2014

1 INTRODUCTION

In October 2010, the General Electric Company (GE) submitted to the U.S. Environmental Protection Agency (EPA) a Revised Corrective Measures Study (RCMS) for the Rest of River part of the GE-Pittsfield/Housatonic River Site. In July 2011, the EPA New England regional office presented site information and potential cleanup strategies for the Rest of River to the EPA National Remedy Review Board (the Board). Representatives of EPA's Contaminated Sediments Technical Advisory Group (CSTAG) also participated in the Board review for this site.

After the review meeting, the Board issued a set of recommendations to EPA New England, dated October 20, 2011. In response to the Board's recommendations, and to further develop a potential cleanup strategy for the Rest of River, EPA conducted additional technical evaluations and worked closely with co-regulators from the Commonwealth of Massachusetts and the State of Connecticut in a series of facilitated technical discussions that began in October 2011. Based on agreements reached with the States of Massachusetts and Connecticut, EPA, in May 2012, published a status report entitled "Potential Remediation Approaches to the GE-Pittsfield/Housatonic River Site 'Rest of River' PCB Contamination." This status report provided an update to the public on the discussions among the agencies and outlined potential remediation approaches for the Rest of River.

While considering the input from the Board and the States during these technical discussions, EPA compiled additional technical information, conducted additional modeling work to refine the potential remediation approaches, and evaluated these approaches in light of the criteria outlined in the Resource Conservation and Recovery Act (RCRA) Permit. All of this work led EPA to supplement the original analysis, and a revised Comparative Analysis of Alternatives was presented to the Board in August 2012. At the same time, EPA entered into a series of meetings with GE and co-regulators from the States of Massachusetts and Connecticut to discuss and refine the potential approaches to remediation of the river. The meetings concluded in December 2013 and resulted in minor revisions to the potential remediation approaches for Rest of River. The revised information, as well as certain additional supporting documentation, is presented in this document.

This comparative analysis is intended to provide a more detailed analysis of the different alternatives under consideration for Rest of River.

1.1 DESCRIPTION OF SED 9/FP 4 MOD ALTERNATIVE

SED 9/FP 4 MOD, a new alternative developed following the meetings among EPA, GE, and the States of Massachusetts and Connecticut described above, consists of SED 9/FP 4 with minor revisions, and includes the following components:

River Sediment and Banks

- Reach 5A

For Reach 5A, the approximately 5-mile stretch of the Housatonic River from the confluence of the East and West Branches of the Housatonic (at Fred Garner Park in Pittsfield) to the Pittsfield Wastewater Treatment Plant (WWTP), SED 9/FP 4 MOD requires the removal of river bed sediment throughout the entire reach, removal of bank soil in contaminated eroding riverbanks, and stabilization of contaminated erodible riverbanks to meet cleanup levels in fish tissue and to reduce ecological risk and downstream transport. Residual polychlorinated biphenyls (PCBs) in the bed sediment would subsequently be capped, and the bed of the river generally returned to original grade. Additional data will need to be collected to better quantify the concentrations of PCBs in riverbanks and the locations of erodible riverbanks and to determine the actual riverbed removal depth and cap thickness. For the purpose of this comparative analysis, a sediment removal depth of 2.5 feet has been assumed for Reach 5A.

An important focus of the riverbank work will be to reduce bank erosion to acceptable levels while maintaining the dynamic nature of the Housatonic River using the principles of natural channel design, where appropriate. For banks that require excavation, the hierarchy below of most-preferred to least-preferred reconstruction alternatives will be followed:

1. Reconstruct the disturbed banks with bio-engineering "soft” restoration techniques.

2. Reconstruct the disturbed banks with a cap layer extending into the riverbank covered with a bio-engineered “soft” layer.

3. Place a riprap cap or hard armoring on the surface of the banks (for example, if necessary to protect adjacent infrastructure and property).

Some of the aspects of natural channel design are discussed in the context of channel realignment in Attachment 1, Use of Channel Realignment along the Housatonic River for Restoration and Remediation of PCB Contamination, and Attachment 2, Channel Dynamics and Ecological Conditions in the Housatonic River Primary Study Area. Additional information on Natural Channel Design can be found in Chapter 11, Rosgen Geomorphic Channel Design, in *Part 654 National Engineering Handbook*, *Stream Restoration Design* (U.S. Department of Agriculture, Natural Resources Conservation Service, 2007).

- Reach 5B

For Reach 5B, the approximately 2-mile stretch of the river from the Pittsfield WWTP to Roaring Brook in Lenox, MA, SED 9/FP 4 MOD requires the excavation and restoration of areas of river bed sediment and bank soil that exceed the reach-specific cleanup level of 50 milligrams per kilogram (mg/kg) total PCBs (tPCBs), and use of Enhanced Monitored Natural Recovery (EMNR) throughout the reach. Additional data will be collected to determine PCB concentrations in the bed and banks that exceed reach-specific cleanup standards. Any excavated Reach 5B riverbanks would be restored using the hierarchy as discussed for Reach 5A. Backfill, including a suitable habitat layer, will be used to restore the riverbed.

EMNR in this reach would involve the use of a sediment amendment, such as activated carbon (see Attachment 3), to reduce the bioavailability of PCBs, thereby assisting in achieving cleanup levels in fish tissue and reducing ecological risk and the downstream transport of contaminants. The effectiveness of any amendment would first be evaluated in a pilot study and would be implemented using an adaptive management framework throughout Reach 5B.

- <u>Reach 5C</u>

For Reach 5C, the approximate 3-mile stretch of Housatonic River between Roaring Brook and the headwaters of Woods Pond, SED 9/FP 4 MOD requires removal of river bed sediment throughout the reach to meet fish tissue cleanup levels and to reduce ecological risk and the downstream transport of contaminants. The residual PCBs in bed sediment below the depth of excavation would subsequently be capped, as discussed further below. There are few, if any, eroding riverbanks in this reach; therefore, banks in this reach will be left intact, unless disturbed by other remediation activities.

- <u>Backwaters</u>

SED 9/FP 4 MOD requires, in areas outside Core Area 1 (see Attachment 4), surficial sediment removal where either surface or subsurface average concentrations exceed 1 mg/kg PCBs. In addition, sediment excavation will be required in any area with surficial PCB contamination that exceeds 50 mg/kg. An Engineered Cap will be placed in these areas to sequester the PCB-contaminated sediment that remains at depth. Sufficient sediment will be removed to allow an Engineered Cap to be placed such that the riverbed is generally returned to original grade. Final removal depths, locations, and Engineered Cap configurations will be determined during remedial design.

Backwaters in certain areas designated as having high-quality habitat for state-listed species (known as “Core Area 1,” see Attachment 4) will generally not be remediated, except in discrete areas with PCB concentrations greater than 50 mg/kg. In these discrete areas, sediment will be removed such that an Engineered Cap can be installed and the area returned to original grade. Core 1 areas with sediment PCB concentrations between 1 and 50 mg/kg will be evaluated for possible use of a sediment amendment such as activated carbon, as discussed above for Reach 5B.

- <u>Reach 6 (Woods Pond)</u>

In Reach 6 (Woods Pond), SED 9/FP 4 MOD specifies the removal of contaminated sediment in all areas of the pond and the placement of a cap, with the design generally providing a minimum water depth of 6 feet in the pond with shallower water depths in the near-shore areas. In deeper areas of the pond, sufficient sediment will be removed to allow an Engineered Cap to be placed such that the riverbed is generally returned to or below original grade. In addition to reducing human health risk from fish (and other biota) consumption and ecological risk, this action in Woods Pond will reduce human health risk due to direct contact with the sediment. This remedy also will remove a significant mass of PCBs, reducing the potential for release in the case of dam failure, and increasing the sediment/PCB-trapping efficiency of Woods Pond, thus assisting in reducing downstream transport. Reach 6 will be monitored over the long term following the cleanup and, if substantial PCBs accumulate in the pond, removal of the accumulated sediment will be required.

- Columbia Mill Impoundment (Reach 7B), Eagle Mill Impoundment (Reach 7C), Willow Mill Impoundment (Reach 7E), Glendale Impoundment (Reach 7G),

  This component of SED 9/FP 4 MOD allows a number of potential approaches to better integrate the cleanup with potential dam or impoundment use, maintenance, or removal. First, if dam maintenance or removal is planned, SED 9/FP 4 MOD provides for GE to coordinate with those planning work on these dams, to fund sampling and analysis, and to take responsibility for the incremental costs associated with the presence of PCBs. Dam removal itself is not a component of this cleanup plan and would be conducted by others in coordination with GE and appropriate state and federal agencies.

  If no dam removal is planned by the time GE would otherwise be required to move forward with remediation of these impoundments, surficial sediment would be removed in areas where either surface or subsurface average concentrations exceed 1 mg/kg PCBs. An Engineered Cap will be placed in these areas to sequester the PCB-contaminated sediment that remains at depth. In addition, sediment excavation will be required in any area with surficial PCB contamination that exceeds 50 mg/kg. Sufficient sediment will be removed in these areas to allow an Engineered Cap to be placed such that the riverbed is generally returned to original grade. Final removal depths, locations, and Engineered Cap configurations will be determined during remedial design. An additional option, in lieu of capping, would allow GE to excavate the sediment in each impoundment to meet an average 1 mg/kg PCBs cleanup standard in surface and subsurface sediment. These actions will allow flexibility to address the dams and also result in achieving cleanup levels in fish tissue, and reducing direct contact risk, ecological risk, and downstream transport of contaminants.

- Reach 8 (Rising Pond)

  SED 9/FP 4 MOD requires surficial sediment removal in areas where either surface or subsurface average concentrations exceed 1 mg/kg PCBs. In addition, sediment excavation will be required in any area with surficial PCB contamination that exceeds 50 mg/kg. An Engineered Cap will be placed in these areas to sequester the PCB contaminated sediment that remains at depth. Sufficient sediment will be removed to allow an Engineered Cap to be placed such that the riverbed is generally returned to original grade. Final removal depths, locations, and Engineered Cap configurations will be determined during remedial design. An additional option, in lieu of capping, would allow GE to excavate the sediment in Rising Pond to meet an average 1 mg/kg PCBs cleanup standard in surface and sediment. These actions will result in achieving cleanup levels in fish tissue, and reducing ecological risk and downstream transport of contaminants.

- Flowing Subreaches in Reach 7 (Reaches 7A, 7D, 7F, 7H) and Reaches 9 through 16

  Monitored natural recovery (MNR) would be implemented in the flowing subreaches in Reach 7 (between Woods Pond and Rising Pond) as well as Reaches 9 through 16 (from Rising Pond Dam through Connecticut). MNR would include monitoring to confirm progress toward achieving cleanup levels in fish tissue and reducing ecological risk and downstream transport, compliance with state and National Recommended Water Quality Criteria (NRWQC) (to the extent not waived), and to support modifications to fish consumption advisories.

Engineered Cap Design

Several components of SED 9/FP 4 MOD require construction of an Engineered Cap following sediment removal. In each area to be capped, sediment would be removed to allow the placement of an Engineered Cap to the final grades determined to be appropriate during design of the remedy and to result in no net loss of flood storage capacity. Each cap will likely consist of sacrificial mixing layer, a chemical isolation layer to minimize PCB migration up through the cap, a protective layer (to prevent disruption and erosion of the isolation layer and exposure of the underlying contaminated sediment), and a habitat layer. During remedial design, it will be determined whether additional cap components are necessary (e.g., a filter layer or a mixing layer) or other cap configurations are appropriate (see Attachment 5). As outlined above, if dam removal activities take place in the Reach 7 impoundments, sediment contaminated with PCBs at levels greater than 1 mg/kg could be removed as part of the dam removal project, thus making the installation of a cap in those areas unnecessary.

Floodplain/Vernal Pools Adjacent to Reaches 5 through 8

This part of SED 9/FP 4 MOD would be performed in the floodplain while sediment cleanup activities in adjacent sections of the river (described above) are taking place. Remediation of floodplain soil under SED 9/FP 4 MOD includes:

- Gathering additional information to support the final cleanup design and to achieve cleanup levels.

- Removing floodplain soil contaminated above cleanup levels (exposure area-specific concentrations corresponding to a residual human health risk from direct contact of 1×10^{-5} or a Hazard Index (HI) of 1, whichever is lower) to a depth of 1 foot, except in frequently used subareas, which will be excavated to 3 feet. "Frequently used subareas" are portions of the floodplain that were determined during the human health risk assessment to be used more intensively than other areas and thus are proposed to undergo more cleanup than required for other direct contact exposure pathways.

- Avoiding, minimizing, or mitigating impacts to state-listed species and habitats identified by the Commonwealth of Massachusetts. These areas are referred to as "Core Areas" as designated by the Massachusetts Natural Heritage and Endangered Species Program (see Attachment 4). Core 1 Areas would be remediated only if necessary to achieve exposure area-specific concentrations corresponding to a residual human health risk of 1×10^{-4} or an HI of 1, whichever is lower. Impacts to

Core 2 and Core 3 Areas would be minimized and/or mitigated on a case-by-case basis.

- Remediation of vernal pools to achieve the ecological risk-based amphibian cleanup level of 3.3 mg/kg, while considering avoidance of Core Areas, as discussed above. This work will be implemented using an adaptive management framework based on the results of pilot studies, beginning with a subset of vernal pools. Concurrently, other means to reduce the bioavailability of PCBs in vernal pools will be investigated and tested. Based on the outcome of the remediation of the initial set of vernal pools, other investigations and pilot testing, the location of the vernal pools and associated habitat, determinations will be made about how and where additional vernal pool remediation will occur.

- Restoring the excavated floodplain areas, access roads, and staging areas.

Additional SED 9/FP 4 MOD Remedy Components

The SED 9/FP 4 MOD alternative would also include long-term monitoring, maintenance, inspection, periodic reviews, and institutional controls (ICs).

1.2 DIFFERENCES BETWEEN SED 9/FP 4 AND SED 9/FP 4 MOD

As noted above, the SED 9/FP 4 MOD alternative was derived from the SED 9 and FP 4 alternatives as described and evaluated in the RCMS. In EPA's discussions with GE and the States of Massachusetts and Connecticut following release of the RCMS, each of the area-specific components of SED 9/FP 4 was examined and, where appropriate, refined. Although much of SED 9/FP 4 was retained without modification in some reaches, changes were incorporated for other reaches. A reach-wide summary comparison of the original SED 9/FP 4 components and the refined SED 9/FP 4 MOD components is discussed briefly below. In addition, Attachment 6 summarizes how the estimated volumes were derived for each component of SED 9/FP 4 MOD.

In developing Alternative SED 9 MOD, Alternative SED 9 was modified as follows:

In Reach 5A, from the confluence of the East Branch and West Branch of the Housatonic River at Fred Garner Park in Pittsfield to the Pittsfield WWTP, the depth of sediment removal was increased from 2.0 to 2.5 ft. This increase in the removal depth results in an increase from an estimated 134,000 cubic yards (cy) to an estimated 168,000 cy in the volume of contaminated sediment to be excavated and disposed of. This sediment removal depth was derived from an estimate of the thickness of the Engineered Cap to be placed in this reach. Actual cap thickness will be determined during the design and implementation of the remedy. The area of riverbank in Reach 5A targeted for remediation was defined quantitatively as banks containing greater than 5 mg/kg tPCBs and with a moderate-high or greater Bank Erosion Hazard Index (BEHI) and

Near Bank Stress (NBS) rating[1]. Actual bank removal amounts will be determined during the design and implementation of the remedy. Based on the current data, this would result in the excavation of approximately 25,000 cy of bank soil. In addition, as discussed above, there are provisions for restoring the banks through a hierarchy of options and incorporating the concepts of natural channel design into remediation and restoration activities.

In Reach 5B, SED 9 called for removing all bed sediment to a depth of 2 ft. Instead, SED 9 MOD provides that only sediment in areas that are determined, based on additional sampling, to have PCB contamination in excess of 50 mg/kg will be removed to a depth of 1 ft. This change is expected to reduce the volume of sediment from Reach 5B requiring disposal from an estimated 88,000 cy to an estimated 500 cy. In lieu of sediment removal, the remainder of the reach will be subject to Enhanced Monitored Natural Recovery (EMNR), using activated carbon or a similar amendment. A pilot study will be performed to determine the most appropriate amendment to reduce the mobilization and bioavailability of PCBs. Based on the results of that study, an amendment will be placed throughout Reach 5B. In SED 9 MOD, riverbanks in Reach 5B will be remediated only if the PCB concentration exceeds 50 mg/kg. Actual bank removal amounts will be determined during the design and implantation of the remedy. Based on current data, this refinement will reduce the estimated amount of contaminated bank soil requiring disposal from 10,000 cy to an estimated 500 cy.

In Reach 5C, the depth of sediment removal was retained at 2 feet over the upstream 20 acres as specified in SED 9. The depth of excavation was increased from 1.5 feet to 2 feet for the downstream 37 acres of this reach. The increased removal depth in the lower section of Reach 5C will result in an estimated total volume of contaminated sediment of 186,000 cy to be removed in SED 9 MOD vs. the estimated 156,000 cy for SED 9. This sediment removal depth was derived from an estimate of the thickness of the Engineered Cap to be placed in this reach. Actual cap thickness will be determined during the design and implementation of the remedy.

Changes in backwaters were implemented primarily to afford protection to Core Area 1 habitats that are important for the protection of state-listed species. Rather than remove (or, in deeper areas, only cap) sediment from all backwater areas with sediment PCB concentrations in excess of 1 mg/kg, as was required in SED 9, SED 9 MOD will not involve excavating sediment in Core Area 1 habitats unless the concentration exceeds 50 mg/kg. In core habitats from which sediment is not removed due to this exclusion, the use of activated carbon or another amendment to reduce bioavailability of PCBs will be investigated. In addition, instead of excavating and capping in all backwater areas outside of Core Area 1 with a discrete concentration of 1 mg/kg PCBs, excavation and capping will be required only in areas where the average concentration of PCBs in surface or subsurface sediment exceeds 1 mg/kg, and in areas with greater than 50 mg/kg in surficial sediment. However, all areas with surficial sediment concentrations above 1 mg/kg will require excavation. Also, GE's RCMS proposed capping areas with existing water depths of 4 feet or greater without excavating any sediment. Capping without excavating in backwaters was deleted from SED 9 MOD. These changes reduce the total estimated sediment removal

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[1] The BEHI, which defines bank characteristics, and the NBS, which is based on flow characteristics, are used in the "Bank Assessment for Non-point Source Consequences of Sediment" (BANCS) model developed by Dr. David Rosgen to predict stream bank erosion rates.

volume from 109,000 cy to 95,000 cy and reduce the area of excavation to an estimated 59 acres of backwaters.

In Woods Pond (Reach 6), SED 9 specified the removal of sediment over the entire pond to a depth of 1 foot in the deep hole (23 acres) and to 3.5 feet in shallower areas of the pond. In SED 9 MOD, contaminated sediment will be removed over the entire area of the pond, but the requirement will be to increase the minimum depth of water in the pond to 6 feet (except in nearshore areas) after capping is completed. This modification in the remedy increased the estimated volume of sediment to be removed from 244,000 cy to 285,000 cy. In addition, following remediation, SED 9 MOD requires that PCB concentrations in accumulating pond sediments be monitored. If EPA determines that significant concentrations and a significant depth of PCB-contaminated sediment have accumulated above the Engineered Cap in Woods Pond, these sediments will be removed.

For the impounded subreaches in Reach 7 and also for Rising Pond (Reach 8), SED 9 specifies one option—the removal of contaminated sediment to a depth of 1 foot in low shear-stress areas and 1.5 feet in high shear-stress areas. SED 9 MOD provides for three options:

- Coordinating with entities that are undertaking dam removal and providing funding for sampling and analysis, and assuming responsibility for the incremental costs associated with the presence of PCBs.

- Surficial sediment removal followed by capping in areas where either surface or subsurface average concentrations exceed 1 mg/kg PCBs. In addition, sediment excavation followed by capping in any area with surficial PCB contamination that exceeds 50 mg/kg. This variation from SED 9 allows averaging of PCB concentrations in the subreach/reach rather than requiring excavation and capping throughout the subreach.

- Surface and subsurface sediment removal to achieve 1 mg/kg PCBs in sediment, without the requirement for subsequent capping.

Both alternatives specify MNR for the free-flowing subreaches of Reach 7, as well as for Reaches 9 through 16.

In developing Alternative FP 4 MOD, Alternative FP 4 was modified as follows:

In the floodplain, FP 4 required removal of 1 foot of contaminated soil (3 feet in heavily used sub-areas) to meet the excess cancer risk level of $1x10^{-5}$ or an HI =1, whichever is lower, based on direct contact with floodplain soils and consumption of agricultural products from floodplain soil; and additional soil removal to meet the upper-bound IMPGs for ecological receptors.

FP 4 MOD generally adopts the same risk-based cleanup requirements for protection of human health, but would avoid Core Area 1 habitats unless necessary to achieve a risk level of $1x10^{-4}$ or an HI=1, whichever is lower, and would evaluate the need for remediation in Core Areas 2 and 3 habitats on a case-by-case basis. No additional remediation is required to meet ecological IMPGs, except for amphibians in vernal pools. FP 4 MOD specifies a multi-phased adaptive management approach to the remediation of vernal pools, requiring cleanup to the lower-bound amphibian IMPG of 3.3 mg/kg tPCBs but generally avoiding Core Area 1 habitats. Remediation of vernal pools using traditional means (excavation and reconstruction), placement of activated carbon, and at least one other method will be evaluated in an initial set of pools. Based on this evaluation, and taking into consideration Core Area habitat, EPA will determine the preferred method/approach for each subsequent vernal pool remediation. These refinements would reduce the volume of excavated contaminated floodplain soil from an estimated 121,000 cy to an estimated 75,000 cy and would reduce the area subject to remediation from 72 acres to an estimated 45 acres.

2 EVALUATION OF SEDIMENT/FLOODPLAIN ALTERNATIVES

The seven combined alternatives for river sediment and floodplain soil that were described in Section 8 of the GE RCMS, with the addition of SED 9/FP 4 MOD and a “no action alternative” (SED 1/FP 1), were selected to represent the full range of potential approaches to address contamination in the Rest of River. These alternatives were evaluated relative to each other using the evaluation criteria specified in the Reissued Resource Conservation and Recovery Act (RCRA) Permit for the GE-Pittsfield/Housatonic River Rest of River Site.

2.1 OVERVIEW OF ALTERNATIVES

The nine combined sediment and floodplain alternatives are described in this section. Although not explicitly referenced in the comparison for each criterion, this section essentially includes an evaluation of the “no action” combination alternative (SED 1/FP 1). SED 1/FP 1 is identical to SED 2/FP 1 except that SED 2 calls for MNR of sediment in all reaches, thus requiring monitoring and institutional controls in all reaches. Therefore, other than cost and references to monitoring, SED 1/FP 1 performs the same as SED 2/FP 1.

The nine selected combinations are as follows (see Table 1):

- SED 1/FP 1
- SED 2/FP 1
- SED 3/FP 3
- SED 5/FP 4
- SED 6/FP 4
- SED 8/FP 7
- SED 9/FP 8
- SED 10/FP 9
- SED 9 MOD/FP 4 MOD

The alternatives were compared using a variety of quantitative, semi-quantitative, and qualitative metrics (see Attachment 7) so that the principal advantages and disadvantages of each alternative were identified.

Table 1 Combination Alternatives Matrix

Combination Alternative	Reach 5A	Reach 5B	Reach 5 Erodible Banks	Reach 5C	Reach 5 Backwaters	Reach 6 Woods Pond	Reach 7 Impoundments	Reach 7 Channel	Reach 8 Rising Pond	Reaches 9-16	Floodplain
1 (SED 1/FP 1)	No Action	No Action	No Action	No Action	No Action	No Action	No Action	No Action	No Action	No Action	No Action
2 (SED 2/ FP 1)	MNR	MNR	MNR	MNR	MNR	MNR	MNR	MNR	MNR	MNR	No Action
3 (SED 3/FP 3)	2 ft removal with capping	MNR	Removal/ stabilization	Combination of TLC and MNR	MNR	TLC	MNR	MNR	MNR	MNR	Remove/replace top 12 inches to 10-4 ICR or HI = 1; In frequently used areas remove/replace top 3 feet to 10-5; Additional floodplain excavation to achieve the less strict ecological risk-based IMPGs; Remove/replace vernal pool soils > 5.6 mg/kg
4 (SED 5/FP 4)	2 ft removal with capping	2 ft removal with capping	Removal/ stabilization	Combination of 2 ft removal with capping (in shallow areas) and capping (in deeper areas)	Combination of TLC and MNR	Combination of 1.5 ft removal with capping in shallow areas and capping in deep area	MNR	MNR	TLC	MNR	Remove/replace top 12 inches to 10-5 ICR or HI = 1 In frequently used areas remove/replace top 3 feet to 10-5; Additional floodplain excavation to achieve the less strict ecological risk-based IMPGs; Remove/replace vernal pool soils > 5.6 mg/kg
5 (SED 6/ FP 4)	2 ft removal with capping	2 ft removal with capping	Removal/ stabilization	2 ft removal with capping	Removal of sediments in >50 mg/kg in top 1 ft (with capping/ backfill); TLC for remainder >1 mg/kg	Combination of 1.5 ft removal with capping in shallow areas and capping in deep area	TLC	MNR	Combination of TLC in shallow areas and capping in deep areas	MNR	Remove/replace top 12 inches to 10-5 ICR or HI = 1; In frequently used areas remove/replace top 3 feet to 10-5; Additional floodplain excavation to achieve the less strict ecological risk-based IMPGs; Remove/replace vernal pool soils > 5.6 mg/kg
6 (SED 8/ FP 7)	Removal to 1 mg/kg depth horizon with backfill	Removal to 1 mg/kg depth horizon with backfill	Removal/ stabilization	Removal to 1 mg/kg depth horizon with backfill	Removal to 1 mg/kg depth horizon with backfill	Removal to 1 mg/kg depth horizon with backfill	Removal to 1 mg/kg depth horizon with backfill	MNR	Removal to 1 mg/kg depth horizon with backfill	MNR	Remove/replace top 12 inches to 10-6 ICR but not <2 ppm; In frequently used areas remove/replace top 3 feet to 10-6; Additional floodplain excavation to achieve the more strict ecological risk-based IMPGs; Remove/replace vernal pool soils > 3.3 mg/kg
7 (SED 9/ FP 8)	2 ft removal with capping	2 ft removal with capping	Removal/ stabilization	2 ft removal with capping in upper reach and 1.5 ft removal with capping in lower reach	Combination of sediment removal with capping and capping without removal	3.5 ft removal and capping in shallow areas and 1 ft removal and capping in deep areas	Removal depths of 1 to 1.5 ft with capping	MNR	Removal depths from 1 to 1.5 ft with capping	MNR	Remove/replace top 12 inches to 10-5 ICR or HI = 1; In frequently used areas remove/replace top 3 feet to 10-5; Remove/replace vernal pool soils > 3.3 mg/kg; Remove/replace any additional soils in top 12 inches > 50 mg/kg
8 (SED 10/ FP 9)	2 ft removal capping in selected areas	MNR	Removal/stabilization in selected areas	MNR	MNR	Removal of 2.5 ft in areas > 13 mg/kg in top 6 inches	MNR	MNR	MNR	MNR	Remove/replace top 12 inches to 10-4 ICR or HI = 1; In frequently used areas remove/replace top 3 feet to 10-4
9 (SED 9/ FP 4 MOD)	2.5 ft removal and capping	Removal and backfill of areas > 50 mg/kg and EMNR in remainder of reach	Removal/ stabilization of erodible river banks in Reach 5A and banks in reach 5B w/PCBs > 50mg/kg	2 ft removal with capping	Combination of 1 ft removal and capping in areas > 1 mg/kg, excluding certain high priority habitat	Combination of removal with capping ranging from 4 to 7 ft of removal based on water depth	Coordinate w/ dam removal; Removal depths of 1 to 1.5 ft with capping; or cleanup to 1 mg/kg	MNR	Removal depths of 1 to 1.5 ft with capping or cleanup to 1 mg/kg	MNR	Remove/replace top 12 inches to 10-5 ICR or HI = 1; Except in in high priority habitat areas, then remove/replace top 12 inches to 10-4 ICR or HI = 1; In frequently used areas remove/replace top 3 feet to 10-5; Remove/replace vernal pool soils > 3.3 mg/kg

Note: Sediment removal depths specified in this table are approximate and are for volume/cost estimation and for comparison purposes only. Actual removal depths would be determined in accordance with the Modification of the Reissued RCRA Permit.

MNR – Monitored Natural Recovery	ICR – Incremental Cancer Risk	TLC – Thin-Layer Capping
EMNR – Enhanced Monitored Natural Recovery	IMPGs – Interim Media Protection Goals	

The SED 9/FP 4 MOD alternative was modeled in 2012, and the model-derived metrics summarizing the performance of this alternative are presented in Attachment 7. Subsequent refinements to the SED 9/FP 4 MOD alternative resulting from meetings with GE and the co-regulators, as discussed in Section 1, are relatively minor for modeling purposes, and it was not necessary to generate new metrics. Accordingly, the metrics for the refined SED 9/FP 4 MOD alternative are unchanged from the original SED 9/FP 4 MOD. A refined cost estimate was generated for SED 9/FP 4 MOD (Attachment 8).

The criteria for evaluation of remedial alternatives for the Rest of River are specified in Part II, Section G, of the Reissued RCRA Permit for the GE-Pittsfield/Housatonic River Site (Appendix G to the Consent Decree) and are similar, but not identical to, evaluation criteria delineated in the National Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Section 300.430(e)(9)(iii). The nine evaluation criteria include three general standards, and six selection decision factors:

- General standards:
    - Overall protection of human health and the environment.
    - Control of sources of releases.
    - Compliance with federal and state applicable or relevant and appropriate requirements (ARARs).
- Selection decision factors:
    - Long-term reliability and effectiveness.
    - Attainment of Interim Media Protection Goals (IMPGs).
    - Reduction of toxicity, mobility, or volume (TMV) of wastes.
    - Short-term effectiveness.
    - Implementability.
    - Cost.

Each of these nine criteria is evaluated with respect to the degree to which it is achieved by the eight selected combinations of SED and FP alternatives in Sections 2.2 through 2.10. Although an individual analysis of SED 9/FP 4 MOD against the nine criteria is not provided in this document, the analysis below sufficiently analyzes how this alternative meets the criteria while also comparing it to the eight other combination alternatives.

An overview and a comparative analysis of treatment/disposition alternatives are presented in Section 3. The nine criteria for the treatment/disposal alternative analysis are the same as described above for the SED and FP alternatives.

2.2 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The evaluation of whether a particular remedial alternative would provide overall human health and environmental protection relies heavily on the evaluations under several other permit criteria, including but not limited to the following: (1) attainment of IMPGs, (2) compliance with ARARs, (3) long-term reliability and effectiveness, and (4) short-term effectiveness. A summary of the comparative evaluation of the alternatives considering these factors is presented below.

SED 2/FP 1 (MNR in all reaches of the river and no action in the floodplain) is the least protective alternative, relying on natural recovery processes to achieve reductions in PCB concentrations in sediment, surface water, and fish tissue, and a reduction in PCB loading to the river and PCB transport to the floodplain. Given the persistence and unsafe concentrations of PCBs in floodplain soil, riverbanks, sediment, and biota in many reaches of the river, and the continuing input and downstream transport of PCBs from eroding banks and channel incision into the floodplain, this alternative is not protective.

The other alternatives would result in reductions in PCB concentrations and potential exposures by permanently removing PCB-contaminated sediment, removing and stabilizing riverbank soil, capping certain areas of the river, and removing PCB-contaminated floodplain soil. These alternatives offer varying degrees of protection and short-term disturbance and include MNR and ICs for the flowing subreaches in Reach 7 and in Reaches 9 through 16.

SED 10/FP 9 includes selective removal of some sediment in Reach 5A and some bank stabilization, and limited floodplain soil removal. These actions would result in some reduction in the mass of PCBs transported through the system and a marginal improvement in fish tissue PCB concentrations. In the floodplain, the soil removal would result in reasonable maximum exposure (RME) human health risks below an HI of 1 and a $1 x 10^{-4}$ cancer risk. Some ecological IMPGs would be achieved in some areas of the floodplain and river. This alternative has limited short-term impacts but is questionable in its long-term effectiveness.

SED 3/FP 3 includes remediation of all of Reach 5A, but relies on MNR and ICs in Reach 5B, a portion of Reaches 5C, 5D, and Reach 7 impoundments, and on thin-layer capping in a portion of Reach 5C and in Reach 6. This alternative offers a marginal reduction in the PCB mass transported through the system and in fish tissue concentrations when compared to SED 10/FP 9, and achieves the RME $1 x 10^{-6}$ risk for one sediment exposure area (EA). The upper-bound ecological IMPGs are achieved. Human health risks for direct contact in the floodplain are below an HI of 1 and achieve $1 x 10^{-4}$ for the RME individual. In addition, the RME $1 x 10^{-5}$ risk level is achieved in the frequently used subareas. This alternative also has limited short-term impacts but uncertain long-term effectiveness.

The remaining alternatives, SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, SED 9/FP 8, and SED 9/FP 4 MOD, include various remediation techniques and amounts of removal and capping. SED 5/FP 4 and SED 6/FP 4 include some components of thin-layer capping and capping without removal. Capping without removal will impact the bathymetry and hydrodynamics of the river. Thin-layer capping is not a suitable technology considering the mass and high concentrations of PCBs in the sediment and is not expected to result in significant long-lasting benefits in the reaches for which it is considered. Model predictions for the annual mass of PCBs transported through the system are similar for all of these alternatives, as are the predicted fish tissue concentrations. Although SED 8/FP 7 removes the majority of the PCBs from the river and a significant amount of PCBs from the floodplain, it is projected to take approximately 50 years to implement, thus the improvements are not realized as rapidly as with the other alternatives.

For the floodplain, these alternatives would involve removal of progressively more PCB-contaminated soil, in increasing order of removal: SED 9/FP 4 MOD, SED 5/FP 4, SED 6/FP 4, SED 9/FP 8, and finally, SED 8/FP 7. Consequently, there would be progressively greater reduction in exposure and risk to human health and ecological receptors, yet with associated increasing impacts to floodplain habitat and potential adverse impacts to habitat supporting state-listed species. The floodplain component of SED 9/FP 4 MOD was developed specifically with these adverse impacts in mind and represents a balance between reducing risks to humans and ecological receptors and impacts to Core Area habitats. This alternative will achieve a human health direct contact level of $1x10^{-5}$ or an HI of 1 in many areas, yet avoids conducting remediation in Core Area 1 habitats unless necessary to achieve an HI of 1 non-cancer or $1x10^{-4}$ cancer risk level.

To evaluate the PCB concentrations in fish tissue and resulting human health risks due to consumption of fish, computer modeling was used to predict fish tissue concentrations during and following the implementation of each alternative. The boundary conditions used for this model framework reflect the cleanup that has been completed in the upstream reaches (see Attachment 9). The output from the model is included in Attachment 10. As noted above, the model results shown for SED 9/FP 4 MOD reflect the August 2012 specifications for this alternative; the refinements made subsequently were minor and would not result in any meaningful differences in the resulting fish tissue concentrations for this alternative.

These modeling results indicate that fish tissue PCB concentrations predicted to result from all remedial alternatives at the end of the model simulation period (52 to ~80 years) would not achieve the RME IMPGs in all reaches (Table 2). As a result, under all alternatives, ICs (including but not limited to fish consumption advisories) would likely be needed for a period of time following remediation to provide human health protection from fish consumption. However, a number of alternatives do achieve other less stringent IMPGs, and there are differences among the alternatives in the time necessary to achieve various risk levels. For example, as indicated in the far right column of Table 2, Page 2, for the CTE (central tendency or average) individual, the probabilistic risk model shows some alternatives achieving an HI of 1 within the 52-year modeling period in all reaches. Fate and transport modeling indicates that SED 9/FP 4 MOD achieves this IMPG in all reaches except 5B, in most cases more rapidly than all other alternatives except SED 9/FP 8. The modeling does not simulate the effect of the placement of activated carbon in Reach 5B.

The performance of the alternatives for all risk levels is shown in Attachment 10. For many of the alternatives shown in the figures in Attachment 10, upon completion of the remediation, the trajectories shown in the plots converge at a particular concentration (which varies by reach) and then indicate a very slight additional decrease over time. This behavior is primarily driven by the non-zero PCB boundary conditions specified in the model (see Attachment 9) and, therefore, is uncertain. If the boundary PCB loads are less than were assumed, the fish tissue concentrations would decline more than the model predictions before leveling off; however, if the boundary PCB loads are greater than assumed, the point of convergence would be at a higher tissue concentration.

Table 2
Evaluation of IMPG Attainment for Human Consumption of Fish for Combined SED/FP Scenarios

River Reach	Average Fish (fillet) Concentrations (mg/kg)[1,2]								10^{-6} Cancer Risk								
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
									Human Consumption of Fish (Bass Fillets, Deterministic RME)								
5A	7.3	0.25	0.26	0.26	0.17	0.31	4.2	0.26	0.0019	>250	237	249	230	>250	234	>250	>52
5B	9.3	3	0.23	0.22	0.15	0.27	6.6	3.48		>250	>250	>250	235	>250	232	>250	>52
5C	7.4	1.8	0.17	0.16	0.11	0.18	5.8	0.82		>250	>250	>250	242	>250	229	>250	>52
5D	9.5	6.3	0.36	0.35	0.29	0.41	11	1.1		>250	>250	>250	>250	>250	IT	>250	>52
6 (WP)	8.6	0.71	0.18	0.17	0.13	0.16	3.7	0.74		>250	>250	>250	>250	>250	231	>250	>52
7A	6.4	1.3	0.42	0.4	0.34	0.42	4.2	1.12		>250	>250	>250	>250	>250	>250	>250	>52
7B	5.7	2.1	1.6	0.41	0.1	0.21	4.2	0.67		>250	>250	>250	>250	>250	>250	>250	>52
7C	6.3	1.8	1	0.2	0.12	0.2	4.4	0.81		>250	>250	>250	>250	>250	>250	>250	>52
7D	5.5	1.4	0.79	0.7	0.63	0.75	3.7	1.37		>250	>250	>250	>250	>250	>250	>250	>52
7E	4.1	1	0.57	0.34	0.18	0.22	2.8	0.64		>250	>250	>250	>250	>250	>250	>250	>52
7F	3.2	0.82	0.49	0.45	0.38	0.45	2.2	0.82		>250	>250	>250	>250	>250	>250	>250	>52
7G	3.5	1.3	1	0.4	0.15	0.22	2.6	0.38		>250	>250	>250	>250	>250	>250	>250	>52
7H	2.8	0.72	0.43	0.39	0.35	0.39	1.9	0.69		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)	3.6	1.6	0.34	0.22	0.17	0.24	2.7	0.37		>250	>250	>250	>250	>250	>250	>250	>52
BBD	0.16	0.04	0.01	0.009	0.006	0.009	0.1	0.022		>250	244	126	91	116	101	>250	>52
LL	0.11	0.03	0.009	0.006	0.005	0.006	0.08	0.015		>250	222	113	82	106	90	>250	>52
LZ	0.08	0.02	0.006	0.005	0.004	0.004	0.05	0.011		>250	199	99	73	96	78	>250	>52
LH	0.08	0.02	0.006	0.004	0.003	0.004	0.05	0.010		>250	197	97	72	94	77	>250	>52
									Human Consumption of Fish (Bass Fillets, Probabilistic RME (5th percentile))								
5A	7.3	0.25	0.26	0.26	0.17	0.31	4.2	0.26	0.0064	>250	191	200	186	242	190	>250	>52
5B	9.3	3	0.23	0.22	0.15	0.27	6.6	3.48		>250	>250	207	188	242	188	>250	>52
5C	7.4	1.8	0.17	0.16	0.11	0.18	5.8	0.82		>250	>250	213	190	241	181	>250	>52
5D	9.5	6.3	0.36	0.35	0.29	0.41	11	1.1		>250	221	>250	>250	>250	IT	>250	>52
6 (WP)	8.6	0.71	0.18	0.17	0.13	0.16	3.7	0.74		>250	>250	>250	229	>250	182	>250	>52
7A	6.4	1.3	0.42	0.4	0.34	0.42	4.2	1.12		>250	>250	>250	>250	>250	>250	>250	>52
7B	5.7	2.1	1.6	0.41	0.1	0.21	4.2	0.67		>250	>250	>250	>250	>250	>250	>250	>52
7C	6.3	1.8	1	0.2	0.12	0.2	4.4	0.81		>250	>250	>250	242	>250	228	>250	>52
7D	5.5	1.4	0.79	0.7	0.63	0.75	3.7	1.37		>250	>250	>250	>250	>250	>250	>250	>52
7E	4.1	1	0.57	0.34	0.18	0.22	2.8	0.64		>250	>250	>250	>250	>250	>250	>250	>52
7F	3.2	0.82	0.49	0.45	0.38	0.45	2.2	0.82		>250	>250	>250	>250	>250	>250	>250	>52
7G	3.5	1.3	1	0.4	0.15	0.22	2.6	0.38		>250	>250	>250	>250	>250	>250	>250	>52
7H	2.8	0.72	0.43	0.39	0.35	0.39	1.9	0.69		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)	3.6	1.6	0.34	0.22	0.17	0.24	2.7	0.37		>250	>250	>250	>250	>250	>250	>250	>52
BBD	0.16	0.04	0.01	0.009	0.006	0.009	0.1	0.022		>250	165	>250	59	79	60	>250	>52
LL	0.11	0.03	0.009	0.006	0.005	0.006	0.08	0.015		>250	143	64	51	68	50	>250	>52
LZ	0.08	0.02	0.006	0.005	0.004	0.004	0.05	0.011		>250	120	51	38	62	36	>250	>52
LH	0.08	0.02	0.006	0.004	0.003	0.004	0.05	0.010		>250	117	50	37	62	35	>250	>52

River Reach	10^{-5} Cancer Risk									10^{-4} Cancer Risk								
	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
	Human Consumption of Fish (Bass Fillets, Deterministic RME)																	
5A	0.019	>250	149	156	146	188	151	>250	>52	0.19	>250	62	64	62	74	68	>250	>52
5B		>250	>250	159	145	186	148	>250	>52		>250	>250	59	56	70	63	>250	>52
5C		>250	>250	159	143	179	139	>250	>52		>250	207	44	44	48	51	>250	>52
5D		>250	195	>250	>250	>250	IT	>250	>52		>250	138	>250	>250	117	IT	>250	>52
6 (WP)		>250	>250	187	170	193	138	>250	>52		>250	>250	50	48	51	44	>250	>52
7A		>250	>250	>250	>250	>250	>250	>250	>52		>250	233	138	112	166	120	>250	>52
7B		>250	>250	>250	>250	205	>250	>250	>52		>250	>250	>250	>250	46	60	>250	>52
7C		>250	>250	>250	181	200	171	>250	>52		>250	>250	>250	53	52	52	>250	>52
7D		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	210	>250	>250	>250	>52
7E		>250	>250	>250	213	>250	209	>250	>52		>250	154	173	83	64	61	>250	>52
7F		>250	>250	>250	>250	>250	>250	>250	>52		>250	195	165	128	182	140	>250	>52
7G		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	154	52	63	>250	>52
7H		>250	>250	>250	>250	>250	>250	>250	>52		>250	219	174	139	226	147	>250	>52
8 (RP)		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	65	63	72	>250	>52
BBD		230	94	40	36	60	34	246	>52		31	11	11	18	15	13	17	10
LL		200	72	33	31	57	26	207	36		26	9	8	9	11	11	9	8
LZ		170	49	25	26	56	23	167	27		6	6	4	6	7	9	6	0
LH		167	46	25	26	56	22	162	26		5	5	4	5	6	8	4	0
	Human Consumption of Fish (Bass Fillets, Probabilistic RME (5th percentile))																	
5A	0.064	>250	103	108	102	127	108	>250	>52	0.64	240	15	15	15	17	19	186	17
5B		>250	>250	106	98	123	103	>250	>52		>250	213	16	16	20	15	>250	>52
5C		>250	>250	98	91	110	91	>250	>52		>250	123	19	20	31	14	>250	>52
5D		>250	165	>250	>250	>250	IT	>250	>52		>250	108	21	21	31	15	239	>52
6 (WP)		>250	>250	114	105	120	88	>250	>52		>250	79	22	23	41	16	189	>52
7A		>250	>250	>250	205	>250	216	>250	>52		>250	117	24	24	43	120	235	>52
7B		>250	>250	>250	>250	114	162	>250	>52		>250	232	>250	23	43	15	>250	>52
7C		>250	>250	>250	114	121	108	>250	>52		>250	197	166	23	44	16	>250	>52
7D		>250	>250	>250	>250	>250	>250	>250	>52		>250	142	83	62	76	74	>250	>52
7E		>250	222	>250	144	171	131	>250	>52		232	79	38	23	44	16	224	>52
7F		>250	>250	>250	225	>250	251	>250	>52		205	75	25	26	45	21	>250	>52
7G		>250	>250	>250	>250	172	155	>250	>52		243	156	142	23	45	16	>250	16
7H		>250	>250	>250	>250	>250	>250	>250	>52		188	66	23	23	46	16	>250	>52
8 (RP)		>250	>250	>250	173	200	179	>250	>52		233	190	22	24	53	18	>250	19
BBD		125	22	21	22	34	16	107	18		0	0	0	0	0	0	0	0
LL		96	17	19	20	31	15	68	15		0	0	0	0	0	0	0	0
LZ		66	12	15	19	17	13	27	12		0	0	0	0	0	0	0	0
LH		62	12	11	19	17	13	26	12		0	0	0	0	0	0	0	0

River Reach	Non-Cancer: Child									Non-Cancer: Adult								
	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
	Human Consumption of Fish (Bass Fillets, Deterministic RME)																	
5A	0.026	>250	137	144	134	172	140	>250	>52	0.062	>250	105	109	103	129	109	>250	>52
5B		>250	>250	146	133	170	136	>250	>52		>250	>250	108	99	125	104	>250	>52
5C		>250	>250	143	129	161	127	>250	>52		>250	>250	100	92	111	93	>250	>52
5D		>250	187	>250	>250	>250	IT	>250	>52		>250	165	>250	>250	>250	IT	>250	>52
6 (WP)		>250	>250	168	153	174	125	>250	>52		>250	>250	116	106	122	89	>250	>52
7A		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	207	>250	219	>250	>52
7B		>250	>250	>250	>250	181	245	>250	>52		>250	>250	>250	>250	116	164	>250	>52
7C		>250	>250	>250	164	180	155	>250	>52		>250	>250	>250	116	123	110	>250	>52
7D		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	>250	>250	>250	>250	>52
7E		>250	>250	>250	195	>250	189	>250	>52		>250	224	>250	146	174	133	>250	>52
7F		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	228	>250	>250	>250	>52
7G		>250	>250	>250	>250	>250	232	>250	>52		>250	>250	>250	>250	176	158	>250	>52
7H		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	177	204	182	>250	>52
BBD		203	74	27	28	56	25	210	37		128	22	21	22	34	16	111	19
LL		173	52	24	25	55	21	171	28		98	17	19	20	31	15	72	16
LZ		143	34	22	23	54	18	131	21		68	12	15	19	17	13	27	12
LH		140	27	22	23	41	18	126	20		65	12	11	19	17	13	26	12
	Human Consumption of Fish (Bass Fillets, Probabilistic RME (5th percentile))																	
5A	0.059	>250	106	111	105	131	111	>250	>52	0.12	>250	80	82	79	96	85	>250	>52
5B		>250	>250	110	101	128	106	>250	>52		>250	>250	79	74	91	80	>250	>52
5C		>250	>250	102	94	114	94	>250	>52		>250	239	67	63	76	67	500	>52
5D		>250	167	>250	>250	>250	IT	>250	>52		>250	149	>250	>250	173	IT	>250	>52
6 (WP)		>250	>250	119	109	125	91	>250	>52		>250	>250	75	71	82	62	>250	>52
7A		>250	>250	>250	211	>250	223	>250	>52		>250	>250	188	151	234	161	>250	>52
7B		>250	>250	>250	>250	120	169	>250	>52		>250	>250	>250	>250	70	103	>250	>52
7C		>250	>250	>250	118	126	112	>250	>52		>250	>250	>250	79	82	76	>250	>52
7D		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	>250	>250	>250	>250	>250	>52
7E		>250	227	>250	149	179	136	>250	>52		>250	183	223	109	110	91	>250	>52
7F		>250	>250	>250	232	>250	>250	>250	>52		>250	240	219	169	>250	187	>250	>52
7G		>250	>250	>250	>250	182	162	>250	>52		>250	>250	>250	218	101	102	>250	>52
7H		>250	>250	>250	>250	>250	>250	>250	>52		>250	>250	242	196	>250	210	>250	>52
8 (RP)		>250	>250	>250	181	210	187	>250	>52		>250	>250	>250	111	120	117	>250	>52
BBD		132	26	21	22	39	17	116	19		71	11	11	18	15	13	17	13
LL		103	19	20	21	32	16	77	16		26	9	8	9	11	11	9	11
LZ		73	14	18	20	26	14	41	13		6	6	4	6	7	9	6	9
LH		69	13	18	19	22	14	37	12		5	5	4	5	6	8	4	9

Table 2
Evaluation of IMPG Attainment for Human Consumption of Fish for Combined SED/FP Scenarios

River Reach	Average Fish (fillet) Concentrations (mg/kg) ^{1,2}								10^{-6} Cancer Risk								
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
Human Consumption of Fish (Bass Fillets, Deterministic CTE)																	
5A	7.3	0.25	0.26	0.26	0.17	0.31	4.2	0.26	0.049	>250	113	118	111	141	117	>250	>52
5B	9.3	3	0.23	0.22	0.15	0.27	6.6	3.48		>250	>250	118	109	137	113	>250	>52
5C	7.4	1.8	0.17	0.16	0.11	0.18	5.8	0.82		>250	>250	111	102	125	102	>250	>52
5D	9.5	6.3	0.36	0.35	0.29	0.41	11	1.1		>250	171	>250	>250	>250	IT	>250	>52
6 (WP)	8.6	0.71	0.18	0.17	0.13	0.16	3.7	0.74		>250	>250	130	119	136	99	>250	>52
7A	6.4	1.3	0.42	0.4	0.34	0.42	4.2	1.12		>250	>250	>250	227	>250	240	>250	>52
7B	5.7	2.1	1.6	0.41	0.1	0.21	4.2	0.67		>250	>250	>250	>250	134	186	>250	>52
7C	6.3	1.8	1	0.2	0.12	0.2	4.4	0.81		>250	>250	>250	129	138	122	>250	>52
7D	5.5	1.4	0.79	0.7	0.63	0.75	3.7	1.37		>250	>250	>250	>250	>250	>250	>250	>52
7E	4.1	1	0.57	0.34	0.18	0.22	2.8	0.64		>250	239	>250	159	197	148	>250	>52
7F	3.2	0.82	0.49	0.45	0.38	0.45	2.2	0.82		>250	>250	>250	249	>250	>250	>250	>52
7G	3.5	1.3	1	0.4	0.15	0.22	2.6	0.38		>250	>250	>250	>250	203	178	>250	>52
7H	2.8	0.72	0.43	0.39	0.35	0.39	1.9	0.69		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)	3.6	1.6	0.34	0.22	0.17	0.24	2.7	0.37		>250	>250	>250	200	234	205	>250	>52
BBD	0.16	0.04	0.01	0.009	0.006	0.009	0.1	0.022		148	37	22	23	54	19	138	22
LL	0.11	0.03	0.009	0.006	0.005	0.006	0.08	0.015		119	23	21	22	36	17	99	18
LZ	0.08	0.02	0.006	0.005	0.004	0.004	0.05	0.011		89	17	19	20	31	15	58	15
LH	0.08	0.02	0.006	0.004	0.003	0.004	0.05	0.010		85	17	19	20	31	15	54	14
Human Consumption of Fish (Bass Fillets, Probabilistic CTE (50th percentile))																	
5A	7.3	0.25	0.26	0.26	0.17	0.31	4.2	0.26	0.057	>250	108	112	106	133	112	>250	>52
5B	9.3	3	0.23	0.22	0.15	0.27	6.6	3.48		>250	>250	111	103	129	107	>250	>52
5C	7.4	1.8	0.17	0.16	0.11	0.18	5.8	0.82		>250	>250	104	96	116	96	>250	>52
5D	9.5	6.3	0.36	0.35	0.29	0.41	11	1.1		>250	167	>250	>250	>250	IT	>250	>52
6 (WP)	8.6	0.71	0.18	0.17	0.13	0.16	3.7	0.74		>250	>250	121	111	127	93	198	>52
7A	6.4	1.3	0.42	0.4	0.34	0.42	4.2	1.12		>250	>250	>250	214	>250	226	>250	>52
7B	5.7	2.1	1.6	0.41	0.1	0.21	4.2	0.67		>250	>250	>250	>250	122	172	>250	>52
7C	6.3	1.8	1	0.2	0.12	0.2	4.4	0.81		>250	>250	>250	120	128	114	>250	>52
7D	5.5	1.4	0.79	0.7	0.63	0.75	3.7	1.37		>250	>250	>250	>250	>250	>250	>250	>52
7E	4.1	1	0.57	0.34	0.18	0.22	2.8	0.64		>250	229	>250	151	182	138	>250	>52
7F	3.2	0.82	0.49	0.45	0.38	0.45	2.2	0.82		>250	>250	>250	235	>250	>250	>250	>52
7G	3.5	1.3	1	0.4	0.15	0.22	2.6	0.38		>250	>250	>250	>250	186	165	>250	>52
7H	2.8	0.72	0.43	0.39	0.35	0.39	1.9	0.69		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)	3.6	1.6	0.34	0.22	0.17	0.24	2.7	0.37		>250	>250	>250	185	215	190	>250	>52
BBD	0.16	0.04	0.01	0.009	0.006	0.009	0.1	0.022		135	26	21	22	39	17	120	20
LL	0.11	0.03	0.009	0.006	0.005	0.006	0.08	0.015		106	19	20	21	32	16	81	16
LZ	0.08	0.02	0.006	0.005	0.004	0.004	0.05	0.011		75	14	18	20	26	14	41	14
LH	0.08	0.02	0.006	0.004	0.003	0.004	0.05	0.010		72	13	18	19	22	14	37	13

River Reach	10^{-5} Cancer Risk									10^{-4} Cancer Risk								
	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
Human Consumption of Fish (Bass Fillets, Deterministic CTE)																		
5A	0.49	>250	22	22	22	23	35	205	26	4.9	82	8	8	8	10	8	36	9
5B		>250	241	18	18	21	22	>250	>52		123	12	10	10	14	9	81	16
5C		>250	142	20	20	32	15	>250	>52		98	10	14	14	17	10	69	11
5D		>250	115	21	21	31	16	>250	>52		136	58	17	17	27	12	108	12
6 (WP)		>250	134	22	23	42	16	209	>52		132	11	18	19	37	12	25	12
7A		>250	142	36	33	44	37	>250	>52		78	9	10	10	12	11	26	12
7B		>250	>250	>250	23	43	16	>250	>52		69	9	10	10	12	11	26	11
7C		>250	234	227	24	45	17	>250	>52		78	10	10	10	13	12	36	12
7D		>250	174	124	94	127	114	>250	>52		64	9	9	10	12	11	11	12
7E		>250	96	69	24	45	17	>250	>52		34	9	7	9	11	11	9	11
7F		231	102	51	41	48	39	>250	>52		9	8	6	8	10	10	8	11
7G		>250	196	193	24	46	17	>250	31		10	8	6	8	11	10	8	9
7H		214	99	34	26	47	22	>250	>52		7	7	5	7	8	9	6	10
8 (RP)		>250	231	23	25	53	19	>250	30		10	8	6	8	11	11	8	9
BBD		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Human Consumption of Fish (Bass Fillets, Probabilistic CTE (50th percentile))																		
5A	0.57	249	18	18	18	18	23	194	21	5.7	71	7	7	7	9	7	26	9
5B		>250	225	17	17	21	18	>250	>52		107	11	10	10	13	9	65	13
5C		>250	131	19	20	31	14	>250	>52		81	10	11	11	14	9	54	10
5D		>250	111	21	21	31	15	341	>52		122	54	17	17	27	11	122	12
6 (WP)		>250	103	22	23	41	16	52	>52		113	11	17	19	37	11	10	12
7A		>250	128	25	25	43	25	246	>52		63	9	9	9	11	11	11	12
7B		>250	250	>250	23	43	16	>250	>52		52	9	9	9	11	11	11	10
7C		>250	213	192	24	44	17	>250	>52		62	9	9	9	12	11	12	12
7D		>250	155	101	76	98	91	>250	>52		38	9	8	9	11	11	9	11
7E		243	86	52	23	44	16	>250	>52		11	8	6	8	10	10	8	10
7F		216	87	36	32	46	30	>250	>52		7	7	5	7	8	9	7	10
7G		>250	173	164	24	46	17	>250	28		8	7	5	7	9	9	7	8
7H		199	80	24	24	46	17	>250	>52		4	5	3	5	7	8	3	9
8 (RP)		246	208	23	24	53	18	>250	23		7	7	5	7	9	10	6	8
BBD		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0

River Reach	Non-Cancer: Child									Non-Cancer: Adult								
	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD	IMPG (mg/kg)	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
Human Consumption of Fish (Bass Fillets, Deterministic CTE)																		
5A	0.19	>250	62	64	62	74	68	>250	>52	0.43	>250	26	26	26	39	38	214	33
5B		>250	>250	59	56	70	63	>250	>52		>250	>250	21	20	23	34	>250	>52
5C		>250	207	44	44	48	51	>250	>52		>250	151	20	21	32	16	>250	>52
5D		>250	138	>250	>250	117	IT	>250	>52		>250	118	22	22	32	24	>250	>52
6 (WP)		>250	>250	50	48	51	44	>250	>52		>250	161	23	24	42	17	219	>52
7A		>250	233	138	112	166	120	>250	>52		>250	155	48	41	48	48	>250	>52
7B		>250	>250	>250	>250	46	60	>250	>52		>250	>250	>250	23	43	16	>250	>52
7C		>250	>250	>250	53	52	52	>250	>52		>250	>250	>250	24	45	18	>250	>52
7D		>250	>250	>250	210	>250	>250	>250	>52		>250	189	144	110	153	134	>250	>52
7E		>250	154	173	83	64	61	>250	>52		>250	104	84	24	45	17	>250	>52
7F		>250	195	165	128	182	140	>250	>52		244	114	68	55	61	56	>250	>52
7G		>250	>250	>250	154	52	63	>250	>52		>250	216	218	24	47	18	>250	35
7H		>250	219	174	139	226	147	>250	>52		226	116	51	37	48	35	>250	>52
8 (RP)		>250	>250	>250	65	63	72	>250	>52		>250	>250	24	25	54	19	>250	33
BBD		31	11	11	18	15	13	17	10		0	0	0	0	0	0	0	0
LL		26	9	8	9	11	11	9	8		0	0	0	0	0	0	0	0
LZ		6	6	4	6	7	9	6	0		0	0	0	0	0	0	0	0
LH		5	5	4	5	6	8	4	0		0	0	0	0	0	0	0	0
Human Consumption of Fish (Bass Fillets, Probabilistic CTE (50th percentile))																		
5A	0.71	232	14	14	14	16	16	179	15	1.5	174	11	11	11	13	10	125	12
5B		>250	202	16	16	20	14	>250	>52		>250	124	14	14	18	11	203	>52
5C		>250	116	19	19	31	14	>250	>52		226	65	18	18	28	12	193	14
5D		>250	105	20	21	31	15	320	>52		249	87	19	19	29	13	249	35
6 (WP)		>250	53	22	23	41	15	180	>52		>250	14	20	21	40	14	122	15
7A		>250	107	24	24	42	17	225	>52		192	26	21	22	39	14	152	18
7B		>250	217	238	22	42	15	>250	35		201	103	63	21	41	14	193	14
7C		>250	182	141	23	44	16	>250	>52		202	76	23	22	42	14	177	16
7D		>250	129	68	51	60	58	>250	>52		206	38	22	22	42	15	180	33
7E		222	73	27	23	44	15	212	35		149	23	21	21	40	14	124	14
7F		195	65	24	24	44	17	236	>52		122	19	20	21	33	14	113	16
7G		231	140	122	23	45	16	>250	15		145	34	21	21	42	14	158	13
7H		178	52	22	23	45	16	>250	38		106	15	19	20	32	13	99	14
8 (RP)		222	174	22	24	52	18	>250	18		141	58	20	22	50	16	182	15
BBD		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0

Key:

☐ = *post-remediation EPC is higher than IMPG*

▨ = *post-remediation EPC is lower than IMPG*

<value> = time to achieve predicted by the model

<value> = time to achieve based on highly uncertain extrapolation of the model results as described in Section 3.2.1 of the Revised CMS Report

Notes:

[1] Model endpoint concentrations after projection (autumn average); whole body concentrations divided by a factor of 5.0 to convert to fillet basis

[2] Results for CT impoundments are highly uncertain as they were estimated from the CT 1-D Analysis.

CTE = central tendency exposure

RME = reasonable maximum exposure

BBD: Bulls Bridge Dam Impoundment; LL: Lake Lillinonah; LZ: Lake Zoar; LH: Lake Housatonic

IT = Increasing trend in model extrapolation; no time-to-achieve

Estimates from the Connecticut one-dimensional (1-D) analysis indicate that the RME $1x10^{-5}$/ HI = 1 deterministic IMPGs for fish consumption are not achieved in any of the four impoundments modeled in Connecticut under SED 2/FP 1 (MNR) or SED 10/FP 9 (SED 10/FP 9 achieves the adult non-cancer IMPG only in two of the impoundments). All other alternatives achieve these IMPGs in all or most of the Connecticut impoundments by the end of the modeling period (see Table 2). Notwithstanding, the State of Connecticut has calculated more stringent criteria for unlimited fish consumption that may not be met in any of these impoundments at the end of the modeling period.

In addition, alternatives SED 2/FP 1 and SED 10/FP 9 would not meet federal and state water quality criteria for freshwater aquatic life and therefore would not be protective of the environment; however, the other alternatives do meet these criteria in all reaches by the end of the modeling period. None of the alternatives analyzed would achieve the federal and state water quality criteria for human consumption of organisms in any of the Massachusetts reaches. SED 2/FP 1, SED 3/FP 3, and SED 10/FP 9 would not achieve these criteria in any Connecticut impoundments, although the results for Connecticut have a high degree of uncertainty due to the empirical semi-quantitative nature of the model used to predict the water column PCB concentrations following remediation. Acknowledging that uncertainty, however, the analysis does show that SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, SED 9/FP 8, and SED 9/FP 4 MOD would restore water quality consistent with the criteria in significant segments of the river in Connecticut.

All alternatives rely to varying degrees on ICs throughout the river in both Massachusetts and Connecticut to be protective of human health in the long term. Those alternatives that rely more extensively on these controls (SED 2/FP 1 and SED 10/FP 9) over longer timeframes and larger areas have more uncertainty that they will protect human health in the long term, and such controls provide no protection for ecological risks. Those alternatives that rely on these controls over shorter timeframes or smaller areas (SED 8/FP 7, SED 9/FP 8, and SED 9/FP 4 MOD) have higher overall protection of human health.

In summary, the standard of overall protection of human health and the environment requires a balancing of the short-term and long-term adverse impacts of the alternatives with the benefits achieved by each alternative. Restoration of the riverbed, riverbanks, and floodplain can be achieved and maintained (see Attachments 11 and 12); therefore, the short-term impacts to the environment can be successfully mitigated. Among the alternatives evaluated in this comparative analysis, SED 9/FP 4 MOD was judged to provide the best overall protection of human health and the environment because it achieves this important balance between both short- and long-term risks and long-term benefits.

2.3 CONTROL OF SOURCES OF RELEASES

The extent to which each of the alternatives reduces or minimizes further PCB releases was evaluated. This evaluation is driven by a comparison of the sediment and riverbank components of the sediment-floodplain alternatives because the floodplain soil is not a significant source of PCB releases to the river, except in the situation of the river channel relocating into contaminated floodplain.

2.3.1 Mass of PCBs Transported Downstream

The model simulation predicts that, in 52 years, the reductions from upstream source control and other upstream and facility remediation, along with natural recovery processes within the Rest of River (as reflected in SED 2), would result in reductions of 37% and 41% in the annual mass of PCBs passing Woods Pond and Rising Pond Dams, respectively, and a reduction of 50% in the annual mass of PCBs transported from the river to the floodplain in Reaches 5 and 6.[2]

The reductions relative to current conditions in the annual PCB mass transported within the river (as represented by the predicted PCB mass passing Woods Pond and Rising Pond Dams) and to the floodplain within Reaches 5 and 6 at the end of the model projection period for the various alternatives are summarized in Table 3.

Table 3 Percent Reduction in Annual PCB Mass Passing Woods Pond and Rising Pond Dams and Transported to the Reach 5/6 Floodplain for Alternatives (relative to current conditions) and Solids Trapping Efficiency for Woods Pond

Location	SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Woods Pond Dam	37%	94%	97%	97%	98%	97%	62%	89%
Rising Pond Dam	41%	87%	93%	95%	96%	96%	62%	89%
Reach 5/6 Floodplain	50%	97%	98%	98%	99%	98%	68%	92%
Solids Trapping Efficiency in Woods Pond	15%	13%	15%	15%	15%	26%	24%	30%

The model results show that, relative to current conditions, the decrease in the mass of PCBs passing Woods Pond and Rising Pond Dams, respectively, ranges from 37% and 41% for SED 2 to 98% and 96% for SED 8. All alternatives that include some active remediation would achieve a decrease of at least 87% for all three compliance points, except for SED 10, which provides for PCB mass reductions in the 60 to 70% range.

Reduction in PCB mass transport in the river and transport to the floodplain is directly related to the amount of PCB-contaminated sediment that is removed and/or capped and the extent to which erosion from contaminated banks is decreased for each alternative. Accordingly, SED 2/FP 1 and SED 10/FP 9 do the least to control continuing releases. Although SED 8/FP 7 and SED 9/FP 8 do the most to control releases, SED 3/FP 3, SED 5/FP 4, SED 6/FP 4, and SED 9/FP 4 MOD also provide significant control of releases.

PCBs are attached to solids that move through the river system. Therefore, trapping of solids in Woods Pond is a mechanism to reduce downstream migration of PCBs. SED 9/FP 8, SED 9/FP 4 MOD, and SED 10/FP 9 nearly double the solids trapping efficiency of Woods Pond when compared to the other alternatives. These three alternatives also control sources of releases by removing a significant mass of PCBs from behind Woods Pond Dam. In the event of a

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[2] The initial (i.e., current) annual PCB mass values used in the model are 20 kilograms per year (kg/yr) passing Woods Pond Dam, 19 kg/yr passing Rising Pond Dam, and 12 kg/yr transported from the river to the floodplain in Reaches 5 and 6.

serious breach or failure of the dam, the release of PCBs downstream would be less for these alternatives than for the other alternatives that rely primarily on capping or MNR.

2.3.2 Releases Due to Extreme Flood Event

The different alternatives are expected to have different responses in an extreme flood event. SED 2/FP 1, which includes no active remediation, will result in the same amount of PCB-contaminated sediment and soil from eroding banks being released and mobilized downstream as would be the case under current conditions. SED 10/FP 9 is expected to result in similar, but slightly less, downstream transport because it specifies the remediation of only a small area in Reach 5A and the residual PCB-contaminated sediment in Woods Pond is not capped.

SED 3/FP 3 will result in slightly less transport than the previous alternatives; however, the use of a thin-layer cap in Reach 5C and Woods Pond, and MNR in Reach 5B, the backwaters, and Reach 7 impoundments is not expected to adequately control sources of releases in an extreme event. Alternatives SED 5/FP 4 and SED 6/FP 4 are expected to provide adequate protection in an extreme event in Reaches 5 and 6, but the use of thin-layer capping and backfill in the downstream reaches provides a high level of uncertainty in performance. Alternatives SED 8/FP 7 and SED 9/FP 8 are expected to provide the highest level of protection of all the alternatives because they include the greatest amount of remediation and engineering controls. SED 9/FP 4 MOD is expected to provide adequate protection in an extreme flood event in all reaches, with the exception of Reach 5B, from which PCB-contaminated bed sediment and bank soil may erode and be transported downstream. However, the areas of the highest concentrations in Reach 5B will be removed, and the remaining concentrations are low enough that the impacts are not expected to be unacceptable.

To assess the extent to which the sediment components of these alternatives would mitigate the potential effects of an extreme high-flow event that could cause buried sediment (deeper than the 15-centimeter (cm) zone of biogenic reworking) to be exposed, model predictions of erosion and reach-average PCB concentrations in surface sediment following an extreme high-flow event were compared. Although the model simulation predicts varying responses to high-flow events, including the extreme event (50- to 100-year flood) simulated in Year 26 of the projection, the results generally show that buried sediment containing PCBs would not be exposed to any significant extent during high-flow events under any remediation alternative. However, this conclusion has some uncertainty because survey transects, Acoustic Doppler Current Profiler measurements, and deep sediment cores collected in the river indicate that high-flow events have the potential to remobilize the sediment column to considerable depths that are not reflected in the two-dimensional averaged model grid cells. Therefore, the alternatives that include thin-layer capping or backfill are not likely to perform as well as the model predicts. Although thin-layer capping has been used successfully at other sites, site-specific conditions (e.g., higher PCB contamination levels and high river flows), have raised concerns about its suitability in Rest of River.

2.3.3 Releases Due to River Channel Meandering

The projected releases for SED2/FP 1 and SED 10/FP 9 have greater uncertainty because the model does not simulate changes in the planform of the river channel, which could result in large contributions of soil (and associated PCBs) from erosion into the floodplain over time. The results for the remaining alternatives are less uncertain than those associated with SED 2/FP 1 and SED 10/FP 9 because they include bank stabilization and operation, maintenance, and monitoring (OMM), both of which reduce the potential for large contributions of soil (and associated PCBs) from the banks and floodplain. SED 9/FP 4 MOD addresses all eroding contaminated banks in Reach 5A and targets only banks in Reach 5B that have PCB concentrations exceeding 50 mg/kg and specifies bioengineering techniques wherever possible.

2.3.4 Releases During Implementation

There are differences among the alternatives in terms of the potential for releases during implementation, including both resuspension-related releases during sediment removal as well as potential releases from open excavations in the floodplain during an extreme weather event. Although engineering controls and/or best management practices (BMPs) would be applied to minimize such releases, they could not entirely prevent such releases. The potential for such short-term releases would be a function of the duration of the remedy and the overall extent of open excavation/dredging areas. For alternatives involving active remediation, durations range from 5 to 52 years and areas of excavation and dredging range from 76 acres to over 700 acres. The effects of such releases are reflected in the model output.

2.4 COMPLIANCE WITH FEDERAL AND STATE ARARs

A summary of some of the more significant chemical-, location-, and action-specific ARARs applicable to the range of alternatives considered in this comparative analysis is presented in this section. A chart summarizing the determination of ARARs for SED 9/FP 4 MOD is provided in Attachment 13. Charts summarizing ARARs for other alternatives can be found in the RCMS.

2.4.1 Chemical-Specific ARARs

Chemical-specific ARARs include federal and state water quality criteria for PCBs (such as NRWQCs). These criteria consist of freshwater aquatic life and human health criteria (based on consumption of water and/or organisms).

Alternatives SED 2/FP 1 and SED 10/FP 9 would not achieve the federal and state water quality criteria for freshwater aquatic life in Massachusetts (but would in Connecticut). All other alternatives would achieve these criteria in all reaches of the river.

None of the alternatives would achieve the federal and state water quality criteria for consumption of organisms in any of the Massachusetts reaches, and the model indicates that the alternatives may not meet the criteria in all Connecticut reaches. However, alternatives SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, SED 9/FP 8, and SED 9/FP 4 MOD would likely restore water quality in significant segments of the river (greater than 50% of the impoundments) in Connecticut.

2.4.2 Location-Specific ARARs

All alternatives that include active remediation would involve temporary disturbance of wetlands and a discharge of dredged or fill material into waters of the state and/or the United States.

SED 9/ FP 4 MOD is the least damaging practicable alternative; it uses a less intrusive method of sediment remediation and balances the extent of remediation with avoidance, minimization, and mitigation in locations designated by the Commonwealth of Massachusetts as sensitive areas, as discussed below. See also EPA's Clean Water Act Section 404 Wetlands and Floodplain Analysis (Attachment 14).

The Massachusetts Endangered Species Act (MESA) is applicable to all alternatives except SED 2/FP 1. MESA and its regulations were promulgated to protect state-listed species and their habitats. Unacceptable levels of PCBs are present in such habitat areas in the Rest of River. During the implementation of the preferred alternative, the removal of PCBs from the Rest of River is anticipated to provide a benefit to state-listed species inhabiting the area due to the reduction in adverse effects to ecological receptors. In overseeing the response actions, EPA, in coordination with the Massachusetts Department of Fish and Game/Division of Fisheries and Wildlife (DFW), consistent with the requirements of MESA (Massachusetts General Laws (MGL) c. 131A) and its implementing regulations (321 Code of Massachusetts Regulations (CMR) 10.00; MESA), will guide efforts to avoid, minimize, and mitigate impacts to state-listed species.

Although a final MESA evaluation will not be completed until the remedy design phase, by focusing on the Core Areas (Attachment 4), EPA and the Commonwealth believe that a framework has been established to achieve MESA standards of assessing alternatives to both temporary and permanent impacts to state-listed species, and of limiting the impact to an insignificant portion of the local populations of affected species (see 321 CMR 10.23). For example, the parties focused on avoidance of some of the most important and sensitive rare species habitats in Core Area 1. Similarly, in Core Areas 2 and 3, minimization and mitigation efforts will be employed, including careful consideration of PCB remediation methods, the sequence and timing of remediation activities, and after-the-fact habitat mitigation. These approaches will assist in achieving the substantive requirements of MESA.

Although the Core Areas play an important role in guiding avoidance and minimization of impacts to state-listed species, in some cases the "take" of state-listed species may be unavoidable. In those cases, consistent with MESA's status as a location-specific ARAR, EPA will work with the Commonwealth to minimize impacts and to ensure that an adequate long-term net-benefit mitigation plan for the affected state-listed species is designed and implemented, as required by 321 CMR 10.23(2)(c).

2.4.3 Action-Specific ARARs

All alternatives meet action-specific ARARs; therefore, this criterion does not provide a basis for distinguishing among the alternatives.

2.5 LONG-TERM RELIABILITY AND EFFECTIVENESS

The assessment of long-term reliability and effectiveness for the alternatives included an evaluation of the magnitude of residual risk, the adequacy and reliability of the alternatives, and the potential long-term impacts on human health or the environment.

2.5.1 Magnitude of Residual Risk

The magnitude of residual risk for each of the alternatives is evaluated in this section considering the individual sediment and floodplain components separately, primarily because residual risks differ between the in-river and floodplain environments.

2.5.1.1 Potential Residual Risks Associated with River Sediment, Water, and Fish

SED 2/FP 1 would rely on natural processes to reduce PCB concentrations and would include monitoring the effectiveness of these processes. Implementation of the sediment component of the other alternatives would further reduce the potential for exposure to PCBs for humans and ecological receptors through various combinations of removal, capping, thin-layer capping, and/or natural recovery processes. The Housatonic River models were used to predict the extent to which each sediment alternative would reduce PCBs in surficial sediment, surface water, and fish tissue. For purposes of comparison, fish tissue PCB concentrations are presented here because fish tissue concentrations integrate the effects of changes in surface sediment and water column concentrations and, therefore, are representative of the relative effectiveness of each alternative in reducing the potential for PCB exposure. Figures 2 and 3 in Attachment 7 show the residual surface sediment concentrations and surface water concentrations.

Table 4 presents the subreach-average largemouth bass fillet[3] PCB concentrations at the start of the model projection period and at the end of the projection period[4], and shows the percent reduction in tissue PCB concentrations for each of the alternatives. These results are also presented graphically for Reaches 5 through 8 and for the Connecticut impoundments in Attachment 10.

Based on these comparisons, SED 2/FP 1 and SED 10/FP 9 provide the least long-term reductions in fish PCB concentrations. All of the remaining alternatives produce a reduction of approximately 99% in Reach 5A. For the other reaches, SED 3/FP 3 results in markedly less reduction in comparison to the more active alternatives (SED 5/FP 4 through SED 9/FP 4 MOD), which are effective in achieving large reductions in fish tissue PCB concentrations over all reaches of the river. The sole exception is Reach 5B for the SED 9/FP 4 MOD alternative. This alternative would reduce the bioavailability of PCBs in the sediment with an amendment such as activated carbon. The Housatonic River model, upon which these results are based, is not able to simulate this process and therefore, fish tissue concentrations are likely overestimated in Reach 5B. The resulting reduction in concentrations from the amendment is expected to be greater than model predictions, although the extent of these reductions cannot be quantified.

Although some level of fish consumption advisory would need to be maintained at the conclusion of remediation for many of the alternatives, an additional measure of long-term reliability and effectiveness that can be used to distinguish among the alternatives is the time required to achieve a certain IMPG.

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[3] The fillet concentrations are derived by dividing the whole-body tissue concentrations output from the food-chain model by a factor of 5.

[4] The simulation period is 52 years for all alternatives except SED 8/FP 7, which is 81 years due to the longer construction time for SED 8/FP 7 and the requirement for 30-year projections post-remediation.

Table 4 Modeled Subreach Average Fish (Fillet) PCB Concentrations at End of Project Modeling Period and Percent Reductions for Alternatives

Reach	Initial Conc.	SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Fish PCB Concentration (mg/kg wet weight)									
Reach 5A	*18*	7.3	0.3	0.3	0.3	0.2	0.3	4.2	0.3
Reach 5B	*17*	9.3	3.0	0.2	0.2	0.2	0.3	6.6	3.5
Reach 5C	*14*	7.4	1.8	0.2	0.2	0.1	0.2	5.8	0.8
Reach 5D (Backwaters)	*22*	9.5	6.3	0.4	0.4	0.3	0.4	11	1.1
Reach 6	*15*	8.6	0.7	0.2	0.2	0.1	0.2	3.7	0.7
Reach 7	*6.4 -13*	2.8 - 6.4	0.7 - 2.1	0.4 - 1.6	0.2 - 0.7	0.1 - 0.6	0.2 - 0.7	1.9 - 4.4	0.4 - 1.4
Reach 8	*6.3*	3.6	1.6	0.3	0.2	0.2	0.2	2.7	0.4
Connecticut (Bulls Bridge Dam Impoundment)	*0.4*	0.2	0.04	0.01	0.009	0.007	0.009	0.1	0.02
Percent Reduction in Fish PCB Concentration Relative to Initial Conditions									
Reach 5A		60%	99%	99%	99%	99%	98%	77%	99%
Reach 5B		47%	83%	99%	99%	99%	98%	62%	80%
Reach 5C		48%	87%	99%	99%	99%	99%	59%	94%
Reach 5D (Backwaters)		57%	72%	98%	98%	99%	98%	51%	95%
Reach 6		44%	95%	99%	99%	99%	99%	76%	95%
Reach 7		45 - 63%	80 - 91%	84 - 97%	94 - 98%	94 - 99%	93 - 98%	59 - 75%	86 - 95%
Reach 8		43%	75%	95%	97%	97%	96%	57%	94%
Connecticut (Bulls Bridge Dam Impoundment)		60%	91%	97%	98%	98%	98%	73%	95%
Percent Reduction in Fish PCB Concentration Relative to SED 2 (MNR)									
Reach 5A			96%	96%	96%	97%	96%	42%	96%
Reach 5B			68%	98%	98%	98%	97%	29%	61%
Reach 5C			76%	97%	97%	99%	97%	22%	89%
Reach 5D (Backwaters)			34%	96%	96%	97%	96%	-16%	89%
Reach 6			92%	98%	98%	99%	98%	57%	91%
Reach 7			67 - 75%	75 - 86%	89 - 93%	91 - 96%	89 - 93%	31 - 32%	75 - 88%
Reach 8			56%	92%	94%	94%	94%	25%	87%
Connecticut (Bulls Bridge Dam Impoundment)			80%	95%	96%	97%	96%	50%	81%

Notes:

1. PCB concentrations shown (except for the initial concentrations) represent subreach-average values predicted by EPA's model at the end of the model projection period (52 years for SEDs 2, 3, 5, 6, 9, and 10, and 81 years for SED 8).
2. For SED 9/FP 4 MOD, the Reach 5B PCB concentrations do not factor in the use of an amendment, such as activated carbon. The use of this amendment is expected to reduce fillet PCB concentrations to less than the 3.5 mg/kg predicted by the modeling; the modeling does not factor in the effects of the amendment.
3. Values shown as ranges in Reach 7 represent the range of modeled PCB concentrations at the end of the projection within each of the Reach 7 subreaches.
4. The results from the Connecticut model are very uncertain due to the empirical, semi-quantitative nature of the analysis.
5. Percent reduction represents the change in annual average PCB concentrations predicted by EPA's model between the beginning and the end of the projection period.
6. Reach 7 reductions were calculated separately by subreach. Individual subreach initial and SED 2 concentrations were not provided by GE in the CMS, so reductions shown for SED 9/FP 4 MOD were calculated from EPA model results.

Plots of fish tissue concentrations by reach in Attachment 10 (average fillet PCB concentrations) show that although SED 10/FP 9 would have the shortest implementation schedule and would achieve some reductions quickly relative to other removal alternatives, SED 9/FP 8 has improved performance relative to all other alternatives, balancing the magnitude of the reductions with the time required to achieve them.

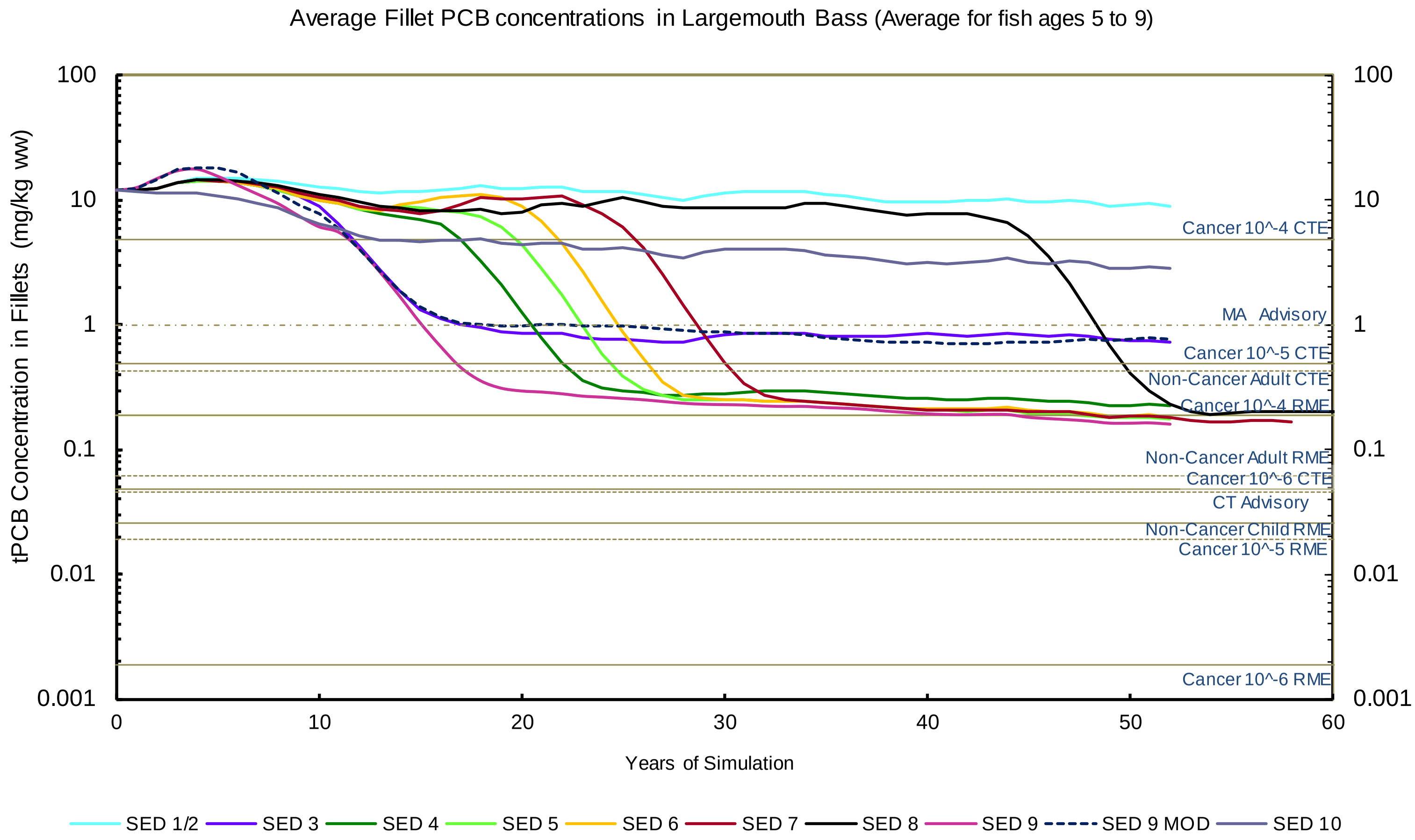
For example, in Reach 6 (Woods Pond) (see Figure 1), reduction in fillet tissue PCB concentrations corresponding to the CTE $1x10^{-5}$ cancer risk would not be achieved by SED 2/FP 1 and SED 10/FP 9 during the 52-year simulation period and, based on the trajectories, for many years thereafter. SED 3/FP 3 and SED 9/FP 4 MOD similarly do not achieve the CTE $1x10^{-5}$ cancer risk concentration during the simulation period but have significantly better performance than SED 2/FP 1 and SED 10/FP 9, achieving the Massachusetts consumption advisory concentration and a trajectory that will reach the CTE $1x10^{-5}$ cancer risk concentration many decades earlier than SED 2/FP 1 and SED 10/FP 9.

SED 9/FP 8 achieves significant reductions in a shorter period of time than comparable alternatives. SED 5/FP 4 and SED 6/FP 4 achieve significant reductions in a time period greater than SED 9/FP 8, but sooner than SED 8/FP 7. SED 8/FP 7, while achieving the largest overall reductions, has a long implementation period, such that the time to achieve risk reduction is extended beyond that of other alternatives.

Because SED 10/FP 9 specifies only partial remediation in Reach 5A, allowing unremediated sediment to remain exposed in that reach, and does not include remediation in the other reaches upstream of Woods Pond, potential recontamination of the remediated areas due to transport of PCBs from unremediated areas is a concern for this alternative.

2.5.1.2 Potential Residual Risks Associated with Floodplain Soil

Under SED 2/FP 1, floodplain soil PCB concentrations, as well as any potential risks, will remain generally similar to current conditions. Implementation of the floodplain component of the other alternatives (FP 3, FP 4, FP 4 MOD, FP 7, FP 8, and FP 9) would reduce the potential risks to humans and ecological receptors from exposure to PCBs in the floodplain by removing PCB-contaminated soil and backfilling those excavations with clean material. The reduction in potential exposure and associated risks would occur upon completion of remediation in a given area. As the removal volume and area affected among the alternatives increase, the reduction in exposure also increases. Among the alternatives evaluated, SED 8/FP 7 would provide the greatest reduction in potential exposures, removing the largest volume of PCB-contaminated soil over the greatest area of the floodplain (377 acres), and over the longest period (52 years) (see Table 5).



Notes: Average calculated for days from Aug. 28th through Oct. 26th of each year; average calculated for fish ages 5 to 9.
Fillet- based concentrations were calculated as whole body concentrations divided by 5.0.
Horizontal lines represent fish consumption (deterministic) IMPGs.
(Figures for other reaches are presented at the end of Attachment 10.)

Figure 1 Average Fillet PCB Concentrations in Largemouth Bass from Reach 6

Table 5 Summary of Percent of Floodplain and Sediment Exposure Areas Achieving IMPGs for Direct Human Contact

Exposure Assumptions	Risk Level	Percent of 128 Floodplain and Sediment Exposure Areas Achieving IMPGs							
		SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
RME	Cancer 1x10^{-4}	100	100	100	100	100	100	100	100
	Cancer 1x10^{-5}	56	71	100	100	100	100	61	71-100
	Cancer 1x10^{-6}	7	9	13	14	100	15	7	9-13
	Non-Cancer	81	100	100	100	100	100	100	100
CTE	Cancer 1x10^{-4}	100	100	100	100	100	100	100	100
	Cancer 1x10^{-5}	100	100	100	100	100	100	100	100
	Cancer 1x10^{-6}	88	98	99	99	100	99	97	98-99
	Non-Cancer	99	100	100	100	100	100	100	100
		Percent of 12 Floodplain Frequently Used Subareas Achieving IMPGs							
RME	Cancer 1x10^{-4}	92	100	100	100	100	100	100	100
	Cancer 1x10^{-5}	42	100	100	100	100	100	67	100
	Cancer 1x10^{-6}	17	42	42	42	100	42	17	42
	Non-Cancer	58	100	100	100	100	100	100	100
CTE	Cancer 1x10^{-4}	100	100	100	100	100	100	100	100
	Cancer 1x10^{-5}	92	100	100	100	100	100	100	100
	Cancer 1x10^{-6}	67	100	100	100	100	100	92	100
	Non-Cancer	67	100	100	100	100	100	100	100

Because different areas of the floodplain are used by human and ecological receptors in different ways and with varying degrees of frequency and intensity, the extent to which each of the alternatives evaluated in this section would reduce potential residual risks from PCB exposure in the floodplain has been evaluated in terms of the extent to which they would achieve the IMPGs. The comparative evaluation of the alternatives based on achievement of IMPGs is presented in Section 2.6. An evaluation of the achievement of the IMPGs and the time relative to no action is provided in Section 2.6.3.

For all alternatives specifying removal of floodplain soil, PCBs will remain in soil below the depths designated for removal (1 foot except in the frequently used subareas where the removal is to 3 feet). Exposure to this deeper soil is not anticipated under current uses. In the event that future exposure to such deeper soil may be reasonably anticipated in particular areas, it would be addressed, under all alternatives except SED 2/FP 1, by ICs. Additionally, under those alternatives, ICs would be implemented where necessary to address potential risks from reasonably anticipated future uses.

2.5.2 Adequacy and Reliability

2.5.2.1 Use of Technologies Under Similar Conditions

SED 1/FP 1 is the no action alternative, and SED 2/FP 1 involves MNR with ICs in the river and no action in the floodplain. MNR has been selected at other contaminated sediment sites as part of the overall remedy, and no action has been adopted as a remedy component at other sites. The other seven alternatives involve different combinations of remedial technologies and processes.

For the sediment alternatives, the selected approaches include removal in the dry and/or wet (followed by capping or backfilling in most cases), capping without prior removal, thin-layer capping, riverbank stabilization (using a combination of bioengineering and hard stabilization techniques), and MNR. All of the remedial technologies included in the sediment alternatives under evaluation have been used at other sites.

The floodplain components of the alternatives involving remediation would rely primarily on removing floodplain soil from areas of various types of habitats and backfilling the excavations, and implementation of ICs. These technologies and combinations of technologies have been implemented at other sites. (Restoration is discussed in the following subsection.)

2.5.2.2 General Reliability and Effectiveness

The alternatives under evaluation generally use technologies that have been shown to be reliable and effective at other sites. However, as noted in Section 13 of the June 2011 Site Information Package, thin-layer capping is not expected to be a reliable or effective component for this site, and backfill may not be suitable for reaches with higher bed shear stresses.

For all of the active alternatives except SED 9/FP 4 MOD and SED 10/FP 9, eroding riverbanks in Reach 5A would be stabilized using a combination of bioengineering and, if necessary, hard engineering technologies. SED 9/FP 4 MOD would be designed to target specifically sections of riverbank that are highly erodible and also contain elevated concentrations of PCBs in Reach 5A and riverbank soils with PCB concentrations greater than 50 mg/kg in Reach 5B. The stabilization techniques would be similar for all of the alternatives, and are expected to be reliable and effective in stabilizing the banks and controlling erosion. Any potential for long-term impacts would be mitigated through proper construction, and OMM practices. Natural channel design concepts would be used, where practical, to ensure that bank stabilization does not accelerate erosion in other areas, and would not result in ecological impacts.

Any areas remediated would require subsequent restoration to reestablish habitat functions and values. Remediation and restoration would progress incrementally from upstream to downstream, affecting small stretches of the river and floodplain at any given time. OMM programs, including invasive species control, would ensure proper reestablishment of vegetation for a period of time following remediation. There is a significant body of knowledge with respect to ecosystem restoration that documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats (see Appendix D of the 2011 Site Information Package). Accordingly, restoration is expected to be fully effective and reliable in returning these habitats, including vernal pool habitat, to their pre-remediation state. As a result, the likelihood of effective restoration is equal under any of the alternatives.

2.5.2.3 Reliability of Operation, Maintenance and Monitoring Requirements and Technical Component Replacement Requirements

All alternatives would incorporate reliable long-term maintenance and/or monitoring following remediation. For example, all sediment alternatives would include inspection and repair or replacement of any caps or bank stabilization measures. In general, the extent of such maintenance and monitoring programs would increase as the extent of capping and bank stabilization increases for the various alternatives (i.e., progressively more from SED 10/FP 9 to SED 9/FP 8).

Similarly, the backfilled/restored areas of the floodplain would be monitored through periodic inspections to verify that planted vegetation is surviving and growing, and to identify areas where the backfill may be eroding or in need of repair. This is a reliable means of assessing the need for maintenance and would be similar for all alternatives except that the alternatives involving more extensive remediation in the floodplain will necessarily require more extensive maintenance and monitoring, which could be difficult to implement in certain areas of the floodplain due to remoteness, the extent of standing water, and the extent of vegetation. Depending on the timing, location, and scale of any repairs, temporary access roads and staging areas may need to be constructed in the floodplain. These difficulties can be overcome to a great extent through proper planning, selection of experienced contractors, and effective oversight of activities.

2.5.3 Potential Long-Term Impacts on Human Health and the Environment

The evaluation of potential long-term impacts on human health or the environment includes evaluation of potentially affected populations, long-term impacts on the various habitats that would be affected by the remedial alternatives, and the biota that inhabit those habitats (including impacts on state-listed species), impacts on the aesthetics and recreational use of the river and floodplain, impacts on banks and bed load movement (i.e., fluvial geomorphic processes), and potentially available measures that may be employed to mitigate these impacts. The long-term impacts of exposure to PCBs left in place are not evaluated in this section.

2.5.3.1 Potentially Affected Populations

Implementation of all of the alternatives except SED 2/FP 1 (which would not involve remedial construction activities) would result in some short- and long-term impacts on floodplain habitats, with the impacts occurring over longer periods of time as the alternatives become more comprehensive and the duration for implementation increases. For all alternatives, however, implementation of remediation would generally proceed from upstream to downstream, affecting short stretches of the river and associated floodplain at any given time. In the case of SED 9/FP 4 MOD, impacts to habitats supporting state-listed species would be limited due to the design of the alternative, which includes specific protocols for addressing Core Areas. The long-term impacts of the alternatives on the affected habitats and the plants and animals that inhabit or use those habitats, as well as the long-term impacts on the aesthetics and recreational use of the affected habitats by people, are discussed and compared below.

2.5.3.2 Long-Term Impacts on Habitats and Biota

The extent and severity of long-term impacts from remedial construction activities are dependent on the types of habitat affected, the size of the affected areas, the success of the restoration approach(es), and the length of time needed for restoration. Table 6, from GE's RCMS, identifies the habitat types and summarizes the areas of each habitat affected by the alternatives.[5] As discussed above, long-term impacts would be mitigated through proper restoration measures. Because restoration of affected habitats is dependent on several factors and processes, the length of time necessary to restore a habitat is variable.

<u>Aquatic Riverine Habitat</u>: The potential post-restoration impacts of sediment removal/capping, as well as capping or thin-layer capping without removal, on aquatic riverine habitat include the following:

- The caps would change the surficial substrate type from its current condition (sand, sand and gravel, or silt) to armor stone, lasting until deposition of natural sediment from upstream changes the surficial sediment back to a condition similar to its prior condition. To the extent that a habitat layer is specified as the part of any cap in the final design, this impact would be reduced or eliminated.
- There may be a temporary loss of woody debris and shade in Reaches 5A and 5B depending on the removal areas, bank stabilization techniques, and restoration techniques. These changes could alter the riverine habitat because woody debris provides structure that is important to many aquatic and semi-aquatic species, and shade limits the temperature increases in the river water. The reintroduction of woody debris and replanting of trees would be a component of the restoration plan.
- Sediment removal and/or capping would remove or bury the existing aquatic vegetation and benthic invertebrates, and temporarily displace the fish. Recolonization would occur, and the vegetation and invertebrates that would recolonize these areas are not expected to differ substantially from the pre-existing species if a habitat layer is included in the cap design. In addition, after the removal of the negative effect of PCBs on the benthic community, it is expected that overall improvements to the community would be realized.
- There is the potential that the disturbed areas could be colonized by invasive species. This impact may be mitigated via active control of invasive species.
- For alternatives that specify capping without excavation or require thin-layer capping, the increase in substrate elevation due to the cap could change the hydrodynamics and vegetative characteristics of the areas and the biota dependent on them.

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[5] EPA does not believe that the infrastructure included in these estimates provided by GE has been optimized and expects that, for the selected remedy, the staging areas and roads will be designed to minimize the footprint and adverse impacts to the floodplain, neighborhoods, and local roads while allowing the remediation to proceed in a timely and effective manner.

Table 6 Habitat Areas in Primary Study Area Affected by Alternatives[a]

Habitat	SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Aquatic Riverine Habitat (acres)	-	79	127	127	127	127	20	99
Riverbank (linear miles)	--	14	14	14	14	14	1.6	3.5
Impoundment Habitat (acres)	--	60	101	139	139	139	42	139
Backwater (acres)	--	0	61	70	86	66	0	59
Floodplain Wetland Forest (acres)	-	38	60	60	178	56	14	TBD[d]
Shrub and Shallow Emergent Wetlands (acres)	-	19	22	22	70	31	3.7	TBD[d]
Deep Marshes (acres)	-	1.9	0.3	0.3	4.7	3.1	0	TBD[d]
Vernal Pools (acres) [b]	-	15 (58)	15 (58)	15 (58)	17 (61)	18 (61)	0	TBD[d]
Disturbed Upland Habitats (acres)	-	14	15	15	25	11	7.5	TBD[d]
Upland Forested Habitats (acres)	-	4.2	4.9	4.6	6.4	2.8	0.7	TBD[d]
Total (acres)[c]	--	231	406	453	653	454	88	343

[a] Includes habitat areas within the boundaries of the Woodlot (2002) natural community mapping; includes remediation areas as well as areas impacted by access roads and staging areas.

[b] Number of vernal pools affected is shown in parentheses.

[c] Total habitat area affected does not include riverbanks, and can differ from total surface area affected since the total shown includes all habitats within the boundaries of the Woodlot (2002) mapping (see note a).

[d] EPA estimates that the total area of floodplain to be affected equals 45 acres. Specific locations and habitat types are to be determined based on habitats and occurrences of state-listed species as defined by the Core Areas. These estimates do not include supporting infrastructure.

In summary, in the aquatic riverine habitat, impacts due to remediation will be temporary. It is expected that over time the physical substrate type in the river would approximate its prior condition, and a biotic community consistent with that substrate type would become reestablished. The inclusion of a habitat layer in any cap design and implementation of an appropriate restoration plan is expected to accelerate the recovery of the aquatic biota. For all alternatives, areas either upstream or downstream of the immediate remediation at any given time would act as sources of and refuge for aquatic species both during and after remediation of an area is completed.

<u>Riverbank Habitat</u>: The potential impacts of bank stabilization on riverbank habitat include the following:

- The implementation of stabilization measures that eliminate vertical and/or undercut banks would result in a loss of habitat for birds and other animals that depend on such banks (e.g., kingfisher, bank swallow, and the state-listed wood turtle). However, proven techniques are available to provide adequate bank stabilization with minimal loss of this type of habitat.
- The removal of any mature trees overhanging the river as part of bank stabilization/remediation would result in a temporary change in the vegetative character of the banks. Although this impact may be mitigated to some extent by

planting of trees following remediation, it is not practical to replant large trees that are currently found along the banks. However, in the long term, normal growth will result in mature trees that overhang the river and essentially restore the vegetative character to its preremediation conditions.

- The use of bank stabilization measures could potentially result in a temporary reduction in slides and burrows of muskrat and beaver, and could potentially also reduce access routes and movement of reptiles, amphibians, and smaller and less mobile mammals between the river and wetland habitats. These potential impacts can be taken into account and mitigated in the design of bank stabilization.
- Any colonization by invasive plant species would require active control measures.

As a result of these potential impacts, stabilized riverbanks would not immediately return to their current condition or level of function; however, over time they are expected to do so. Because all of the alternatives except SED 2/FP 1 would involve stabilization of the eroding banks in Reaches 5A and/or 5B, temporary impacts along those banks would result from any alternative specifying active remediation. SED 10/FP 9 would involve remediation and stabilization of only a small portion of the banks in Reaches 5A and 5B, totaling approximately 1.6 linear miles. SED 9/FP 4 MOD would limit removal/stabilization of banks in Reach 5A to only those areas with both moderate-high or greater erosion potential and PCB concentrations greater than 5 mg/kg based on sampling to be performed during remedial design. SED 9/FP 4 MOD also would specify a decision-tree approach to bank stabilization with soft restoration techniques favored over hard armoring. For SED 9/FP 4 MOD, in Reach 5B, only a very small percentage of riverbanks will be affected because only those areas with soil PCB concentrations greater than 50 mg/kg would be remediated. Actual bank removal amounts will be determined during the design and implementation of the remedy. Based on existing data, SED 9/FP 4 MOD would entail disturbance of approximately 3.5 linear miles of Reach 5A riverbank and less than 0.2 linear miles of Reach 5B riverbank.

<u>Impoundment Habitat</u>: The potential impacts from removal and/or capping or thin-layer capping on the habitat of impoundments are similar to the impacts on aquatic riverine habitat discussed above. In general, they would include a temporary or longer-term change in the surface substrate, and an alteration in the biological community in the affected impoundment. It is anticipated that as sand and organic sediment from upstream are deposited over time, a biological community typical of such impoundments would reestablish itself. The alternatives that involve capping or thin-layer capping without removal in the impoundments would change the bottom elevation, potentially changing the vegetative characteristics, and the biota dependent on them, in the shallow portions of the impoundments. By contrast, the placement of a cap or a thin-layer cap in deeper areas of the impoundments, including the “deep hole” portion of Woods Pond, is not expected to have any significant long-term ecological impacts. The inclusion of a habitat layer in a cap would accelerate the recovery. The amount of acreage affected in each alternative is summarized in Table 6.

Backwater Habitat: The potential impacts of thin-layer capping or sediment removal/capping in backwaters include the following:

- Change in surficial substrate from organic silty material to sand, which would continue until enough silt and organic material have been deposited to approximate prior conditions.
- Change in vegetative characteristics corresponding to the change in substrate type and elevation (including, in shallower areas where the thin-layer cap exceeds the depth of water, a potential change from emergent wetlands vegetation to species more tolerant of less frequently inundated or drier conditions).
- Change in the wildlife communities using the backwaters until such time as the soil, hydrological, and vegetative conditions of the backwaters return to conditions comparable to preremediation conditions.

The area disturbed in each alternative is summarized in Table 6. All of the alternatives (except SED 2/FP 1) would have the potential impacts described above, which would be mitigated through the inclusion of a habitat layer and using proper restoration techniques.

Floodplain Wetland Forest Habitat: The potential post-restoration impacts of floodplain soil removal, as well as the construction of access roads and staging areas, on floodplain wetland forest habitat include the following:

- The removal of mature trees from the forested floodplain areas subject to soil removal or the construction of access roads and staging areas would result in a loss of mature forested habitat in those areas. Following replanting, the plant community succession in these areas would progress as a maturing forest for a period of years.
- Tree removal would cause a temporary loss of the coarse woody debris that is used as structural wildlife habitat and, for a short period of time, the annual leaf litter that provides habitat for numerous woodland species.
- There would be a temporary relocation or loss of the forest wildlife species that currently use the mature forested habitats that would be removed, and the return of those species, including sensitive species, would be encouraged through proper restoration that reestablishes the functions of the ecosystem.

The area impacted by each alternative is summarized in Table 6.

Shrub and Shallow Emergent Wetlands and Deep Marshes: The potential post-restoration impacts of floodplain soil removal include:

- Changes in soil composition and chemistry due to the replacement of existing wetland soil.
- Changes in the hydrology of these wetlands due to impacts on the swales, drainage features, and microtopography that influence the hydrology.
- Changes in vegetative characteristics due to the changes in soil and hydrological conditions.

These potential impacts would be mitigated through proper restoration to ensure that soil and hydrological conditions similar to preremediation conditions are reestablished. Table 5 shows the area impacted by each alternative.

<u>Vernal Pools and Surrounding Habitat</u>: The potential impacts of floodplain soil removal and associated facilities on vernal pools and the surrounding non-breeding habitat for vernal pool amphibians, include the following:

- The excavation and replacement of the surface soil and vegetation within and around vernal pools could potentially change the sediment types and stratigraphy, microtopography, and foliage cover of these pools, as well as the surface flow patterns into and out of the pools. These changes could alter the hydrology of the pools. However, these impacts would be mitigated by proper restoration techniques.

- There is also the potential for temporary changes in the vegetative characteristics of vernal pools because the vegetative composition (living and dead) of these pools would take some time to become reestablished following remediation. In addition, mature trees around the periphery of the pools, if removed, would take time to become reestablished.

- Changes in soil composition in the vernal pools are possible; however, replacement soil would be selected to match as closely as possible the characteristics of the existing vernal pool soil.

- Habitats immediately adjacent to vernal pools are important for maintaining water quality and providing shade and vegetative litter for the pool. The proximate non-breeding terrestrial habitats, with features such as coarse woody debris and the burrows of small mammals, provide a variety of protective cover, temperature and moisture regulation, and overwintering habitat functions for vernal pool amphibians. Any impacts to these adjacent areas will be restored using supplemental plantings to reestablish the native plant community and habitat.

- Implementation of effective restoration techniques would reestablish vernal pool functions that would allow sensitive vernal pool species (including wood frogs, spotted salamanders, and the state-listed Jefferson salamander) to return to the vernal pools following completion of remediation.

The area affected by each alternative is listed in Table 6. Due to the iterative decision-tree approach to vernal pools included in SED 9/FP 4 MOD, it is not possible to calculate comparable acreage for that alternative. The floodplain component of SED 9/FP 4 MOD would specifically recognize Core Area habitats and/or known occurrences of state-listed species and thus would have more limited impacts on these resources than the other alternatives specifying remediation in the floodplain.

<u>Upland Habitats</u>: Most of the affected upland areas consist of disturbed upland habitats, which include agricultural fields and cultural grasslands. Because these areas support altered or early successional plant communities that have limited ecological value, no long-term impacts would be expected from the remediation in these areas under any of the remedial alternatives.

Where the remediation or supporting activities would affect upland forested habitats, they would have similar potential impacts as discussed for floodplain forests. As shown in Table 6, except for SED 2/FP 1, all of the sediment and floodplain alternatives would have some, although relatively limited, impacts on these habitats.

2.5.3.3 Long-Term Impacts on State-Listed Species

All of the alternatives, except SED 2/FP 1, would affect the priority habitats of some state-listed species of concern regulated under MESA. GE conducted an evaluation for each potentially affected state-listed species to assess whether each of the remedial alternatives would result in a "take" of that species under MESA and, where there would be a take, to assess whether the alternative would impact a significant portion of the local population(s) of the species.

The SED 9/FP 4 MOD alternative differs from the other alternatives in providing more specificity about the options for avoiding, minimizing, or mitigating impacts to state-listed species. As part of their Priority Habitat mapping process, taxonomic experts from DFW's Natural Heritage and Endangered Species Program (NHESP) routinely delineate habitat for each state-listed species based on field-documented records or "occurrences." NHESP has outlined four types of Housatonic Core Areas for this project (see Attachment 4). Core Areas 1, 2, and 3 represent subsets of the delineated state-listed species habitat found in the Primary Study Area (PSA). Core Area 4 represents a subset of the documented and potential vernal pool habitat in the PSA. Although an estimate for the number of species affected cannot be summarized in a manner similar to that of other alternatives, the SED 9/FP 4 MOD approach will target cleanup depending on the location of these Core Areas.

The effect of the additional flexibility incorporated into SED 9/FP 4 MOD can best be demonstrated by a comparison with the SED 5/FP 4 alternative, which has the same specifications for floodplain remediation without the consideration of Core Areas. For SED 5/FP 4, there are an estimated 57.8 acres of floodplain soil (excluding vernal pools) that would require remediation to address the direct contact pathway. The overlap of these 57.8 acres with Core Areas 1 through 3 is shown in Table 7.

Table 7 Overlap of the 57.8 Acres of Floodplain Soil Requiring Remediation under FP 4 with Core Areas 1 through 3

Total Acreage	Overlap Only with Core Area 1	Overlap with Core Area 3 (Excluding Core Area 1)	Overlap with Core Area 2 (Excluding Core Areas 1 and 3)	No Overlap with Core Areas 1, 2, and 3
57.8 acres	11.6 acres	13 acres	17 acres	16.2 acres

SED 5/FP 4 specifies the extent of remediation needed to achieve a PCB concentration corresponding to a risk level of $1x10^{-5}$ or an HI of 1, whichever is lower, regardless of the presence of Core Areas. In SED 9/FP 4 MOD, however, remediation may be reduced or minimized in certain Core Areas, provided that the residual concentration will meet a risk level of $1x10^{-4}$ or an HI of 1, whichever is more stringent. A procedure to address Core Areas was included in the Draft Modification to the RCRA Permit to be released in June 2014. Based on that procedure, the area to be remediated in SED 9/FP 4 MOD was estimated to be reduced by approximately 11 acres if Core Area 1 habitats were not remediated. A reduction of remediation in 20% of the overlap of Core Areas 2 and 3, along with mitigation/restoration for remediation in these areas, could reduce the area to be remediated by an additional 6 acres, thus reducing the total estimated acreage of floodplain remediation to approximately 40 acres under SED 9/FP 4 MOD.

Based on the iterative approach for vernal pools called for in SED 9/FP 4 MOD, 5 acres of vernal pool are estimated to require active remediation as part of the initial set of pools. Thus, the total acreage of floodplain excavation for SED 9/FP 4 MOD, including vernal pools, is estimated to be approximately 45 acres. Remediation of additional vernal pools may occur, based on the adaptive management approach described above. Therefore, this approach is expected to have less of a long-term impact on state-listed species than other alternatives such as SED 5/FP 4.

2.5.3.4 Long-Term Impacts on Aesthetics and Recreational Use

All alternatives, except SED 2/FP 1, would have some short-term impacts on the aesthetic features of the Rest of River. Floodplain soil excavation, as well as the construction of access roads and staging areas necessary to support sediment and soil removal, would require removal of trees and vegetation, which would detract from the natural appearance of those areas until restoration plantings have matured. The various alternatives would have impacts on aesthetics corresponding to the amount of area remediated (see Table 6) and the duration of the implementation of the remedy. Similarly, all of the alternatives, except SED 2/FP 1, would disrupt, to some extent, recreational use of the river and floodplain during the remediation period. These affected uses include canoeing, fishing, waterfowl and other game hunting, hiking, dirt biking, and general recreation. However, because remediation would proceed incrementally from upstream to downstream, these impacts would affect small areas at a given time. It is expected that any alternative will include a component to manage and maintain public recreational opportunities safely during remediation.

None of the alternatives is expected to have long-term impacts on aesthetics or recreational use. In addition, the preference for the use of bioengineering or “soft” restoration techniques on riverbanks in SED 9/FP 4 MOD is expected to produce a more aesthetically pleasing method of bank stabilization over other alternatives that could rely more heavily on the use of riprap or other armoring methods.

2.5.3.5 Long-Term Impacts on Fluvial Geomorphic Processes

Bank stabilization activities, which are intended to prevent bank erosion and channel migration from exposing new areas of PCB-contaminated soil, would minimize the current processes of bank erosion and lateral channel migration. As discussed in Attachment 1, the river was altered substantially by human activities over the past centuries. These alterations have resulted in an unstable river channel, which is acting to regain a state of dynamic equilibrium that includes changes in the planform of the river channel. All of the alternatives involving active remediation, except SED 10/FP 9 and SED 9/FP 4 MOD, would rely on stabilization of eroding riverbanks in Reach 5A and in Reach 5B. In SED 10/FP 9 and SED 9/FP 4 MOD, only select areas of the banks are proposed for stabilization. During remedial design, natural channel design techniques could be implemented to reduce the instability of the river channel and banks. Natural channel design, coupled with bank stabilization and restoration techniques, would provide for a mix of riverbank types, including vertical and undercut banks, and less near-bank sheer stress.

The stabilization of the banks, as well as the capping of the riverbed, would reduce the supply of sediment to the river from these sources. This reduction could affect in-river processes such as sediment transport (as bed load or suspended load), point bar development, and changes in channel dimension (i.e., width and/or depth), as determined by sediment deposition/erosion patterns. Based on geomorphological considerations and modeling results, the reduction in sediment load associated with riverbank stabilization and riverbed armoring under any of the alternatives would not be expected to result in a large-scale, long-term impact on these river morphologic processes or on in-river hydrologic characteristics such as water depth and current velocity.

2.5.3.6 Potential Measures to Mitigate Long-Term Impacts

For all of the alternatives that involve active remediation, a variety of restoration measures are available to mitigate long-term impacts resulting from their implementation. As summarized above, these methods, when implemented properly, will reestablish functions and values and minimize the potential for long-term negative impacts from the remediation.

2.6 ATTAINMENT OF IMPGs

In the assessment of IMPG attainment for the alternatives, the post-remediation average PCB concentrations in an exposure area, as defined in the Human Health Risk Assessment (WESTON, 2005), were compared to the relevant IMPGs for both the sediment and floodplain components. In addition, the whole-body fish tissue PCB concentrations predicted by the model (or estimated by the Connecticut 1-D analysis) at the end of the model projection period were converted to fillet concentrations and compared to the fish consumption IMPGs (Attachment 10).

For ecological receptors, the modeled sediment or prey tissue concentrations at the end of the projection period, and/or the estimated floodplain soil concentrations for the appropriate averaging areas, were compared to the relevant IMPGs. For insectivorous birds and piscivorous mammals, these comparisons used procedures that consider both the sediment and the floodplain components of the alternatives.

This comparative analysis focused on a comparison of the total number of averaging areas with predicted PCB concentrations that achieve the applicable IMPG(s). In addition, for the sediment component of each alternative, as required by the Permit, the time that it would take to achieve the IMPGs was estimated. For the floodplain component of each alternative, the timeframe to achieve IMPGs is assumed to be the same as that required to complete the remediation in a particular area (i.e., the reduction in soil concentrations would occur upon completion of backfill placement). IMPG attainment for each of these human exposure pathways and ecological receptor groups is described in the following subsections.

2.6.1 Comparison to Human Health IMPGs

2.6.1.1 Human Direct Contact with Floodplain Soil and Sediment

For all of the alternatives under evaluation, a detailed comparison of human direct contact IMPG attainment (RME and CTE IMPGs, respectively[6]) for the floodplain soil and sediment exposure areas (EAs) was conducted and is summarized in Table 5, taken from GE's RCMS. These comparisons indicate the following regarding IMPG attainment in the floodplain and sediment EAs:

Floodplain Direct Contact EAs: The floodplain components of the alternatives, with the exception of SED 2/FP 1, were by design established to achieve designated risk levels for the RME cancer risk or HI of 1. For direct contact with floodplain soil, the floodplain soil PCB concentrations under SED 2/FP 1 (which were assumed to be the same as current levels) are within or below the range of the RME and CTE IMPGs associated with the cancer risk of $1x10^{-4}$ in all 120 floodplain EAs. However, the PCB concentrations exceed the non-cancer-based RME IMPG (HI = 1) in 24 of the EAs. Furthermore, 5 of the 12 frequently used subareas do not achieve the non-cancer RME IMPG (and one does not achieve the RME IMPG associated with a cancer risk of $1x10^{-4}$). The risk levels achieved by the SED 9/FP 4 MOD alternative, which was not evaluated in GE's RCMS, are also shown in Table 5. This alternative achieves the human health risk target of $1x10^{-5}$ or $1x10^{-4}$ for RME receptors (depending on the impact to core habitat areas and following the process outlined above), or an HI of 1, while avoiding Core Area 1 habitat areas unless necessary to achieve a minimum risk level of $1x10^{-4}$ or an HI of 1).

Sediment Direct Contact EAs: For direct contact with sediment, for sediment [exposure] area (SA) 3 (Woods Pond, and a small portion of Reach 5C and the backwaters immediately upstream of Woods Pond) and SA 7 (Glendale impoundment)[7], which are the sediment EAs that do not currently achieve acceptable risk levels due to RME non-cancer risk exceeding an HI of 1, model projections indicate that during the modeling period, the RME non-cancer risk level (HI = 1) would be achieved with no action. The remaining alternatives all involve active remediation in Woods Pond, and all achieve an HI of 1 in less time, ranging from 21 years for SED 8/FP 7, to approximately 15 years for SED 5/FP 4 and SED 6/FP 4, and less than 10 years for SED 3/FP 3, SED 9/FP 8, SED 10/FP 9, and SED 9/FP 4 MOD.

2.6.1.2 Human Consumption of Floodplain Agricultural Products

Because there are no current EAs in the floodplain being used for agricultural production, this pathway does not pose current risks. However, there is the potential for future risk if land uses change and, in that case, ICs would need to be established for all remedial alternatives.

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[6] The RME IMPGs are those based on RME assumptions (representing more highly exposed individuals), and the CTE IMPGs are those based on CTE assumptions (representing individuals with average exposure).

[7] It appears that due to rounding issues GE in the RCMS does not recognize that SA 7 exceeds the RME HI of 1.

2.6.1.3 Human Consumption of Fish

Table 2, reproduced in large part from GE's RCMS, presents a detailed evaluation, for all of the alternatives, of whether the fish tissue PCB concentrations predicted by the model for each river reach or subreach at the end of the modeled period (when converted to fillet concentrations) would achieve the various RME and CTE IMPGs for human consumption of fish. The risk levels for fish consumption for the SED 9/FP 4 MOD alternative, which was not evaluated in GE's RCMS, have been included in this table. Attachment 10 provides a graphical representation of how the alternatives perform when compared to the various risk levels.

2.6.2 Comparison to Ecological IMPGs

This section compares the extent to which each alternative under evaluation would achieve the IMPGs for the various ecological receptors. The tables included in this section are taken in large part from GE's RCMS.

2.6.2.1 Benthic Invertebrates

The IMPGs for benthic invertebrates apply to bed sediment in 32 averaging areas in Reaches 5 through 8; achievement of IMPGs for the alternatives evaluated is summarized in Table 8 and shown graphically in Attachment 7, Figure 4. The table shows, for each alternative, the percentage of the averaging areas in which the model-predicted sediment concentrations would achieve the upper-bound and lower-bound IMPGs. The figure presents the same data in terms of the total area over which the benthic invertebrate IMPGs are achieved.

All alternatives evaluated, with the exception of SED 2/FP 1 and SED 10/FP 9, achieve the upper-bound IMPG for benthic invertebrates of 10 mg/kg tPCBs in sediment in all areas. SED 6, SED 7, and SED 8 also achieve the lower-bound IMPG of 3 mg/kg tPCBs in all averaging areas. SED 2, SED 3, SED 4, and SED 10 achieve the lower bound IMPG in 22% to 91% of the averaging areas. SED 9/FP 4 MOD achieves the lower-bound IMPG in 93% of the averaging areas, but is anticipated to have better performance due to the amendment of Reach 5B sediment with activated carbon, which will protect benthic invertebrates by reducing the bioavailability of PCBs, a process that cannot be simulated by the model.

Table 8 Summary of Percent Averaging Areas Achieving IMPGs for Benthic Invertebrates

IMPGs	Percent of Averaging Areas Achieving IMPGs in Surface Sediments							
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
Upper Bound (10 mg/kg in sediment)	72	100	100	100	100	100	84	100
Lower Bound (3 mg/kg in sediment)	22	63	91	100	100	100	34	931

Note: Addition of activated carbon to Reach 5B sediment may achieve protection equivalent to 3 mg/kg at current total organic carbon (TOC).

2.6.2.2 Amphibians

The IMPGs for amphibians apply to the 66 vernal pools identified by EPA in the Reach 5 floodplain (Woodlot, 2002) and to 29 defined backwater areas. Table 9 provides a summary of the percent of the averaging areas achieving the lower-bound and upper-bound amphibian IMPGs in the 66 vernal pools (based on the floodplain component of each alternative) and in the 29 backwater areas (based on the sediment component). Attachment 7, Figure 5, presents the same data graphically in terms of the actual area achieving the IMPGs. Note that Table 9 and Attachment 7, Figure 5 do not include data for SED 9/FP 4 MOD because the extent of vernal pool and backwater remediation is dependent upon further analysis in Core Areas.

SED 8/FP 7 and SED 9/FP 8 would achieve both the upper-bound (5.6 mg/kg tPCBs) and lower-bound (3.27 mg/kg tPCBs) amphibian IMPGs in all areas, whereas SED 10/FP 9, the lowest performing alternative, would provide only marginal improvement over MNR (SED 2/FP 1). Although SED 3/FP 3 achieves the upper-bound IMPG in 85% of the averaging areas, as shown in Attachment 7, Figure 5, these represent only 51% of the total acreage. SED 9/FP 4 MOD will achieve protection of amphibians through an iterative decision-tree process that will be followed after extensive data collection to select a subset of vernal pools for remediation and restoration using traditional techniques, and pilot testing of remediation technology options, followed by implementation of concepts proven in this process. This approach will ensure that remediation of vernal pools will not result in more harmful impacts than the current exposure to PCBs. SED 9/FP 4 MOD will achieve the upper- and lower-bound IMPGs in all backwaters, except potentially in backwaters, or portions thereof, that coincide with Core Area 1 habitats. In these areas, an amendment such as activated carbon may be used to further reduce bioavailability of any residual contamination.

Table 9 Summary of Percent of Averaging Areas Achieving IMPGs for Amphibians

IMPGs	Percent of Averaging Areas Achieving IMPGs in Surface Soil/Sediment						
	SED 2 / FP 1	SED 3 / FP 3	SED 5 / FP 4	SED 6 / FP 4	SED 8 / FP 7	SED 9 / FP 8	SED 10 / FP 9
Upper Bound (5.6 mg/kg in soil/sediment)	18	85	98	100	100	100	21
Lower Bound (3.27 mg/kg in soil/sediment)	13	27	40	48	100	100	14

2.6.2.3 Warmwater and Coldwater Fish

The IMPGs for fish protection apply to whole-body fish tissue PCB concentrations; the IMPG for warmwater fish is 55 mg/kg and the IMPG for coldwater fish is 14 mg/kg. Table 10 is a summary presentation of IMPG attainment for warmwater fish within the 14 subreaches of Reaches 5 through 8 and for coldwater fish within the 8 subreaches of Reach 7. Attachment 7,

Figure 6, presents the projected warmwater fish tissue PCB concentrations by reach for the alternatives evaluated. Attachment 7, Figure 7 presents the projected fish tissue PCB concentrations for coldwater fish for the Reach 7 subreaches.

All alternatives would achieve the warmwater fish IMPG in 100% of the areas. SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, SED 9/FP 8, and SED 9/FP 4 MOD would also achieve the coldwater fish IMPG in all areas. SED 3/FP 3 would achieve the coldwater fish IMPG in all except one of the Reach 7 subreaches, whereas SED 10/FP 9 would not achieve the coldwater fish IMPG in any reach and, in effect, would provide no improvement over MNR (SED 2/FP 1).

Table 10 Summary of Percent of Averaging Areas Achieving Warmwater and Coldwater Fish Protection IMPGs

IMPGs	Percent of Averaging Areas Achieving IMPGs in Fish Tissue							
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
Warmwater Fish Protection (55 mg/kg in fish)	100	100	100	100	100	100	100	100
Coldwater Fish Protection (14 mg/kg in fish)	0	88	100	100	100	100	0	100

2.6.2.4 Insectivorous Birds

The IMPG for insectivorous birds (represented by wood duck) applies to PCB tissue concentrations in their prey, which consists of both aquatic and terrestrial insects, and thus, it depends on both sediment and floodplain concentrations in the 12 designated averaging areas. Because each remedial alternative involves a sediment component and a floodplain component, an assessment of the achievement of the insectivorous bird IMPG was made by using the model-predicted sediment endpoint concentration in each averaging area to determine the corresponding target floodplain soil level in that area that would result in achievement of the IMPG, and then comparing the estimated floodplain soil exposure point concentration (EPC) in that area to the target level.

Table 11 summarizes, for each alternative, the percentage of the 12 averaging areas that would achieve the IMPG for insectivorous birds, based on a comparison of the calculated target floodplain soil concentration in each averaging area to the post-remediation floodplain EPC in each area. Attachment 7, Figure 8, presents the same data in terms of the acreage achieving the IMPG. Note that Table 11 and Attachment 7, Figure 8 do not include data for SED 9/FP 4 MOD because the extent of vernal pool and backwater remediation is dependent upon further analysis in Core Areas.

Table 11 Summary of Percent of Averaging Areas Achieving IMPGs for Insectivorous Birds

IMPG	Percent of Averaging Areas Achieving IMPG						
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9
Insectivorous Birds (4.4 mg/kg in prey)	33	83	100	100	100	100	58

All alternatives evaluated, with the exception of SED 2/FP 1, SED 3/FP 3, and SED 10/FP 9, SED 9/FP 4 MOD (except as discussed below) would achieve the wood duck IMPG at the end of the model simulation period in 100% of the areas. Under MNR (SED 2/FP 1), the IMPG is achieved in 33% of the averaging areas, representing 265 acres of the total 720 acres. SED 10/FP 9, would achieve the IMPG in 58% of the areas (381 acres), whereas SED 3/FP 3 would achieve the IMPG in 83% of the averaging areas (573 acres). SED 9/FP 4 MOD will protect insectivorous birds by substantially reducing sediment PCB concentrations that drive contaminant concentrations in the aquatic portion of the diet while simultaneously reducing floodplain soil PCB concentrations that lead to elevated PCBs in the terrestrial portion of the diet.

2.6.2.5 Piscivorous Birds

The IMPG for piscivorous birds (represented by osprey) applies to whole-body fish tissue concentrations in the 14 subreaches in Reaches 5 through 8.

Table 12 summarizes, for each alternative, the percentage of the 14 subreaches (considered the averaging areas) in which the model-predicted fish concentrations would achieve the piscivorous bird IMPG. SED 6/FP 4, SED 8/FP 7, and SED 9/FP 8 would achieve the osprey IMPG in 100% of the 14 averaging areas; SED 5/FP 4 would achieve the IMPG in 93% (13) of the averaging areas; and SED 9/FP 4 MOD would achieve the IMPG in 71% (10) of the areas. SED 3/FP 3 would achieve the IMPG in only 43% (6) of the 14 averaging areas, and SED 10/FP 9 would achieve the IMPG in none of the areas, which represents no improvement over MNR. Attachment 7, Figure 9, shows the same data in terms of the acreage achieving the IMPG.

Table 12 Summary of Percent of Averaging Areas Achieving Piscivorous Bird IMPGs

IMPG	Percent of Averaging Areas Achieving IMPG in Fish Tissue							
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9	SED 9/FP 4 MOD
Piscivorous Birds (3.2 mg/kg in fish)	0	43	93	100	100	100	0	71

2.6.2.6 Piscivorous Mammals

As is the case for insectivorous birds, the IMPGs for piscivorous mammals (represented by mink) apply to PCB concentrations in their prey, which consists of both aquatic and terrestrial animals. There are two designated averaging areas for mink, Reaches 5A/5B and Reaches 5C/5D/6. Because each remedial alternative involves a sediment component and a floodplain component, an assessment of the achievement of the piscivorous mammal IMPGs was made by using the model-predicted sediment endpoint concentration in each averaging area to determine the corresponding target floodplain soil concentration in that area that would result in achievement of the upper- and lower-bound IMPGs, and then comparing the estimated post-remediation floodplain soil EPC in that area to those target levels.

Table 13 summarizes the comparison of the post-remediation floodplain EPC in each averaging area to the calculated target floodplain soil concentration in that area, presenting the percentage of the two averaging areas that would achieve the upper-bound and lower-bound IMPGs, respectively, for piscivorous mammals. Attachment 7, Figure 10, presents the same data in terms of the acreage achieving the two IMPGs under each alternative. Note that Table 13 and Attachment 7, Figure 10 do not include data for SED 9/FP 4 MOD because the extent of vernal pool and backwater remediation is dependent upon further analysis in Core Areas.

Only SED 8/FP 7 would achieve both the upper-bound and lower-bound IMPGs in both averaging areas. SED 5/FP 4, SED 6/FP 4, and SED 9/FP 8 would all achieve the upper-bound IMPG only in both averaging areas. SED 10/FP 9 and SED 3/FP 3 would not achieve either IMPG in either of the areas, and therefore, would provide no improvement over MNR (SED 2/FP 1). As discussed earlier with reference to insectivorous birds, SED 9/FP 4 MOD will achieve protection of piscivorous mammals by simultaneously reducing PCB concentrations in both the aquatic and terrestrial dietary components.

Table 13 Summary of Percent of Averaging Areas Achieving IMPGs for Piscivorous Mammals

IMPGs	Percent of Averaging Areas Achieving IMPGs						
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9
Upper Bound (2.43 mg/kg in prey)	0	0	100	100	100	100	0
Lower Bound (0.984 mg/kg in prey)	0	0	0	0	100	0	0

2.6.2.7 Omnivorous/Carnivorous Mammals

The IMPGs for omnivorous/carnivorous mammals (represented by the short-tailed shrew) apply to floodplain soil in seven averaging areas in the PSA. Table 14 summarizes the evaluation of IMPG attainment for omnivorous/carnivorous mammals in the seven averaging areas, presenting the percentage of the areas in which the average floodplain soil concentration would achieve the upper-bound and lower-bound IMPGs for omnivorous/carnivorous mammals. Attachment 7, Figure 11 presents the same data in terms of the total acreage over which the IMPGs are achieved by the various alternatives. Note that Table 14 and Attachment 7, Figure 11 do not include data for SED 9/FP 4 MOD because the extent of vernal pool and backwater remediation is dependent upon further analysis in Core Areas.

This summary shows that each alternative, with the exception of SED 2/FP 1 (MNR), SED 3/FP 3, SED 10/FP 9, and SED 9/FP 4 MOD (except as discussed) would achieve both the upper-bound and lower-bound omnivorous/carnivorous mammal IMPGs in 100% of the areas. Both SED 3/FP 3 and SED 10/FP 9 would achieve only the upper-bound IMPG in 100% of the areas, which is only a slight improvement over SED 2/FP 1 (MNR), which achieves the upper-bound IMPG in 86% of the averaging areas. SED 3/FP 3 would achieve the lower bound in 71% of the areas, whereas both SED 10/FP 9 and SED 2/FP 1 would achieve the lower bound in 57% of the areas. The targeted remediation of floodplain soil included in alternative SED 9/FP 4 MOD will provide some protection of omnivorous mammals; however, because remediation areas have not yet been determined, it is not known in which averaging areas IMPGs will be achieved.

Table 14 Summary of Percent of Averaging Areas Achieving IMPGs for Omnivorous/Carnivorous Mammals

IMPGs	Percent of Averaging Areas Achieving IMPGs in Floodplain Soil						
	SED 2/FP 1	SED 3/FP 3	SED 5/FP 4	SED 6/FP 4	SED 8/FP 7	SED 9/FP 8	SED 10/FP 9
Upper Bound (34.3 mg/kg in floodplain soil)	86	100	100	100	100	100	100
Lower Bound (21.1 mg/kg in floodplain soil)	57	71	100	100	100	100	57

2.6.2.8 Threatened and Endangered Species

The IMPG for threatened and endangered species (represented by the bald eagle) applies to whole-body fish PCB concentrations in the 14 subreaches in Reaches 5 through 8. All alternatives would achieve the threatened and endangered species IMPG in all areas.

2.6.3 Summary

For human health direct contact with floodplain soil and agricultural use, all alternatives, with the exception of SED 2/FP 1, were designed to achieve a specified reduction in risk level upon completion of remediation. It would not be expected under SED 2/FP 1 that any reduction in risk would occur over a reasonable timeframe.

For human health direct contact with sediment, for SA 3 (Woods Pond) and SA 7 (Glendale impoundment), which are the sediment EAs that do not currently achieve acceptable risk levels due to RME non-cancer risk exceeding an HI of 1, model projections indicate that within 22 years the RME non-cancer risk level (HI = 1) would be achieved with no active remediation (SED 2/FP 1). The remaining alternatives all involve active remediation in Woods Pond and all achieve an HI of 1 in shorter periods of time, ranging from 21 years for SED 8/FP 7, to approximately 15 years for SED 5/FP 4 and SED 6/FP 4, and less than 10 years for SED 3/FP 3, SED 9/FP 8, SED 10/FP 9, and SED 9/FP 4 MOD.

For human fish consumption, no active remediation (SED 2/FP 1) would result in the HI of 1 and the RME $1x10^{-4}$ level being exceeded for the RME and CTE adult and child for more than 250 years. The same is the case with SED 10/FP 9 for the HI of 1 and the RME $1x10^{-4}$ level; however, the CTE $1x10^{-4}$ risk level is achieved in some reaches. All other alternatives achieve varying risk levels far sooner than those two alternatives (see Table 2).

For benthic invertebrates, numerous EAs meet the upper-bound IMPG with SED 2/FP 1 and SED 10/FP 9; however, very few EAs attain the lower-bound IMPG within 200 years with these two alternatives. SED 6/FP 4, SED 8/FP 7, SED 9/FP 8, and SED 9/FP 4 MOD all achieve the lower-bound IMPG, or its equivalent in the case of SED 9/FP 4 MOD in Reach 5B, in all EAs within 20 years (with the exception of some EAs for SED 8, which requires a longer duration for implementation).

Neither SED 2/FP 1 nor SED 10/FP 9 achieves either the upper-bound or lower-bound amphibian IMPG in the majority of backwater areas or vernal pools in less than 100 years. The other alternatives achieve either the upper-bound or lower-bound IMPG in many or all areas or pools in much less time, and for alternatives SED 6/FP 4 and SED 9/FP 8, typically in less than 20 years. SED 9/FP 4 MOD would provide protection to amphibians by reducing exposure concentrations through an iterative decision-tree approach to remediating vernal pools.

Warmwater fish IMPGs are attained for all alternatives, including MNR (SED 2/FP 1). However, the coldwater fish IMPGs are not attained in less than 100 years in the subreaches of Reach 7 either with SED 2/FP 1 or with SED 10/FP 9. The other alternatives that include active remediation attain this IMPG in all but one subreach (Subreach 7B, for SED 3/FP 3) within a range of timeframes dependent on the implementation schedule for the alternative.

The IMPG for insectivorous birds is not attained in 8 of 12 EAs with MNR (SED 2/FP 1), and is not attained in 5 of 12 areas with SED 10/FP 9. For other alternatives, most achieve the IMPG in all areas.

The piscivorous bird IMPG is not achieved by SED 2/FP 1 or SED 10/FP 9 for any reach in less than 100 years, and in some cases, over 200 years. SED 6/FP 4, SED 8/FP 7, and SED 9/FP 8 all achieve the IMPG in all reaches in a much reduced timeframe, typically less than 20 years, with the exception of SED 8/FP 7, for which timeframes are controlled by the longer duration of implementation.

The lower-bound IMPG for piscivorous mammals is achieved only by SED 8/FP 7. However, SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, and SED 9/FP 8 achieve the upper-bound IMPG. The other alternatives do not achieve either IMPG. MNR (SED 2/FP 1) would result in the upper-bound IMPG not being achieved for over 250 years.

With MNR (SED 2/FP 1), the omnivorous/carnivorous mammal upper-bound IMPG is not achieved in three of the seven EAs, with two achieving the lower-bound IMPG. All other alternatives achieve either the upper-bound or lower-bound IMPG, with SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, and SED 9/FP 8 all achieving the lower-bound IMPG.

The threatened and endangered species IMPG (based on the bald eagle) is achieved with no action and therefore, for all alternatives.

2.7 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME OF WASTES

The degree to which the alternatives under evaluation would reduce the TMV of PCBs is discussed below.

2.7.1 Treatment Process Used and Materials Treated

None of the sediment-floodplain alternatives, except for SED 9/FP 4 MOD, includes any proposed treatment processes that would reduce the toxicity of PCBs in the sediment or soil.

SED 9/FP 4 MOD specifies sediment amendment with activated carbon, or similar material, in some areas. Although such amendment does not directly reduce the absolute toxicity of PCBs, it reduces the effective toxicity by limiting the bioavailability of the contaminants. Because none of the other alternatives provides for this treatment, SED 9/FP 4 MOD surpasses all other alternatives in the amount of materials treated and the degree of reduction in toxicity due to treatment.

2.7.2 Amount of Hazardous Materials Destroyed or Treated

SED 9/FP 4 MOD includes amendment of some sediments/soils with material(s) that will reduce the bioavailability of contaminants. None of the other remedial alternatives specifies any treatment processes; therefore, no hazardous materials would be destroyed or treated by any of the other alternatives. Accordingly, SED 9/FP 4 MOD surpasses all other alternatives in the amount of materials treated and the degree of reduction in toxicity due to treatment.

2.7.3 Degree of Expected Reductions in Toxicity, Mobility, or Volume

<u>Reduction of Toxicity</u>: Of the remedial alternatives under evaluation, only SED 9/FP 4 MOD includes the evaluation and use of sediment/soil amendments such as activated carbon in Reaches 5B and the backwaters and in selected vernal pools to more effectively bind PCBs to the inorganic sediment/soil matrix. This type of treatment has been documented to reduce the bioavailability of organic contaminants and is, therefore, expected to reduce the toxicity in these areas. Because none of the other alternatives includes this treatment, SED 9/FP 4 MOD surpasses all other alternatives in the amount of materials treated and the degree of reduction in toxicity due to treatment.

<u>Reduction of Mobility</u>: Under SED 2/FP 1, no reduction of mobility of PCBs in the river would be achieved through remedial action, and only past and ongoing upstream source control/remediation and naturally occurring processes would provide for a reduction of PCB mobility. Under all other alternatives, reductions would be achieved through sediment removal, capping, backfilling, thin-layer capping, and/or bank stabilization activities. In the case of SED 9/FP 4 MOD, additional reduction in the mobility of PCBs will be achieved through the use of the sediment amendment(s) discussed above, which prevent PCB release to overlying waters and subsequent transport downstream.

Reduction in sediment PCB mobility can be viewed in terms of reduction in the annual mass of PCBs passing Woods Pond and Rising Pond Dams, and the solids/PCB trapping efficiency of Woods Pond shown in Attachment 7, Figures 1 and 12. The percent reduction in PCB mass passing over Woods Pond and Rising Pond Dams at the conclusion of the 52-year (81-year in the case of SED 8/FP 7) model simulation period for each of the alternatives evaluated is shown in Table 3 and discussed with reference to the General Standard “Control of Sources of Releases” in Section 2.3.

Attachment 7, Figure 12, shows the solids trapping efficiency of Woods Pond at the conclusion of each of the alternatives evaluated. As indicated in this figure, alternatives that include deepening of Woods Pond (SED 9/FP 8, SED 9/FP 4 MOD, and SED 10/FP 9) achieve modest, and nearly equivalent, increases in solids trapping in the pond, increasing the trapping of solids from approximately 15% for MNR and for alternatives that do not include the deepening of Woods Pond, to approximately 25% in the case of SED 9/FP 8 and SED 10/FP 9, and to approximately 30% in the case of SED 9/FP 4 MOD. It is important to note, however, that because of continuing release of PCBs from the trapped sediment, the PCB trapping efficiency will be less than that for solids, although this effect will be similar for all alternatives and, therefore, does not distinguish among them.

Reduction of Volume: Implementation of each of the sediment-floodplain alternatives, except SED 2/FP 1, would reduce the volume of PCB-contaminated sediment, bank soil, and floodplain soil in the Rest of River through permanent removal of the material. Table 15, from GE's RCMS, and Attachment 7, Figure 13, summarize the approximate removal volume and corresponding PCB mass that would be removed under each such alternative. The volume and mass removed under the SED 9/FP 4 MOD alternative, which was not evaluated in GE's RCMS, are also shown in this table.

Table 15 Removal Volume and Corresponding PCB Mass for Alternatives

Alternative	Removal Volume – Sediment/Soil (cy)	Estimated PCB Mass (lb)
SED 2/FP 1	---	---
SED 3/FP 3	243,000	21,700
SED 5/FP 4	533,000	33,300
SED 6/FP 4	677,000	37,300
SED 8/FP 7	2,902,000	94,100
SED 9/FP 8	1,098,000	53,100
SED 10/FP 9	267,700	13,900
SED 9/FP 4 MOD	990,000	46,970

2.7.4 Degree to Which Treatment Is Irreversible

None of the sediment-floodplain alternatives, except SED 9/FP 4 MOD, includes any proposed treatment processes that would reduce the toxicity of PCBs in the sediment or soil. The use of an amendment, as specified in SED 9/MOD 4, is expected to be irreversible.

2.7.5 Type and Quantity of Residuals Remaining after Treatment

None of the sediment-floodplain alternatives, except SED 9/FP 4 MOD, includes any proposed treatment processes that would reduce the toxicity of PCBs in the sediment or soil. The use of an amendment, as specified in SED 9/MOD 4, is not expected to significantly affect the type and quantity of residuals remaining after treatment.

2.8 SHORT-TERM EFFECTIVENESS

Evaluation of the short-term effectiveness of the remedial alternatives includes consideration of the short-term impacts of implementing these alternatives on the environment (considering both ecological effects and increases in greenhouse gas (GHG) emissions), on local communities (including communities along transport routes), and on the workers involved in the remedial activities. Short-term impacts are those that would occur during and immediately after the performance of the remedial activities in a given area. Because SED 2/FP 1 would involve no remedial construction activities, its implementation would not produce any short-term impacts; all of the other alternatives would have some short-term impacts. Because any remediation would be conducted using a phased approach, these impacts would be dispersed over the remedial action period and area, and thus, would not last for the entire duration of the project in all affected areas. The tables shown in this section were taken from GE's RCMS and modified where possible to include the SED 9/FP 4 MOD alternative. The estimated durations of the alternatives evaluated, ranging from 5 years for SED 10/FP 9 to over 50 years for SED 8/FP 7, are summarized in Table 16.

Table 16 Construction Duration for Alternatives

	SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Construction Duration (years)	___	10	18	21	52	14	5	13

2.8.1 Impacts on the Environment – Effects Within the Rest of River Area

Short-term impacts on the Rest of River environment from remedial construction activities would include PCB releases to the water column and air during sediment removal and other in-river activities, as well as alteration of natural habitats where remediation would be conducted or support facilities would be built, with the attendant impacts on the plants and animals that use those habitats. These impacts are described and compared among the alternatives in the following subsections.

PCB Releases: Sediment removal activities would result in some resuspension of PCB-contaminated sediment into the water column. This could potentially result in transient increases in PCB levels in surface water and aquatic biota downstream of the removal operations. Under all of the active remediation alternatives, except SED 9/FP 8 and SED 9/FP 4 MOD, sediment removal in Reach 5A and, where applicable, Reach 5B, would be conducted in the dry using sheetpile containment, which would allow the greatest control of resuspension. However, the potential still exists for suspended or residual sediment containing PCBs to be released from the work area both during sheetpile installation and removal, and during a high-flow event when overtopping of the sheeting could occur. Under SED 9/FP 8 and SED 9/FP 4 MOD, sediment removal in those subreaches would be conducted in the wet, which would have the potential for causing resuspension of PCB-contaminated sediment. In addition, under remedial alternatives that would involve sediment remediation in other reaches, removal activities would be conducted in the wet from barges. These activities, as well as boat and barge traffic, would result in some resuspension of sediment containing PCBs, which would be minimized through the use of engineering controls, such as silt curtains.

Other than SED 2/FP 1, which does not involve sediment removal, SED 3/FP 3 has the lowest potential for PCB resuspension because it would involve the smallest area of sediment removal (42 acres in Reach 5A), and that removal would be conducted in the dry. SED 10/FP 9 would involve a smaller area of dry removal (20 acres in Reach 5A), but would also involve the removal of sediment in the wet from 42 acres in Woods Pond. The other alternatives would involve substantially more sediment removal, with some or much of it conducted in the wet, which would result in more resuspension over a longer period of time than either SED 3/FP 3 or SED 10/FP 9.

Similarly, sediment and soil removal and related processing activities have the potential to produce airborne PCB emissions that could impact downwind communities. This potential also increases with the scope and duration of the removal activities, which increase from SED 3/FP 3 and SED 10/FP 9 through SED 8/FP 7. Monitoring and implementation of best management practices (BMPs) are expected to result in minimal releases.

<u>Impacts on Aquatic Riverine Habitat</u>: The potential short-term impacts of sediment remediation activities, including removal with capping or backfilling and capping or thin-layer capping without removal, on aquatic riverine habitat include the following: removal of the habitat used by aquatic plants, benthic invertebrates, and fish; change in surface substrate from its current condition (sand, sand and gravel, or silt) to armor stone or backfill material; removal or burial of most, if not all, vegetation, benthic invertebrates, and other organisms present in the sediment; disruption and displacement of fish; alteration of habitat for birds and mammals living adjacent to the river that feed in areas subject to remediation; and possible colonization by invasive species. In addition, capping or thin-layer capping without removal would raise the elevation of the river bottom, which, in shallower areas, could change the vegetative characteristics of those areas and the biota dependent on them.

Under SED 3/FP 3, these types of potential short-term impacts would occur over 42 acres of aquatic riverine habitat, all in Reach 5A. Under SED 9/FP 4 MOD, remediation would be 42 acres in Reach 5A and 57 acres in Reach 5C, for a total of 99 acres of riverine habitat. Under SED 5/FP 4, SED 6/FP 4, SED 8/FP 7, and SED 9/FP 8, these impacts would occur over approximately 127 acres of aquatic riverine habitat. Under SED 10/FP 9, which involves the smallest amount of removal of contaminated sediment, these impacts would occur in only 20 acres of such habitat (in Reach 5A).

Incorporation of a habitat layer in the cap design would mitigate some of these impacts. In addition, implementation of the remediation in a phased approach affecting a small area at any given time would also minimize some of these impacts.

<u>Impacts on Riverbank Habitat</u>: The potential short-term impacts of bank stabilization activities in Reaches 5A and 5B on the riverbanks include removal of trees, other vegetation, and woody debris from the riverbanks, with the resulting temporary loss of shade for the river and the loss of the wildlife that use those features; short-term elimination of vertical and undercut banks used by

various species for nesting; short-term loss of slide and burrow habitat for muskrats and beavers; potential short-term reduction in wildlife access routes and movement of various species between their aquatic and terrestrial habitats; and the possible colonization by invasive species.

All of the alternatives, except SED 2/FP 1 (MNR) and SED 10/FP 9, would result in such impacts on the eroding riverbanks subject to stabilization. SED 2/FP 1 would not have any such impacts, and SED 10/FP 9 would limit these impacts to a small portion of the riverbank in Reaches 5A and 5B. The approach to bank remediation in SED 9/FP 4 MOD is based on the consideration of both the erosion potential of areas of bank as well as the PCB concentrations in bank soil, reducing the amount of bank remediation by focusing only on those portions of the banks in Reach 5A that have both high erosion potential and elevated PCB concentration, and in Reach 5B on a limited amount of bank soil with the highest PCB concentrations (greater than 50 mg/kg).

Impacts on Impoundment Habitat: The potential short-term impacts of sediment remediation activities, including removal with capping (or backfilling), capping or thin-layer capping without removal, and removal without capping, on impoundment habitat are similar to the short-term impacts on aquatic riverine habitat, as described above, except that placement of a cap or thin-layer cap in the deep hole portion of Woods Pond would not be expected to have any significant short-term ecological impacts.

Apart from SED 2/FP 1, all of the alternatives under evaluation would have some impacts on impoundment habitat. Table 6 shows the amount of area affected by each alternative.

Impacts on Backwater Habitat: The potential short-term impacts of sediment remediation activities, including thin-layer capping and sediment removal with capping (or backfilling), on backwater habitat include the following: burial or removal of most, if not all, vegetation, benthic invertebrates, and other organisms in the sediment.

Because SED 2/FP 1, SED 3/FP 3, and SED 10/FP 9 would not involve any remediation in the backwaters, they would have no short-term impacts to backwater habitat. The other alternatives would all have short-term impacts to backwater habitat because they would affect 61 to 86 acres of such habitat (see Table 6).

Impacts on Floodplain Habitats: The potential short-term impacts on the various floodplain habitats resulting from floodplain soil removal and the construction and use of access roads and staging areas include the following:

- For floodplain wetland forest habitats, the short-term impacts could potentially include the following: (1) removal of living trees, shrubs, other vegetation, and woody debris, which would result in a temporary loss of cover, nesting, and feeding habitat for wildlife species that rely on forested floodplains; (2) possible colonization by invasive plant species; and (3) increase in construction and equipment traffic, which could disrupt some forest animals or result in mortality to certain slow-moving smaller animals. Many of these short-term impacts can be mitigated by appropriate restoration activities, including replacement of existing soil and leaf litter with backfill soil designed to function similarly to existing native soil, to provide the best opportunity for plant growth and hydraulic conductivity, and implementing an invasive species management program.

- For shrub and emergent wetlands (both shallow and deep), the short-term impacts could potentially include: (1) clearing of vegetation, with consequent impacts on nesting, burrowing, and/or escape habitat and food for birds, amphibians, reptiles, mammals, and invertebrates that use these wetland areas; (2) alteration of the hydrology of the wetlands; (3) possible colonization by invasive species; and (4) increase in construction and equipment traffic, with the resulting potential for disruption or mortality to slow-moving animals. Many of these short-term impacts can be mitigated by appropriate restoration activities, including replacement of existing soil with soil designed to function similarly to existing native soil, to provide the best opportunity for plant growth and hydraulic conductivity and implementing an invasive species management program.

- For vernal pools and the biota that use them, the short-term impacts could potentially include: (1) removal of amphibian and invertebrate eggs, larvae, or adults in the affected portions of the pools; (2) removal of physical components of the pools (organic surface soil, vegetation, and other organic materials) and their replacement; (3) alteration of the hydrology of the pools; (4) tree clearing within and adjacent to the pools, temporarily reducing the shade and infusion of biomass provided to the pools; (5) temporary loss of obligate vernal pool breeding species from all or parts of these pools; (6) possible colonization by invasive species; (7) impacts on the non-breeding terrestrial habitats surrounding the vernal pools; and (8) loss or fragmentation of landscape connectivity among networks of vernal pools and between vernal pools and non-breeding habitats. Many of these short-term impacts can be mitigated by appropriate restoration activities, including replacement of preexisting physical components such as woody debris, implementing an invasive species management program, and conducting remediation in a phased approach.

- For upland habitats, the short-term impacts would potentially include temporary loss of trees and associated vegetation and impacts to the wildlife that use such areas.

- In all of these habitats, and in the absence of any mitigation, the short-term impacts would potentially include the direct removal or disruption of any state-listed species present in the affected areas, as well as alteration of their habitat.

- The short-term impacts could potentially also include impairment of a number of other functions provided by the floodplain, which would be mitigated through proper restoration. For example, by removing woody debris and vegetation and altering microtopography in disturbed areas, the floodplain remedial construction activities would reduce the floodplain roughness that produces flow resistance and contributes to the important flood flow alteration function of the floodplain. In addition, the construction activities could alter the floodplain’s groundwater recharge/discharge function and its functions of water quality maintenance, nutrient process, and production export.

All of the alternatives involving removal would have these potential short-term impacts on the habitats outside the river. Table 6 shows the amount of each habitat type potentially impacted by each alternative.

With specific reference to vernal pools, SED 2/FP 1 (MNR) and SED 10/FP 9 (which does not include remediation of contaminated soil in vernal pools) would have no direct impact on any of the vernal pools. All of the other alternatives, with the exception of SED 9/FP 4 MOD, would impact those vernal pools to a generally similar extent. Because of the iterative pilot-study-based approach to remediation/restoration of vernal pools included in the SED 9/FP 4 MOD alternative, the vernal pool component of SED 9/FP 4 MOD was designed specifically to provide superior performance with regard to vernal pools, comprehensively considering both the positive and negative impacts of active remediation. For additional information on wetland and floodplain impacts, see Attachment 12.

2.8.2 Carbon Footprint – Greenhouse Gas Emissions

Estimates have been developed of the GHG emissions (i.e., carbon footprint) anticipated to occur through sediment removal/capping, floodplain soil and tree removal, and related ancillary activities during the implementation of the alternatives under evaluation. Table 17 summarizes the total carbon footprint associated with each alternative, including a breakdown of direct, indirect, and off-site emission sources. To provide context regarding the emissions reported below, the number of passenger vehicles that would emit an equivalent quantity of $CO_{2\text{-eq}}$ in 1 year is also presented in the table. A graphical comparison of the total GHG emissions for the alternatives evaluated is shown in Attachment 7, Figure 14.

SED 10/FP 9 would have the lowest amount of total GHG emissions (40,000 tonnes); SED 3/FP 3 would have the next lowest amount (47,000 tonnes); SED 5/FP 4, SED 6/FP 4, SED 9/FP 8, and SED 9/FP MOD would have between 100,000 and 190,000 tonnes of such emissions; and SED 8/FP 7 would have by far the greatest amount of GHG emissions (520,000 tonnes).[8]

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[8] Comparison among the three emission categories indicates that, on average, off-site emissions account for more than half of the GHG emissions for each combination (the most significant off-site sources being steel sheeting manufacture [with the exception of SED 9] and production of cement to be used in sediment stabilization). Direct emissions sources (including those associated with construction and transportation activities) generally account for 40 to 50% of the total GHG emissions.

Table 17 Calculated GHG Emissions Anticipated to Result from Alternatives

Alternative	Total GHG Emissions (tonnes)	Direct Emissions (tonnes)	Indirect Emissions (tonnes)	Off-Site Emissions (tonnes)	No. of Vehicles with Equivalent Annual Emissions
SED 2/FP 1	---	---	---	---	---
SED 3/FP 3	47,000	26,000	1,200	20,000	9,000
SED 5/FP 4	100,000	46,000	2,300	53,000	19,100
SED 6/FP 4	140,000	65,000	3,500	72,000	28,800
SED 8/FP 7	520,000	220,000	10,300	290,000	99,400
SED 9/FP 8	190,000	79,000	3,800	110,000	36,300
SED 10/FP 9	40,000	12,000	900	27,000	7,600
SED 9/FP 4 MOD	171,000	70,000	3,400	98,000	32,200

2.8.3 Impacts on Local Communities and Communities Along Truck Transport Routes

Implementation of all alternatives (except SED 2/FP 1) would result in some short-term impacts to the local communities along the Housatonic River. These short-term effects would include changes to the visual appearance of the river, riverbanks, and affected areas of the floodplain, as well as disruption of recreational activities in those areas due to the remediation as well as the construction of access roads and staging areas. They would also include increased construction traffic, noise, and nuisance dust in those areas.

Construction activities would affect some recreational activities along the river and in the floodplain. Depending on the particular alternative, these potentially would include fishing, canoeing (including canoe launches), hiking, dirt biking, general recreation, and both waterfowl and other game hunting. During the period of active construction, restrictions on recreational uses of the river and the floodplain would be imposed in the areas where remediation-related activities are taking place. Due to safety considerations, boaters, anglers, hikers, hunters, and other recreational users would not be able to use the river, floodplain, or riverbank in the construction and support areas. However, due to the phased nature of any remediation, only a small portion of the total recreational acreage would be affected at any one time, and active measures to decrease impacts to recreation (e.g., providing for transport of canoes around the area being impacted) will be considered.

The extent of these impacts on Housatonic River and floodplain use would vary depending on the overall area affected by remediation and support facility construction, as well as the length of time required to complete the remediation. These impacts would be least for SED 10/FP 9 (91 acres, 5 years). They would be more extensive for SED 3/FP 3 (237 acres, 10 years), SED 9/FP 4 MOD (300 to 400 acres, 13.4 years), SED 5/FP 4 (410 acres, 18 years), SED 6/FP 4

(447 acres, 21 years), and SED 9/FP 8 (469 acres, 14 years). The alternative with the greatest potential impact on these uses of the river and floodplain is SED 8/FP 7 (774 acres, 52 years).[9]

In addition, due to the need to deliver equipment to the work areas, remove excavated materials, and deliver capping, backfill, and bank stabilization materials to the site, both on-site and local (off-site) truck traffic would increase over current conditions. This additional traffic could increase the likelihood of accidents, noise levels, emissions of vehicle/equipment exhaust, and nuisance dust to the air, and would persist over the duration of remedial activities. Table 18 summarizes the number of truck trips associated with transporting excavated materials from the staging areas to the disposal or treatment facilities and delivering capping/backfill and bank stabilization materials to the remediation areas. The total annual truck trips and total years of truck traffic for each alternative are show graphically in Attachment 7, Figure 15.

As shown in Table 18, apart from SED 2/FP 1, SED 10/FP 9 would involve the fewest number of total truck trips (31,600) and SED 3/FP 3 would involve the next fewest (49,700). SED 5/FP 4, SED 6/FP 4, SED 9/FP 4 MOD, and SED 9/FP 8 would involve between 115,500 and 188,400 truck trips; and SED 8/FP 7 would require by far the most total truck trips (approximately 515,000). However, on an annual basis, SED 9/FP 8 would involve the greatest number of truck trips per year (13,500) based on its accelerated schedule with work occurring in more than one reach at a time.

Table 18 Estimated Truck Trips for Removal of Excavated Material and Delivery of Capping/Backfill Material for Alternatives

Alternative	Truck Trips for Excavated Material[a]	Truck Trips for Capping/Backfill Material[b]	Total Truck Trips[c]
SED 2/FP 1	---	---	---
SED 3/FP 3	20,100 (2,000)	29,600 (3,000)	49,700 (5,000)
SED 5/FP 4	44,300 (2,500)	71,200 (4,000)	115,500 (6,500)
SED 6/FP 4	56,100 (2,700)	80,500 (3,800)	136,600 (6,500)
SED 8/FP 7	242,000 (4,700)	273,300 (5,300)	515,300 (10,000)
SED 9/FP 8	90,800 (6,500)	97,600 (7,000)	188,400 (13,500)
SED 10/FP 9	22,200 (4,400)	9,400 (1,900)	31,600 (6,300)
SED 9/FP 4 MOD	81,700 (6,100)	68,800 (5,100)	150,500 (11,200)

[a] Truck trips estimated assuming 20-ton capacity trucks for hauling excavated material and 16-ton trucks for local hauling of capping/backfill material. Note that many of these truck trips will not take place on public roads, and will be on a network of on-site roads constructed specifically for the purposes of remediation.
[b] Capping material includes cap, thin-layer cap, backfill, and bank stabilization materials.
[c] The number in parentheses represents average annual truck trips.

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[9] EPA does not believe that the infrastructure included in these estimates by GE has been optimized and expects that, for the selected remedy, the staging areas and roads will be designed to minimize the footprint and adverse impacts to the floodplain, neighborhoods, and local roads while allowing the remediation to proceed in a timely and effective manner.

The additional truck traffic would also increase the risk of traffic accidents along transport routes. The number of injuries or fatalities from the increased off-site truck traffic that would be associated with the alternatives under evaluation[10] is summarized in Table 19, with the annual incidence of injuries and fatalities.

The incidence of potential injuries from accidents associated with increased truck traffic would be lowest for SED 10/FP 9 (1.09 injuries), with estimated injuries for the other alternatives ranging from 1.98 (SED 3/FP 3) to 11.0 (SED 8/FP 7). Similarly, estimated fatalities due to increased truck traffic are lowest for SED 10/FP 9 (0.05), with estimated fatalities for the other alternatives ranging from 0.09 (SED 3/FP 3) to 0.51 (SED 8/FP 7).

Table 19 Incidence of Accident-Related Injuries/Fatalities Due to Increased Truck Traffic

Impacts	SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Non-Fatal Injuries								
Number	---	1.98	3.29	4.03	11.0	5.43	1.09	5.36
Average Annual Number	---	0.21	0.18	0.19	0.21	0.40	0.21	0.40
Probability*	---	0.86	0.96	0.98	1.00	1.00	0.66	1.00
Fatalities								
Number	---	0.09	0.15	0.19	0.51	0.25	0.05	0.25
Average Annual Number	---	0.010	0.008	0.009	0.010	0.019	0.010	0.019
Probability*	---	0.09	0.14	0.17	0.40	0.22	0.05	0.22

*Probability indicates the probability of at least one injury/fatality.

2.8.4 Potential Measures to Avoid, Minimize, or Mitigate Short-Term Community Impacts

A number of measures would be employed in an effort to avoid, minimize, and mitigate potential detrimental effects of construction activities on the affected communities (e.g., minimize truck travel on local roads). As would be expected, the level of impact, and therefore, the extent of the necessary mitigation, is related to the scale/scope of the alternative and the time period of construction. Therefore, SED 8/FP 7 would have the most significant effect on local

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[10] This analysis quantified transport-related risks only for trucks used to import capping, backfill, and bank stabilization materials to the site over public roads, as well as to dispose of materials used for the staging areas and access roads following completion of remediation. The risks from transporting excavated materials to the staging areas are evaluated as part of risks to workers, discussed below; and the risks from transporting such materials from the staging areas to local or off-site disposal or treatment facilities are evaluated as either worker risks or traffic accident risks under the relevant treatment/disposition alternatives.

communities and would require the greatest degree of mitigation. SED 10/FP 9 would have the least such effect.

2.8.5 Risks to Remediation Workers

There would be health and safety risks to site workers implementing each of these alternatives. An estimate of the injuries or fatalities to workers from implementation of the alternatives is summarized in Table 20.

Risks to site workers would be lowest with SED 10/FP 9 (2.6 injuries), with the estimated injuries for all other alternatives at least twice that of SED 10/FP 9, ranging from 5.5 (SED 3/ FP 3) to 30.2 (SED 8/FP 7). Similarly, estimated fatalities for site workers are lowest for SED 10/FP 9 (0.03), with estimated fatalities for the other alternatives ranging from 0.05 (SED 3/FP 3) to 0.34 (SED 8/FP 7).

Table 20 Incidence of Accident-Related Injuries/Fatalities Due to Implementation of Alternatives

Impacts	SED 2/ FP 1[a]	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Labor-hours (hours)	–	597,504	1,071,053	1,154,960	3,281,738	1,179,703	285,106	1,000,000
Duration (yrs)	–	10	18	21	52	14	5	13
Non-Fatal Injuries								
Number	–	5.5	9.9	10.7	30.2	10.9	2.6	9.2
Average Annual Number	–	0.55	0.55	0.51	0.58	0.78	0.53	0.69
Probability[b]	–	1.00	1.00	1.00	1.00	1.00	0.93	1.00
Fatalities								
Number	–	0.05	0.11	0.11	0.34	0.13	0.03	0.10
Average Annual Number	–	0.005	0.006	0.005	0.007	0.009	0.005	0.007
Probability[b]	–	0.05	0.10	0.11	0.29	0.12	0.03	0.10

[a] Although the monitoring activities under SED 2 would involve the potential for accidents to site workers involved in those activities, these risks would be minimal, and would be mitigated through implementation of health and safety measures similar to those successfully applied during such activities on the river in the past.

[b] Probability indicates the probability of at least one injury/fatality.

2.9 IMPLEMENTABILITY

2.9.1 Ability to Construct and Operate the Technology

The equipment, materials, procedures, and personnel necessary to construct and operate the technologies comprising each of the alternatives are all readily available.

All of the alternatives would be implemented using well-established and available in-river remediation and floodplain soil removal methods and equipment, available construction technologies to build land-based support facilities, and readily available methods to implement monitoring and ICs. The remedial components selected (i.e., sediment removal in the dry or wet via mechanical or hydraulic methods, sediment capping and thin-layer capping, floodplain soil removal and backfilling, and MNR) have been used in similar applications as part of previous work at the GE-Pittsfield/Housatonic River Site and at many other sites.

Potential uncertainties include difficulties associated with contracting over long time periods and uncertainties in obtaining the large quantities of capping and backfill materials (which would range from approximately 308,000 cubic yards (cy) to approximately 2.9 million cy, as shown in Table 21 from GE's RCMS). These challenges have been overcome at other sites, and, in addition, the concept of adaptive management would be used to address these uncertainties by reassessing the implementation methods at regular intervals.

In addition, habitat restoration techniques are available and have been used successfully at other sites. Restoration can reliably reestablish pre-remediation conditions for these habitats over the timeframes of the various alternatives, which range from 5 to 52 years, using a phased approach. Post-remediation monitoring and maintenance will ensure that the selected restoration techniques reestablish the prior conditions and functions of the affected habitats.

Table 21 Required Capping/Backfill/Stabilization Material Volumes for Alternatives

Combination	Sand (cy)	Capping Material (cy)	Soil Backfill (cy)	Total Material (cy)
SED 2/FP 1	---	---		---
SED 3/FP 3	150,800	76,100	81,000	307,900
SED 5/FP 4	372,800	246,100	133,000	751,900
SED 6/FP 4	438,800	279,100	133,000	850,900
SED 8/FP 7	1,976,800	255,100	677,000	2,908,900
SED 9/FP 8	446,800	221,400	195,000	863,200
SED 10/FP 9	33,500	34,900	29,000	97,400
SED 9/FP 4 MOD	571,000	155,500	75,000	801,500

Note: Capping material quantities include materials for caps, thin-layer caps, and backfill in the river, as well as bank stabilization. Soil backfill includes the backfill to be placed in floodplain excavations.

2.9.2 Reliability of the Technology

The individual technical components of all alternatives, both individually and in combination, are considered reliable, as shown by previous work conducted at the site, including the ½-Mile and 1½-Mile Reach removal actions, which included many of the components of the alternatives, and similar work performed at riverine/floodplain hazardous waste sites for a number of years. Although information regarding remedies at other sediment sites indicates that there have been a limited number of dredging/removal projects of the magnitude of the largest of the alternatives being considered here (i.e., SED 8/FP 7), the techniques being used are considered readily scalable and adaptable to the size and setting of the Rest of River. As discussed above, although thin-layer capping has been used at other sites, it is not expected to be a reliable or effective component for this site.

2.9.3 Regulatory and Zoning Restrictions

No regulatory and/or zoning restrictions are known that would affect the implementability of any of the alternatives under evaluation. Implementation of all alternatives, except SED 2/FP 1, would require GE to obtain permission for access to the properties where the work would be conducted or where the support facilities would be located. Although many of these properties are owned by the Commonwealth or the City of Pittsfield (which have agreed to allow access in the Consent Decree), it is anticipated that access agreements would be required from numerous other property owners − up to approximately 35 such landowners for SED 10/FP 9, 35 to 45 for SED 3/FP 3, 35 to 50 for SED 9/FP 4 MOD, 40 to 50 for SED 5/FP 4, 50 to 60 for SED 6/FP 4 and SED 9/FP 8, and 80 to 95 for SED 8/FP 7. Obtaining access to all these properties for the type of work and length of time that may be needed would require negotiations with landowners; however, this is feasible given the timeframe over which the work would be accomplished (5 to 52 years). In contrast to other more extensive alternatives, SED 9/FP 8 and SED 9/FP 4 MOD may have an advantage in this respect due to the remediation method (no sheetpile, no large cranes, less clearing, and smaller access roads), requiring less extensive agreements with landowners in Reaches 5A and 5B.

2.9.4 Ease of Undertaking Additional Corrective Measures

None of the alternatives being evaluated would preclude the implementation of additional corrective measures if deemed necessary to meet performance standards and/or to achieve protection of human health and the environment. If additional corrective measures are necessary for those alternatives that include the installation of engineered bank stabilization and/or sediment caps, it may be necessary to remove and reinstall such structures, thereby increasing the overall cost of the remedy in comparison with alternatives that do not include such protective structures. However, this consideration does not provide a reasonable basis for distinguishing between the alternatives. Additional corrective actions, such as repairs, if necessary, should provide the same implementation challenges for all active alternatives.

2.9.5 Ability to Monitor Effectiveness of Remedy

The ability to implement a monitoring program for determining the effectiveness of the remedy is similar for all alternatives evaluated in this Comparative Analysis. Such a monitoring program would typically include some combination of water, sediment, and biota sampling to determine PCB flux, residual sediment PCB concentrations, and concentrations of PCBs in edible fish species. Sampling and analysis of these environmental media is not different for any of the alternatives. However, alternatives that have little or no active remediation are less reliable; therefore, they would require more extensive monitoring.

2.9.6 Coordination with Other Agencies

All of the alternatives would include coordination with EPA and state agencies in implementation of biota consumption advisories and other ICs (e.g., environmental restrictions and easements (EREs) and conditional solutions), discussions on potential MESA issues, obtaining access to state-owned lands, and public/community outreach programs. The alternatives with a greater extent of remediation and a longer implementation time would likely require more extensive and prolonged coordination activities. However, the alternatives in which less remediation is performed would require more extensive ICs.

2.9.7 Availability of Suitable Treatment, Storage, and Disposal Facilities

This component of the selection decision factor is discussed in Section 3, Comparative Analysis of Treatment/Disposition Alternatives.

2.9.8 Availability of Prospective Technologies

This component of the selection decision factor is discussed in Section 3, Comparative Analysis of Treatment/Disposition Alternatives.

2.10 COST

The estimated costs for each of the alternatives evaluated, including total capital costs, estimated annual OMM costs, and total estimated present worth costs, are summarized in Table 22. The total costs for these alternatives (without considering treatment/disposition costs) range from $5 million (for MNR, SED 2/FP 1) to $917 million (most extensive remediation option, SED 8/FP 7). Present worth costs range from $1.8 million (SED 2/FP 1) to $300 million (SED 8/FP 7). The costs for all alternatives, except for SED 9/FP 4 MOD, are based on the information available at the time of the estimate and are based on GE’s cost estimates provided in GE’s RCMS. The cost estimate for SED 9/FP 4 MOD is detailed in Attachment 8. EPA generally believes that GE may have under-estimated all costs. However, because all costs were estimated by the same methodology, they are acceptable for comparing costs relative to each alterative, including the proposed alternative. In addition, the actual costs of remediation depend on many variables, including the quantity of material removed, disposal fees, health and safety regulations, ARARs, actual labor, equipment, fuel and material costs, and the final project scope.

Table 22 Cost Summary for Alternatives

Total Cost	SED 2/ FP 1	SED 3/ FP 3	SED 5/ FP 4	SED 6/ FP 4	SED 8/ FP 7	SED 9/ FP 8	SED 10/ FP 9	SED 9/ FP 4 MOD
Capital ($ M)	0	167	307	384	900	381	84	314
OMM ($ M)	5	10	12	13	17	13	10	12
Total ($ M)	5	177	319	397	917	394	94	326
Present Worth ($M)	1.8	133	193	219	300	251	78	228

Notes:

1. All costs are in 2010 dollars. $ M = million dollars.
2. Total capital costs are for engineering, labor, equipment, and materials associated with implementation.
3. Total OMM costs include costs for monitoring, post-construction inspections and repair activities (if necessary), long-term monitoring (fish, sediment, water column, visual), and for the maintenance of institutional controls and EREs.
4. Total present worth cost is based on using a discount factor of 7%, considering the length of the construction period and an OMM period of 100 years on a reach-specific basis.
5. Estimates do not include costs for treatment or disposition of any soil/sediment removed; those costs are outlined in Section 3.

2.11 OVERALL CONCLUSION FOR REMEDIATION ALTERNATIVES

For the reasons discussed above, EPA believes that of all the remediation alternatives, SED 9/FP 4 MOD is best suited to meet the General Standards in consideration of the Selection Decision Factors.

3 COMPARATIVE ANALYSIS OF TREATMENT/DISPOSITION ALTERNATIVES

This section presents a comparative evaluation of the five alternatives for treatment and/or disposition of excavated contaminated river sediment and floodplain soil that were presented in GE's RCMS, plus an additional alternative that was developed by EPA in consultation with the states of Massachusetts and Connecticut subsequent to the RCMS. The treatment/disposition alternatives were evaluated using the same criteria that were used for the sediment/floodplain remediation alternatives.

This comparative analysis evaluates the relative performance of the various treatment/disposition alternatives under the permit criteria to identify the relative advantages and disadvantages of each alternative. The tables present information from GE's RCMS for the five alternatives included in that document. Information for a new sub-alternative (TD 1 RR) was developed by EPA using, where possible, GE's underlying cost assumptions.

3.1 OVERVIEW OF ALTERNATIVES

All five alternatives would involve some disposition of the sediment and floodplain soil in a disposal facility, either directly or after treatment. The three alternatives involving disposal only are: (1) disposal in off-site permitted landfills (TD 1); (2) disposal in an on-site confined disposal facility (CDF) in a local waterbody, e.g., Woods Pond or one or more backwaters (TD 2); and (3) disposal in an on-site upland disposal facility, for which three potential locations have been identified by GE (TD 3). The other two alternatives would involve treatment, either by a chemical extraction process (TD 4) or by thermal desorption (TD 5). EPA also evaluated an additional alternative based on TD 1 but specifying transport of excavated material by rail be maximized; this variation is termed TD 1 RR.

The results of a bench-scale test of a representative chemical extraction process indicate that PCB concentrations in the treated sediment and soil would not be sufficiently low to allow reuse on-site; therefore, the treated sediment and soil resulting from TD 4 would have to be transported to a landfill for disposal. For TD 5, it is assumed that the thermal desorption process would reduce the concentrations of PCBs in the treated solid materials to levels (around 1 to 2 mg/kg) that could allow reuse in the floodplain[11] and that it would not increase the leachability of metals from those materials so as to preclude such use. However, due to uncertainties regarding the ultimate effectiveness of the treatment process (as well as issues relating to the reuse of the treated soil), TD 5 has also been evaluated based on the additional alternate assumption that all the treated material would be transported to an off-site landfill for disposal.

All of the treatment/disposition alternatives except TD 2 were evaluated considering the same range of sediment and soil volumes that could be removed under any combination of the individual sediment and floodplain alternatives, not just the combinations of alternatives evaluated in Section 2. This range extends from 191,000 cy, based on a combination of SED 3 and FP 2, to 2.9 million cy, based on a combination of SED 8 and FP 7. Under TD 2, however, the in-water CDF(s) would be used only for the disposition of hydraulically dredged sediment from Reaches 5C and 6, which would be generated only under SED 6, SED 7, SED 8, or SED 9. Thus, TD 2 was evaluated for a range of hydraulically dredged sediment volumes from 300,000 cy for SED 6 to 1,240,000 cy for SED 8. For cost comparison purposes, the TD 2 analysis assumes that the sediment and soil not placed in the CDF(s) would be transported off-site for disposal. Under this assumption, the lower-bound costs for TD 2 are based on the combined volumes from SED 6 and FP 2, and the upper-bound costs are based on the combined volumes from SED 8 and FP 7.

All five alternatives were evaluated against the nine criteria discussed in Section 2.1. There is no comparison or evaluation of attainment of IMPGs because this is not applicable to material treatment/disposition.

3.2 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

As with the SED and FP alternatives, the evaluation of whether the treatment/disposition alternatives would provide overall human health and environmental protection draws on the evaluations under several other permit criteria, notably long-term effectiveness and permanence (including long-term adverse impacts), and short-term effectiveness.

TD 1 (off-site disposal) would provide protection of human health and the environment by providing for permanent disposal of the PCB-contaminated sediment and soil in permitted off-

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[11] For reuse as backfill in the floodplain, only 50% of the volume is assumed to be the treated material because following thermal treatment the material would be sterile, requiring amendments to be suitable for floodplain restoration.

site landfills. Relative to other alternatives, only minor on-site short-term impacts would occur under TD 1.

TD 1 RR (off-site disposal with rail transport) would provide protection of human health and the environment equivalent to TD 1 with respect to PCB-contaminated sediment and soil, with some additional protection afforded by the rail transport component, which would reduce the effects on surrounding neighborhoods from truck traffic. There would be somewhat greater on-site short-term impacts due to the need to construct a small rail yard and loading facility at some point along the existing rail right-of-way.

TD 2 (disposition in on-site CDF[s]) would provide protection of human health by permanently isolating the hydraulically dredged sediment from Reaches 5C and 6 in covered in-water CDF(s), which would be subject to monitoring and maintenance to verify their long-term integrity. However, this alternative would not provide for disposition of any remaining sediment or the excavated floodplain soil, which would need to be disposed of elsewhere. Although CDFs have been successfully implemented in other settings, implementation of TD 2 in the Housatonic River could cause significant long-term environmental impacts because the CDF(s) would result in a permanent loss of the aquatic habitat in a large portion of Woods Pond and/or one or more of the backwaters where the CDF(s) would be constructed, and potentially could be breached in the future should a catastrophic event occur. TD 2 would result in a permanent loss of flood storage capacity in those areas (assuming that sufficient compensatory flood storage could not be provided).

TD 3 (on-site upland disposal) would provide protection of human health and the environment by permanently isolating the PCB-contaminated sediment and soil in an upland disposal facility, which would be constructed with an appropriate double liner, cover, and double leachate collection system. Although this alternative would cause a change in existing habitat within the operational footprint of the upland disposal facility, the capped landfill area would be replanted with grass, and the support areas that are no longer needed after closure would be restored. The significance of the long-term or permanent change in habitat would depend on the existing habitat at the selected location and the size of the facility. This alternative would have additional short-term impacts such as truck transport of landfill leachate over public roads to GE's groundwater treatment plant (GWTP) located in Pittsfield, and the operation of the landfill for the duration of the remedy. Alternatively, GE would have to construct, operate, and maintain a treatment facility at each of the upland disposal facilities. If these treatment facilities were not operated properly, there would be the potential for releases of PCBs into the area where the facility is located or into the Housatonic River.

TD 4 (chemical extraction) would provide protection of human health and the environment by reducing the PCB concentrations in the sediment and soil, followed by off-site disposal of the treated material. However, the long-term reliability and effectiveness of the chemical extraction process have not been demonstrated for Housatonic River sediment. A bench-scale study for this technology using material from Rest of River failed to demonstrate that site sediment and soil can be treated effectively, in part due to a failure to achieve reasonable mass balance calculations as well as acceptable residual concentrations.

TD 5 (thermal desorption) would provide human health protection by reducing the PCB concentrations in the sediment and soil, followed by on-site reuse and/or off-site disposal of those treated materials and off-site disposal/destruction of the liquids containing the condensed PCBs. On-site reuse of a portion of the treated soil would be protective of human health because the treated solids would be sufficiently characterized to ensure that residual PCB concentrations would not cause adverse human health effects. However, if a portion of the treated soil is reused as backfill in the floodplain, that reuse would potentially result in long-term adverse environmental impacts in the forested floodplain and other wetland areas due to the differences in soil characteristics between those materials and the existing natural soil in those wetland areas unless the treated soil is properly amended. In addition, regardless of whether treated soil is reused in the floodplain, TD 5 would produce the greatest amount of GHG emissions of any of the alternatives.

3.3 CONTROL OF SOURCES OF RELEASES

All of the treatment/disposition alternatives would control the potential for PCB-contaminated sediment and soil to be released and transported within the river or onto the floodplain, although some alternatives would provide more effective control of such releases than others. TD 1 (or TD 1RR) best meet this criterion, followed by TD 3.

Under both TD 1 and TD 1 RR, placement of the removed PCB-contaminated sediment and soil in a permitted off-site landfill or landfills would effectively isolate those materials from being released into the environment.

Under TD 2, placement of the PCB-contaminated sediment and soil into CDF(s) would most likely effectively isolate the removed materials from being released into the environment. However, there is a potential for releases of sediment into the river during the CDF construction process.

TD 3 would address future releases through the placement of the materials in an upland disposal facility and the implementation of a long-term monitoring and maintenance program. Placement of the PCB-contaminated sediment and soil into an upland disposal facility would most likely effectively isolate the removed materials from being released into the environment. However, the potential remains for releases to occur to the Housatonic River watershed both during operations and in the long term if the facility, including potentially a water treatment plant, was not properly operated and maintained.

Under TD 4 and TD 5, the potential for the PCB-contaminated sediment and soil to be released within the river or onto the floodplain during treatment operations would be minimal. However, the potential remains for releases to occur to the Housatonic River watershed both during operations and in the long term if the facilities were not properly operated and maintained. Under TD 4, the treated solid materials would be transported to an off-site landfill for disposal, the wastewater would be subject to treatment prior to discharge to the river, and the water treatment sludge would also be transported to an off-site landfill for disposal. Under TD 5, to the extent that some of the treated solids are used as backfill in the floodplain, chemical characterization sampling would be performed to verify that those materials would not present concerns regarding future releases or exposure. The remainder of the treated solids, or all such solids if none are reused as floodplain backfill, would be transported to an off-site landfill for disposal, and the concentrated PCB-contaminated liquid condensate from the thermal desorption process would be sent off-site for incineration.

3.4 COMPLIANCE WITH FEDERAL AND STATE ARARs

Each of the TD alternatives would involve moving the sediment, bank soil, and floodplain soil from the point of excavation to the treatment/disposition point, and each TD alternative would attain the ARARs, except as discussed below.

TD 1, with disposal off-site at one or more permitted disposal sites, would have fewer additional ARARs than the other treatment/disposition alternatives, and would attain the requirements. TD 1 RR would have all the same ARARs as TD 1. TD 2, an in-water CDF, would be considered a hazardous waste and solid waste disposal site, and would have ARARs associated with its location in the river, and with being in a potential habitat area for state-listed species. TD 2 would not meet wetland and floodplain requirements. TD 3, on-site landfilling, has ARARs associated with being a hazardous waste and solid waste disposal site, and possibly impacts on wetland areas. In addition, two of the potential locations for the TD 3 upland disposal facility, along with the CDFs, are in, or in close proximity to, a state-designated Area of Critical Environmental Concern (ACEC). As such, not all potential locations of TD 2 or TD 3 will meet the requirements of 310 CMR 30.708 or the site suitability criteria in the Commonwealth's Site Assignment Regulations for Solid Waste Facilities, 310 CMR 16.40(3)(4), which prohibit hazardous waste and solid waste facilities in an ACEC, or adjacent to or in close proximity to an ACEC such that it would fail to protect the outstanding resources of an ACEC. Furthermore, certain locations of TD 3 would not meet the Massachusetts Hazardous Waste Facility Site Safety Council Regulations (990 CMR 5.04), which provide criteria for evaluation of a notice of intent for siting a hazardous waste facility, including that it is not within an ACEC.

TD 4 and TD 5 have ARARs related to the treatment of toxic substances/hazardous waste, and depending on their location, would have wetland, floodplain, and/or species habitat ARARs to attain.

Additional information on federal and state ARARs is provided in Attachment 13.

3.5 LONG-TERM RELIABILITY AND EFFECTIVENESS

The assessment of long-term reliability and effectiveness for the treatment/disposition alternatives included an evaluation of the magnitude of residual risk, the adequacy and reliability of the alternatives, and the potential long-term adverse impacts on human health or the environment.

3.5.1 Magnitude of Residual Risk

Placement of PCB-contaminated sediment/soil in off-site permitted landfills (TD 1 and TD 1 RR), in one or more CDF(s) (TD 2), or in an upland disposal facility (TD 3) would permanently isolate those materials from direct contact with human and ecological receptors. Under TD 2, as noted above, there is a greater potential for releases and resulting risk than under TD 1 and TD 3, although there is some risk of releases from TD 3.

Under TD 4 and TD 5, it is not expected that there would be any significant residual risks, because: (1) all treatment operations would be performed within secured areas, and residual PCBs associated with the operations would be removed following completion of the treatment operations; (2) all treated materials would be subject to verification sampling and successfully and unsuccessfully treated material would be transported off-site for disposal, except for any such material reused on-site under TD 5; and (3) any such treated materials reused on-site under TD 5 would be sampled to verify that the material to be reused would not pose a residual risk.

In summary, all of the treatment/disposition alternatives would minimize future residual risk from exposure to the PCB-contaminated materials, although there would be a greater potential for such exposure under TD 2 and TD 3 than under the other alternatives, for the reasons noted above.

3.5.2 Adequacy and Reliability of Alternatives

There are considerable differences in the adequacy and reliability of the five treatment/disposition alternatives. Based on these differences, the adequacy and reliability criterion favors either TD 1, TD 1 RR, or TD 3 for disposal of the excavated materials under all alternatives.

Use of off-site disposal facilities (TD 1 and TD 1 RR) is a common and effective means for permanent disposition of PCB-contaminated material. As the volume of materials requiring disposal increases, multiple facilities may be required, but that is not expected to be a major consideration.

In-water CDFs (TD 2) have been used to dispose of dredged PCB-contaminated sediment at some sites. In this case, as discussed above, there is a somewhat greater potential for releases from the CDF(s) than from off-site or local upland disposal facilities.

On-site disposal of PCB-contaminated materials in an upland facility (TD 3) has been used as part of a final remedy at a number of sites and is an effective and reliable means for permanently isolating such materials, provided the facility is properly constructed, monitored, and maintained. However, the potential extended duration of the operation of such a facility for the range of volumes of sediment and soil and the length of remedy implementation could necessitate that the facility operate for an extended period of time. In addition, GE proposes to truck the leachate generated under TD 3 to its water treatment facility located in Pittsfield. This involves a one-way trip of between 10 and 20 miles along public roads for the foreseeable future. The proposed facility near Woods Pond could generate as much as 600,000 gallons of leachate per month (based on its maximum size of 18 acres for 2,000,000 cy) for 10 to 20 years, requiring over 1,000 truck trips per year (120 per month) while the facility is still receiving material. Based on SED 8/FP 7, which has a volume of 2,900,000 cy, the amount of leachate could be as high as 1,000,000 gallons per month (based on the maximum landfill footprint at the site near Rising Pond). This volume could occur for up to 52 years and would require 200 truck trips per month or 2,400 per year. Alternatively, GE would have to construct, operate, and maintain a treatment facility at each of the upland disposal facilities. If these treatment facilities were not operated properly, there would be the potential for releases of PCBs into the area where the facility is located or into the Housatonic River. TD 3 relies heavily on proper long-term operation, maintenance, and monitoring activities.

The use of chemical extraction (TD 4) has not been demonstrated at full scale on sediment and soil representative of the Rest of River. The results of bench-scale testing using site sediment and soil did not demonstrate that this technology would be effective. As a result, there are uncertainties about the long-term reliability and effectiveness of operating such a system for a project of the size and duration, and with the range of PCB concentrations, that would be involved at the Rest of River. These and other factors create uncertainties regarding the effectiveness and reliability of using the chemical extraction process in a full-scale application.

Thermal desorption (TD 5) has been used at several sites to treat PCB-contaminated soil; however, there is only limited precedent for use of this technology on sediment due in part to the time and cost of removing moisture from the sediment prior to treatment. At the sites identified where thermal desorption has been used, the volumes of materials that were treated were substantially smaller and the duration of the treatment operations was substantially shorter than the volumes and duration that could be required at the Rest of River. Furthermore, when on-site reuse of treated materials has occurred, the materials have typically been placed in a small area and covered with clean backfill. For these reasons, the adequacy and reliability of this process for a long-term treatment operation with a large volume of materials such as sediment/soil from the Rest of River is uncertain.

3.5.3 Potential Long-Term Adverse Impacts on Human Health or the Environment

Implementation of TD 1, TD 1 RR, TD 2, and TD 3 would isolate the removed sediment/soil from potential human and ecological exposure because the material would be contained in structures designed specifically for that purpose. Under TD 4, removed material would first be treated, and then disposed of off-site. For TD 5, materials would be treated, and then a portion might be reused in the floodplain, assuming that it has acceptable residual levels of contaminants, with the remainder disposed of off-site. Thus, under all the treatment/disposition alternatives, no long-term adverse impacts on humans or ecological receptors from exposure to the PCB-contaminated materials are expected, with the potential exception of TD 2 if a release were to occur (e.g., during an extreme storm event).

TD 1 would not cause any adverse long-term environmental impacts in the Rest of River area because it would involve off-site transport and disposal of the PCB-contaminated materials.

TD 1 RR would also not result in adverse long-term environmental impacts in the Rest of River area. The rail yard and loading facility would be demobilized following completion of the remedy and the area restored to its former condition.

For TD 2, the placement of an in-water CDF in Woods Pond and/or one of the two identified backwaters would have the most significant long-term adverse environmental impacts, including a permanent loss of the aquatic habitat in those areas. Depending on the location and size of the CDF(s), TD 2 could adversely affect the priority habitat of up to nine state-listed species. In addition, the CDF(s) would raise the topography of the CDF area(s), reduce available shoreline/wetland habitat, and produce a loss of the existing flood storage capacity.

For TD 3, the construction of the upland disposal facility, which, for the Woods Pond site, is located within an Area of Critical Environmental Concern, would result in the alteration of existing habitat within the operational footprint of that facility. In the landfill area itself, as well as any support areas (e.g., access roads) that would remain after closure, the habitat alteration would be permanent, although the landfill would be capped and planted. The significance of the change in habitat would depend on the existing habitat at the location of the facility, as well as the size of the facility.

Under TD 4 and TD 5, the construction and operation of a 5-acre treatment facility at the former DeVos property would result in some loss of the relatively low-quality habitat within that area (a former agricultural area that is now open grassland with scattered shrubs) during the period of treatment operations and for a few years thereafter. That loss, as well as increased noise and human presence in the area, would affect the wildlife in the area (which includes the priority habitat for some state-listed species) during that period. However, given the relatively small size of the facility, the altered nature of the habitat, and the planned reseeding of the area with a grassland mix following removal of the facility, long-term ecological impacts associated with construction and operation of the facility would be minimal.

Based on this analysis of the treatment/disposition alternatives, TD 2, and to a lesser extent TD 3 (depending on the actual landfill location selected), would have the greatest long-term adverse environmental impacts. TD 4 and TD 5 would have similar environmental impacts, but less than TD 3 because they would be in place only for the duration of the remedial construction. TD 1 and TD 1 RR would have the least long-term impacts.

3.6 ATTAINMENT OF IMPGs

Attainment of IMPGs is not applicable to evaluation of treatment and disposition alternatives.

3.7 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME

The degree to which the treatment/disposition alternatives would reduce the TMV of PCBs is discussed below.

3.7.1 Treatment Process Used and Materials Treated

TD 1 through TD 3 (including TD 1 RR) would not include any treatment processes that would reduce the toxicity of, or directly affect, PCB concentrations in the removed sediment and soil. TD 4 and TD 5 would incorporate treatment processes that can, to varying degrees, reduce concentrations of PCBs. Under TD 4, the chemical treatment process would reduce the toxicity of the sediment and soil by permanently removing some PCBs from these materials, although the effectiveness of this technology is questionable. Under TD 5, the indirect-fired thermal desorption system would reduce the toxicity of the PCB-contaminated sediment and soil by permanently removing PCBs from these materials, and the PCBs in the liquid stream would be sent to a permitted off-site disposal facility for destruction. The volume and nature of the materials to be treated would be determined by the selected remediation alternative and are, therefore, identical for all treatment/disposition alternatives.

3.7.2 Amount of Hazardous Materials Destroyed or Treated

As noted above, only TD 4 and TD 5 specify the treatment and/or destruction of PCBs. TD 4 would remove PCBs from contaminated soil and sediment via chemical treatment but would not, in itself, destroy any of the PCBs so removed. In addition, the effectiveness of this process on site materials has not been demonstrated. TD 5 would similarly not destroy PCBs on-site, but only separate them from the site soil and sediment. Subsequent destruction of PCBs could be accomplished on-site via further treatment of the waste stream from either TD 4 or TD 5, but is not an inherent component of either alternative.

3.7.3 Degree of Expected Reductions in Toxicity, Mobility, or Volume

Reduction of Toxicity: TD 1 through TD 3 (including TD 1 RR) would not include any treatment processes that would reduce the toxicity of, or directly affect, PCB concentrations in the removed sediment and soil. TD 4 and TD 5 would incorporate treatment processes that can, to varying degrees, reduce concentrations of PCBs and therefore reduce toxicity, as discussed above.

Reduction of Mobility: All of the alternatives would reduce the mobility of PCBs in the sediment and soil. In TD 1, TD 1 RR, TD 2, and TD 3, these materials would be removed and disposed of in off-site permitted landfill(s) (TD 1 and TD 1 RR) or permanently contained within on-site CDF(s) (TD 2) or an upland disposal facility (TD 3). TD 4 and TD 5 would reduce the mobility of PCBs present in the sediment/soil via chemical extraction or thermal desorption.

Reduction of Volume: TD 1, TD 1 RR, TD 2, and TD 3 would not reduce the volume of PCB-contaminated material. For TD 4, treatment of sediment/soil would reduce the volume of PCBs present in those materials by transferring some of the PCBs to an aqueous waste stream for subsequent treatment. PCB-contaminated sludge would be generated from the wastewater treatment system and would be sent to a permitted off-site facility for disposal. For TD 5, treatment of sediment/soil in the thermal desorption system would reduce the volume of PCBs present in those materials, with the liquid condensate transported to an off-site facility for destruction.

3.7.4 Degree to Which Treatment Is Irreversible

This criterion is not applicable to TD 1 through TD 3 because these alternatives do not involve treatment. For TD 4 and TD 5, off-site treatment of the extracted PCB waste streams would result in the permanent and irreversible destruction of PCBs.

3.7.5 Type and Quantity of Residuals Remaining After Treatment

This criterion applies only to alternatives TD 4 and TD 5. Because the materials to be treated would be determined by the remediation alternative selected and the details would be determined in the final design of the remediation, both treatment alternatives would begin with the same type and quantity of material. As discussed above, thermal absorption (TD 5) is a more proven technology than chemical extraction and, recognizing that dewatering of sediment may present additional technical complexity for this process, it is believed that TD 5 will result in residual materials that may be sufficiently low in PCB concentration to be reused on-site. In the case of

TD 4, the chemical extraction process is believed to result in residuals of PCB concentration that will require landfilling following treatment.

3.8 SHORT-TERM EFFECTIVENESS

Evaluation of the short-term effectiveness of the treatment/disposition alternatives includes consideration of the short-term impacts of implementing these alternatives on the environment (considering both ecological effects and increases in GHG emissions), on the local communities (as well as communities along truck transportation corridors), and on the workers involved in the treatment and disposition activities.

3.8.1 Impacts on the Environment

All the treatment/disposition alternatives would produce some short-term adverse impacts on the environment, but to varying degrees depending on the duration and scope of the alternative. TD 1 would have the least impacts of all the TD alternatives, requiring only access roads and staging areas for loading of vehicles for off-site transport. TD 1 RR would require the construction of a rail yard and loading facility at some point along the existing rail right-of-way and would require approximately the same amount of access roads and staging areas as TD 1. The short-term impacts of TD 2 through TD 5 would include loss of habitat and loss or displacement of aquatic biota and other wildlife in the areas where the disposition or treatment facilities are located, as well as in adjacent areas, during construction and operations. TD 2 would affect a portion of Woods Pond and/or one of the two backwaters identified for a CDF, as well as the adjacent floodplain. Specific short-term impacts associated with TD 3 would depend on the habitat at the selected location and the operational footprint of the facility. Construction of a treatment facility for TD 4 or TD 5 on the former DeVos property would result in the temporary reduction of open field habitat on that property.

All of the treatment/disposition alternatives could also have short-term effects on the environment due to the potential for accidental releases of PCB-contaminated materials. In particular, TD 3 has the risk of the release of leachate during its transport from the upland disposal facility(s) to the GE GWTP in Pittsfield if an alternate treatment facility is not constructed. In addition, TD 4 and TD 5 have the potential for failure of process and control equipment during operations, which could result in a release of PCB-contaminated materials. The potential for these types of effects would increase with the volume of materials removed and the length of the implementation period.

3.8.2 Carbon Footprint – GHG Emissions

GHG emission estimates were developed based on the ranges of the potential volumes of sediment and soil that would require disposal or treatment. Table 23 summarizes the resulting ranges of total GHG emissions associated with each TD alternative. To provide context regarding the emissions reported, the number of passenger vehicles that would emit an equivalent quantity of $CO_{2\text{-eq}}$ in 1 year is also presented in the table.

As shown in Table 23 for the TD alternatives evaluated in the RCMS (excluding TD 2, which is not comparable, and TD 1 RR for which estimates were not available), TD 5 would have the greatest amount of total GHG emissions for the range of volumes; TD 4 would have the next largest amount; followed by TD 1. TD 3 would have lowest amount of total GHG emissions for the range of volumes, approximately 3 to 5 times less than the next lowest alternative (TD 1). TD 1 RR would have significantly lower GHG emissions than TD 1 because the emissions due to off-site truck transport would be replaced by the much lower emissions resulting from off-site transport via rail. It should be noted, however, that the magnitude of the differences among alternatives varies with the removal volume. For example, the lower-bound estimates for TD 1 and TD 3 are 19,000 and 5,500 tonnes, respectively, a difference of 13,500 tonnes. However, the upper-bound estimates are 290,000 tonnes for TD 1 and 61,000 tonnes for TD 3, a difference of 229,000 tonnes (17 times more than the difference at the lower bound). The differences in GHG emissions between TD 1 and TD 3 are due to the distance that materials need to be trucked before ultimate disposition. Such differences are even more pronounced when comparing TD 3 with TD 4 and TD 5.

Table 23 Calculated GHG Emissions Anticipated to Result from Treatment/Disposition Alternatives

Alternative	Total GHG Emissions (tonnes)	No. Vehicles with Equivalent Emissions
TD 1	19,000 – 290,000	3,600 – 55,400
TD 2	See Note 1	See Note 1
TD 3 (see Note 2)	5,500 – 61,000	1,100 – 11,700
TD 4	27,000 – 370,000	5,200 – 70,700
TD 5 (with reuse)	66,000 – 1,000,000	12,600 – 191,200
TD 5 (without reuse)	66,000 – 1,100,000	12,600 – 210,300

Notes:

1. Emissions estimated for TD 2 range from 2,700 to 8,800 tonnes and do not include the emissions that would be necessary for off-site transport and disposal of materials that are not placed in the CDF(s). As such, these estimates are not comparable to the emissions listed for the other alternatives.
2. The lower bound of this range for TD 3 is based on disposal of the minimum potential removal volume at the Woods Pond site (which would have the lowest GHG emissions of the identified sites) and the upper bound is based on disposal of the maximum potential removal volume at the Rising Pond site, which is the only one of the identified local disposal sites that could accommodate that maximum volume. Note also that the Woods Pond site is located within the State-designated Area of Critical Environmental Concern.

3.8.3 Impacts on Local Communities

All the alternatives would also result in short-term impacts to the local communities in the Rest of River area. These impacts would include disruption, noise, and other impacts resulting from the increased truck traffic and from the construction and operation of the on-site disposition or treatment facilities. TD 1 RR, due to its use of rail transport, would result in a significant decrease in impacts to local communities due to reduced off-site truck traffic. In addition, unique to TD 3, leachate potentially being transported via truck from the upland disposal facility(s) could be released en route due to malfunctioning equipment or an accident, creating impacts to the local communities, and the operation of the landfill for the duration of the remedy.

The estimated numbers of off-site truck trips for each alternative, based on the estimated range of volumes that could be involved, are shown in Table 24.[12]

Table 24 Estimated Off-Site Truck Trips for Treatment/Disposition Alternatives

Alternative	Off-Site Truck Trips for Lower-Bound Volume	Off-Site Truck Trips for Upper-Bound Volume
TD 1	15,900 (2,000)	243,000 (6,100)
TD 2	See Note 3	See Note 3
TD 3 (see Note 4)	1,450 (180)	68,000 (3,600)
TD 4	15,900 (2,000)	243,000 (6,100)
TD 5 (with reuse)	13,300 (1,700)	190,500 (4,800)
TD 5 (without reuse)	14,300 (1,800)	218,900 (5,500)
TD 1 RR	0 (0) Note 7	0 (0)

Notes:

1. Truck trips estimated assuming 16-ton capacity trucks for importing material and equipment to the site, 20-ton capacity trucks for transporting excavated materials, and 20% bulking factor in the trucks.
2. The number in parentheses represents average annual truck trips.
3. Truck trips estimated for TD 2 range from 5,600 to 19,500 and do not include the truck trips that would be necessary for off-site transport and disposal of materials that are not placed in the CDF(s). As such, these estimates are not comparable to the numbers of truck trips listed for the other alternatives.
4. The lower bound of this range for TD 3 is based on construction of an upland disposal facility at the Woods Pond site and the upper bound is based on construction of such a facility at the Forest Street site. Note that the Woods Pond site is located in a State-designated Area of Critical Environmental Concern, and Forest Street is in close proximity to the ACEC.
5. A 10% volume reduction of sediment/soil after treatment has been assumed for thermal desorption treatment (TD 5).
6. For TD 5 with reuse, it is assumed that approximately 50% of the floodplain soil treated by thermal desorption would be reused on-site and that all remaining materials would be transported off-site for disposal.
7. It was assumed for the purpose of this analysis that there would be zero off-site truck trips; however, use of trucks may be necessary under certain conditions.

As shown in this table, excluding TD 2, which is not comparable, TD 3 would involve the fewest off-site truck trips for the range of volumes, whereas those for the other alternatives are roughly comparable, with somewhat more for TD 1 and TD 4 than for TD 5. TD 1 RR will maximize the transport of the contaminated soil via rail; therefore, off-site truck traffic will be minimized. Again, however, the magnitude of the differences among alternatives varies with the removal volume. The additional truck traffic would also increase the risk of traffic accidents along transport routes. An analysis of potential risks from the increased off-site truck traffic that would be associated with the treatment/disposition alternatives in terms of potential fatalities and non-fatal injuries is presented in Table 25.

The incidence of potential injuries and fatalities resulting from accidents associated with increased off-site truck traffic would be the greatest for TD 1 and TD 4, followed closely by

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[12] For comparability among alternatives, this table shows only off-site truck trips, i.e., those for importation of construction materials and equipment to the site over public roads for construction and closure of a local disposal or treatment facility, as well as those for transport of excavated or treated soil/sediment to off-site disposal facilities. It does not include transport of excavated materials from the staging areas to the local disposal or treatment facility.

TD 5, and would be far lower for TD 3. As with the number of off-site truck trips, the differences in estimated injuries and fatalities resulting from such traffic become more pronounced as the removal volumes increase. Because TD 1 RR would require no off-site truck traffic, no injuries or fatalities are associated with this alternative because it was assumed for the purpose of this analysis that there would be zero off-site truck trips; however, it may be necessary to use trucks instead of rail under certain conditions.

Table 25 Incidence of Accident-Related Injuries/Fatalities Due to Increased Off-Site Truck Traffic

Impacts	TD 1	TD 2	TD 33	TD 4	TD 5 (with Reuse)	TD 5 (without Reuse)	TD 1 RR
Non-Fatal Injuries							
Number	4.34 – 67.03	See Note 2	0.03 – 1.60	4.11 – 62.87	3.44 – 49.24	3.70 – 56.59	Note 4
Average Annual Number	0.45 – 1.28	See Note 2	0.0002 – 0.084	0.51 – 1.57	0.43 – 1.23	0.46 – 1.41	0
Probability[1]	99 – 100%	See Note 2	3 – 80%	98 – 100%	97 – 100%	98 – 100%	-
Fatalities							
Number	0.20 – 3.14	See Note 2	0.002 – 0.07	0.19 – 2.94	0.16 – 2.31	0.17 – 2.65	0
Average Annual Number	0.02 – 0.06	See Note 2	0.0002 – 0.004	0.02 – 0.07	0.02 – 0.06	0.02 – 0.07	0
Probability[1]	18 – 96%	See Note 2	0.2 – 7%	18 – 95%	15 – 90%	16 – 93%	-

Notes:

1. Probability indicates the probability of at least one injury/fatality.
2. The estimated risks of accidents for TD 2 are based only on the truck trips necessary to transport materials to the site for the construction of the CDF(s) and do not consider the truck trips for off-site transport of the materials that would not be placed in the CDF(s). As such, those risks are not comparable to the estimated risks for the other treatment/disposition alternatives (which consider all removed materials). Under the scenario evaluated, the risks estimated for TD 2 are 0.01 to 0.02 fatalities (with a 1% to 2% probability of at least one fatality) and 0.13 to 0.46 non-fatal injuries (with a 12% to 37% probability of at least one injury).
3. The lower bound of this range for TD 3 is based on construction of an upland disposal facility at the Woods Pond site and the upper bound is based on construction of such a facility at the Forest Street site.
4. It was assumed for the purpose of this analysis that there would be zero off-site truck trips; however, use of trucks may be necessary under certain conditions.

3.8.4 Potential Measures to Avoid, Minimize, or Mitigate Short-Term Environmental and Community Impacts

A number of measures would be employed in an effort to avoid, minimize, or mitigate the short-term impacts of the treatment/disposition alternatives on the environment and the affected communities. As would be expected, the level of impact and thus the scope and duration of mitigation measures are related to the scale/scope of the alternative and the duration of implementing the alternative. For TD 1, the mitigation measures would relate to the increased truck traffic, whereas for the other TD alternatives, mitigation measures would address the increase in truck traffic as well as the impacts associated with the construction and operation of the different facilities.

3.8.5 Risks to Remediation Workers

There would also be health and safety risks to site workers implementing each of these alternatives. For TD 1 and TD 1 RR, these risks would consist of risks to the truck drivers and, in the case of TD 1 RR, railroad employees, and to the employees of the off-site disposal facilities, rather than to on-site remediation workers, and thus, were not quantified. For TD 2 through TD 5, an analysis of estimated risks to site workers is summarized in Table 26.

Estimated risks to site workers for the range of volumes would be lowest for TD 2 (due to its fewer years of operation) and higher for the other alternatives, with TD 3 slightly higher than TD 4 and TD 5. In this case, there are no substantial differences among TD 3, TD 4, and TD 5 at the same volumes, but there are significant differences between the lower and upper bounds.

Table 26 Incidence of Potential Accidents/Injuries Due to Implementation of Alternatives TD 2 through TD 5

Impacts	TD 2	TD 3[a]	TD 4	TD 5
Labor-hours (hours)	73,000 – 259,000	306,000 – 1,836,000	160,600 – 1,673,600	160,600 – 1,673,600
Years of Operation	6 – 20	8 – 40	8 – 40	8 – 40
Non-Fatal Injuries				
Number	0.70 – 2.50	2.69 – 16.4	1.27 – 13.1	1.27 – 13.1
Average Annual Number	0.12 – 0.13	0.34 – 0.41	0.16 – 0.33	0.16 – 0.33
Probability[b]	50 – 92%	93 – 100%	72 – 100%	72 – 100%
Fatalities				
Number	0.01 – 0.03	0.02 – 0.11	0.007 – 0.08	0.007 – 0.08
Average Annual Number	0.0012 – 0.0013	0.002 – 0.003	0.0009 – 0.002	0.0009 – 0.002
Probability[b]	1 – 3%	2 – 11%	0.7 – 8%	0.7 – 8%

[a] The lower bound of this range for TD 3 is based on disposal of the minimum potential removal volume at the Woods Pond site, and the upper bound is based on disposal of the maximum potential removal volume at the Rising Pond site, which is the only one of the identified local disposal sites that could accommodate that maximum volume and thus, has the longest period of operations.

[b] Probability indicates the probability of at least one injury/fatality.

3.8.6 Summary of Short-Term Effectiveness

All of the treatment/disposition alternatives would have some short-term negative impacts on the environment, local communities, and communities along transport routes. TD 2 through TD 5 would cause a loss of habitat and loss or displacement of wildlife in the area where the disposal or treatment facility is located, as well as in adjacent areas, during construction and operation of the facility. In addition, all alternatives would involve the potential for accidental releases of various PCB-contaminated materials during transportation to off-site or local disposal or treatment facilities. This potential would increase with TD 2, TD 3, TD 4, and TD 5 because those alternatives would pose additional risks associated with the potential for failure of process and control equipment during operations, and releases of process byproducts/chemicals/leachate to the environment. Although all alternatives would generate GHG emissions, for the range of volumes (excluding TD 2, which is not comparable), TD 5 would produce the most such emissions and TD 3 would produce the least.

Estimates of off-site truck trips and traffic accident risks from that truck traffic indicate that, for the range of volumes (excluding TD 2), TD 1 and TD 4 would involve the most off-site truck trips and cause the most injuries related to such transport, followed closely by TD 5, with far fewer off-site truck trips and transport-related injuries for TD 1 RR and TD 3. In terms of risks to on-site workers, excluding TD 1 (which would not affect site workers) and TD 2 (which is not comparable), the estimated injuries for the other three TD alternatives are roughly comparable for the same volumes.

3.9 IMPLEMENTABILITY

The relative implementability of the treatment/disposition alternatives is evaluated below using the eight specific components of this criterion specified in the RCRA Permit.

3.9.1 Ability to Construct and Operate the Technology

Each of the technologies under evaluation can be constructed and operated as necessary. For the alternatives involving landfilling, hazardous materials landfills are routinely constructed and operated and the techniques involved are well known and of demonstrated effectiveness. Any necessary transportation infrastructure, including construction of a small rail yard and loading facility in the case of TD 1 RR, would similarly present no difficulties.

In the case of TD 2, the construction and operation of in-water CDFs has also been implemented at many locations, particularly in the Great Lakes. Although construction and operation of a CDF in a flowing river is less common, the locations proposed for the CDF(s) in the Rest of River are in non-flowing, or very slightly flowing, areas.

Although the effectiveness of thermal desorption and of chemical extraction technology has not yet been demonstrated for Housatonic River soil and sediment, both basic processes are in use in other locations. Construction and operation of facilities in the Rest of River area may present some minor logistical issues, but none of these issues is believed to present unusual problems.

3.9.2 Reliability of the Technology

For the alternatives involving landfilling, hazardous waste landfills have been proven to be reliable in reducing and/or eliminating exposure to hazardous materials placed in them. Similarly, transportation of hazardous materials via truck or rail is a routine and accepted technology with appropriate controls to safeguard the public and workers. CDFs have similarly been shown to be reliable when constructed and operated properly. In the case of TD 2, construction of CDFs in an area that could be subject to flooding and stronger river flow in the case of extreme storm events makes this technology less reliable than it would be when applied to non-riverine situations.

Chemical extraction is of unknown, but somewhat questionable, reliability in the case of PCB-contaminated soil and sediment from Rest of River. A pilot-scale study of one technology using site-specific materials failed to demonstrate the effectiveness of chemical extraction for these materials; therefore, chemical extraction cannot be considered reliable at this time. Thermal desorption, although generally accepted as a reliable technology for removing contaminants from soil, has similarly not been demonstrated on Housatonic River materials and, in addition, would involve prior dewatering of contaminated sediment. Although sediment dewatering is a generally proven and accepted technology, its effectiveness in conjunction with thermal desorption has not been demonstrated on sediment from Rest of River. Accordingly, thermal desorption cannot be considered a reliable technology for the proposed application at this time.

3.9.3 Regulatory and Zoning Restrictions

TD 1 and TD 1 RR would be conducted in accordance with the requirements of applicable federal, state, and local regulations relating to the off-site transport and disposal. The four other alternatives would be “on-site” activities for the purposes of the permit exemption set forth in Section 121(e) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Paragraph 9.a of the Consent Decree. As such, no federal, state, or local permits or approvals would be required. However, implementation of these alternatives would need to comply with the substantive requirements of applicable or relevant and appropriate regulations (i.e., ARARs) (unless waived), and as noted above, two of the three sites proposed for an upland disposal landfill would likely be affected by ACEC and Massachusetts regulations restricting siting of such facilities within or in close proximity to an ACEC.

Implementation of TD 1 would not require access agreements beyond those necessary to conduct the remediation. Implementation of TD 2 and TD 3 would require permanent access to the location(s) selected for the disposal facility(ies). Implementation of TD 4 and TD 5 would require access to the location selected for the treatment facility; GE is the current owner of the potential location identified for TD 4 and TD 5, as well as one potential location for TD 3. It is EPA’s understanding that GE has negotiated the right to acquire the other two sites identified as potential locations for TD 3. Therefore, assuming use of one or more of these locations, no site access agreements would be required for implementation of TD 3 through TD 5, but such agreements may be required for TD 2. TD 1 RR would require an access agreement for the rail siding and loading facility, which would be assumed to be temporary.

In conclusion, there is a clear distinction among the alternatives with respect to this criterion: TD 1 would be easiest to implement, followed closely by TD 1 RR, with TD 2 and TD 3 being the most difficult and time consuming to implement from an administrative perspective, whereas TD 4 and TD 5 would experience similar difficulties from a technical perspective. Construction of either an in-water CDF (TD 2) or an on-site hazardous waste landfill (TD 3) would face considerable public opposition and would also potentially conflict with the designation of the area as an ACEC.

3.9.4 Ease of Undertaking Additional Corrective Measures

The primary constraint on the ability of any of the treatment/disposition alternatives to accommodate additional corrective measures relates to their ability to deal with increased volumes of contaminated material. In the case of TD 1 and TD 1 RR, there is some uncertainty regarding the future availability of the necessary capacity in off-site landfills, which could present issues if it was deemed necessary to undertake additional corrective measures that would require removal of additional volumes of contaminated soil and/or sediment. Capacity would be an even greater issue with TD 2 because there is some question whether the proposed CDF(s) have sufficient capacity to deal with the volume of material that would be generated by the remedial alternatives already under consideration.

In the case of TD 3, the capacity of the proposed on-site landfills is known and is sufficient to receive a volume of material considerably greater than the most extensive remedial alternative under consideration (SED 8/FP 7). However, the capacity is finite, and if additional remediation well beyond that alternative is proposed, landfill capacity would represent a constraint on the ability to undertake such an expanded remediation.

TD 4 (chemical extraction) does not appear to be capable of lowering PCB concentrations in treated material to a level that would allow treated materials to be reused on site. Because such material would require removal to an off-site landfill and would not be decreased in volume as compared with non-treated material, TD 4 is subject to the same potential issues discussed for TD 1 and TD 1 RR. It is believed that TD 5 (thermal desorption) may produce material that could be reused on-site, so there is decreased concern over landfill capacity limitations, but it remains uncertain that such low concentrations can be achieved.

3.9.5 Ability to Monitor Effectiveness of Remedy

All of the treatment/disposition alternatives can readily be monitored with existing and well-established techniques, and such monitoring would be part of any comprehensive OMM program for the remediation of the river. For an in-river CDF (TD 2), more intensive monitoring to ensure the integrity of the facility would likely be required, but no special techniques would be necessary. Similarly, in the case of TD 4 or TD 5, additional monitoring of the treatment process performance would presumably be part of the monitoring program, but such additional monitoring presents no unique technical challenges.

3.9.6 Coordination with Other Agencies

All alternatives would require coordination with EPA, as well as state and local agencies. TD 2 and TD 3 would require extensive coordination with local government and the public. Based on past public input received, these options could encounter substantial local and state opposition, likely rendering these alternatives difficult, and potentially not feasible, to implement. TD 4 and TD 5 would require similar coordination; however, the level of coordination would likely be less than that for TD 2 and TD 3. The Commonwealth of Massachusetts has expressed a strong preference for treatment/disposition alternatives that will permanently relocate contaminated materials in licensed out-of-state facilities, with a strong preference for the use of rail. Of the evaluated alternatives, only TD 1 and TD 1 RR could satisfy this requirement.

3.9.7 Availability of On-Site or Off-Site Treatment, Disposal, and Storage Facilities

For TD 1 and TD 1 RR, there are uncertainties regarding the future availability of the necessary capacity in off-site landfills for the alternatives that have the larger volumes and longer durations. In addition, TD 1 RR has some additional uncertainty related to the timing and availability of rail transport capacity.

For TD 2, it would likely not be feasible to obtain sufficient flood storage compensation at the appropriate elevations/areas to provide for construction of a CDF(s) large enough to hold the necessary sediment disposal volumes. For TD 3, construction and use of an upland disposal facility would be technically implementable, but practically very difficult, if not impossible, to implement. Three potential locations for such a facility, with varying maximum capacities (ranging from 1.0 to 2.9 million cy), have been identified.

TD 4 and TD 5 would be implementable provided that vendors are available to operate the treatment process. The former DeVos property could be used as a potential area to locate a treatment facility. However, there are several uncertainties regarding full-scale application of both chemical and thermal processes to sediment (e.g., moisture content), particularly with some of the volumes associated with the sediment alternatives.

3.9.8 Availability of Prospective Technologies

The availability of additional and/or innovative treatment/disposition technologies during the life of the project is possible, but at this time, none has been demonstrated. In general, any technologies that become available during the implementation of the remediation would be evaluated in a manner similar to that discussed above for Alternatives TD 4 and TD 5. Such an ex situ technology has been proposed and may be tested during the implementation of the preferred remedy.

3.10 COST

The estimated cost ranges for each treatment/disposition alternative, including total capital cost, estimated annual OMM cost, and total estimated present worth are summarized in Table 27 and are taken from GE's RCMS, except for TD 1 RR, which is summarized in Attachment 8. Note that, in this case, the costs presented for TD 2 include not only the costs for disposition in the CDF(s) of the hydraulically dredged sediment from Reaches 5C and 6 under SED 6 through SED 9, but also the estimated costs for off-site transport and disposal of the remaining sediment removed under those alternatives, as well as the excavated floodplain soil (lower-bound costs consider SED 6 and FP 2, and upper-bound costs consider SED 8 and FP 7). In addition, for TD 3, the range of costs presented are for an upland disposal facility constructed at the Rising Pond site because that is the only single location with the capability to hold the maximum potential volume of 2.9 million cy. As shown in Table 27, TD 3 is the least costly alternative. At the low end of the volume range, it would cost about 2 to 4 times less than the other alternatives; and at the high end of the range, it would cost about 2 to 10 times less. TD 1, TD 1RR, and TD 2 are more costly that TD 3, but less costly than TD 4 and TD 5. TD 5 is the most expensive alternative.

3.11 OVERALL CONCLUSION FOR TREATMENT/DISPOSITION ALTERNATIVES

For the reasons discussed above, EPA believes that of all the treatment/disposition alternatives, TD 1 RR is best suited to meet the General Standards in consideration of the Selection Decision Factors.

Table 27 Cost Summary for Treatment/Disposition Alternatives

	TD 1	TD 2	TD 3	TD 4	TD 5 (with reuse)	TD 5 (without reuse)	TD 1 RR
Total Capital Costs	0	$6 – 20 M	$10 – 67 M	$17 – 20 M	$20 – 232 M	$20 – 232 M	$300,000
Total Disposal, Operations, Monitoring and Maintenance Cost	$55 – 832 M	$94 -490 M	$26 – 134 M	$72 – 979 M	$83 – 1,216 M	$86 – 1,293 M	$52 – 787 M
Total Cost for Alternative	$55 – 832 M	$100 – 510 M	$36 – 201 M	$89 – 999 M	$103 – 1,450 M	$106 – 1,530 M	$52 - 787 M
Total Present Worth	$40 – 220 M	$46 – 131 M	$17 – 49 M	$70 – 286 M	$81 – 569 M	$83 – 590 M	$38 - 210M

Notes:

1. All costs are in 2010 dollars, except total present worth values. $ M = million dollars,
2. The fraction of TSCA material has been assumed to be 35%. A density of 1.62 tons per cubic yard was assumed.
3. The Massachusetts hazardous waste transport fee is not included in these estimates. The fee would potentially apply to TSCA material transported off-site via truck. This fee would potentially apply to TD 1, and portions of TD 2, TD 4, and TD 5. The fee is currently $56.25 per ton, including a vehicle identification fee. For TD 1 for Combination 9, the total fee is estimated to be $31.3 million. The fee is not applicable to off-site disposal via rail (TD 1 RR).
4. With the exception of TD 2, the ranges of costs presented are the minimum and maximum anticipated costs based on the potential range of volumes that would be potentially removed under the sediment and floodplain soil alternatives (191,000 cubic yards to 2.9 million cubic yards). For TD 2, the lower-bound costs are based on the combined volume of SED 6 and FP 2 and the upper-bound costs are based on the combined volume of SED 8 and FP 7, with material not placed in the CDF(s) assumed to be transported off-site for non-TSCA disposal. Thus, the upper-bound costs, but not the lower-bound costs, for TD 2 are comparable to the costs for the other alternatives.
5. Total capital costs are for engineering, labor, equipment, and materials associated with implementation.
6. Total operations costs consist of the total of the average annual costs for operation, placement, and/or treatment of sediment and/or soil, estimated for the range of durations for implementing the alternatives.
7. Total monitoring and maintenance costs are for performance of post-closure monitoring and maintenance programs of 100 years for TD 2 and TD 3 and 5 years for TD 4 and TD 5.
8. Total present worth cost is based on using a discount factor of 7%, considering the range of total potential durations for the alternative, and post-closure monitoring and maintenance periods of 100 years for TD 2 and TD 3 and 5 years for TD 4 and TD 5.
9. For TD 5 with reuse, it is assumed that approximately 50% of the floodplain soil treated by thermal desorption would be reused on-site and that all remaining materials would be transported off-site for disposal.
10. Costs for TD 3 do not include the very likely extensive costs associated with the approval process required for an on-site landfill.

ATTACHMENT 11
BANK EROSION/RESTORATION

BANK EROSION/RESTORATION – HOUSATONIC RIVER, MASSACHUSETTS

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LIST OF FIGURES

1. INTRODUCTION

The health of a riverine ecosystem is directly related to the stable and cyclical nature of river processes, which dictate channel and floodplain form and function (Richards, 1982). Bank erosion is one such natural process that influences stream ecosystems in both stable and unstable channels. During flood events, stream banks undergo deformation and erosion as a result of applied forces. These forces erode sediment from stream banks, and this sediment is then deposited along downstream reaches of the channel. Although all channels experience erosion, the erosion rates for stable channels are low. The purpose of this paper is to provide background information on stream bank erosion processes, discuss stream bank erosion along the Housatonic River between the confluence of the East and West Branches and Woods Pond, and describe methods for restoring the stream banks following environmental remediation.

2. OVERVIEW OF BANK EROSION PROCESSES

River systems are complex and contain many inter-connected parts. Stream banks are just one component in this system and form the critical boundary between the channel and floodplain. Bank height and slope determine the ability of the stream to interact with the floodplain, are important indicators of channel stability, and in healthy systems, provide the foundation on which native riparian vegetation colonizes, grows, and thrives. The near-channel vegetation that grows on stream banks and the materials from it drive healthy ecological processes by being the source of organic matter in the form of leaves and woody debris, by shading the stream and providing cover for aquatic species, and by increasing the strength of soil through the soil-binding ability of the roots (FISRWG, 1998).

Banks can both build through deposition and retreat or deform through erosion. Erosion is defined as the detachment and removal of particles or aggregates from the stream bank surface. Bank erosion occurs when shear stress, the force applied to the bank by flowing water, is greater than the ability of the bank to resist deformation or failure (Leopold, 1992). Critical shear stress and applied shear stress are important factors in bank erosion. Critical shear stress is the minimum amount of force necessary to initiate erosion. Critical shear stress is based on the boundary characteristics of the channel, which include vegetation density and rooting depth, substrate composition, soil cohesion, and channel armoring.

Figure 1: View of Highly Eroded Bank along the Housatonic River

Critical shear stress is most influenced by the hydraulic radius of the channel (typically equal to the mean depth) and water surface slope. As mean depth and slope increase, the applied shear stress created by flow in the river also increases. If the applied shear stress produced by the flow in the river exceeds a critical shear stress, then erosion will occur. Natural stable rivers exhibit bank erosion, although in small quantities (less than approximately 0.005 feet per year [ft/yr]) (Rosgen, 2006). In unstable rivers, accelerated bank erosion often occurs, and it is not uncommon for banks to migrate several feet in a single storm event (Leopold, 1992). Although natural erosion in a stable stream system can be a healthy process for a river system, accelerated bank erosion decreases water quality, can cause channels to over-widen, and can be detrimental to stream side vegetation.

3. BANK EROSION ALONG THE HOUSATONIC RIVER

Over the past 200 years, the Housatonic River ecosystem has undergone a long history of channel disturbances and channel relocations, and in some cases has adapted to these channel and watershed disturbances through changes to planform and dimension. As a result of these past disturbances, significant evidence of bank erosion is present throughout the Housatonic River. These disturbed banks are often nearly vertical, contain sparse vegetation, and contribute significant amounts of sediments to the river system. The Housatonic River is currently recovering from these past disturbances and over time, the ecosystem will continue to adapt until the river reaches a sustainable dynamic equilibrium.

Figure 2: Extreme Erosion along a Section of the Housatonic River

Although the current stream bank and floodplain processes define the ecosystem of the Housatonic River, this ecosystem is not sustainable in its current state. Over time, the Housatonic River will move toward a state of uniform energy dissipation that will result in reduced bank erosion, a reduction in bar formation, and fewer channel processes that form and maintain the oxbows.

To better quantify the instabilities on the Housatonic River, a Meander Survey and Soil Bank Loss study (WESTON, 2006) and a Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) evaluation (Stantec, 2009) were performed. The BEHI/NBS methodology quantified sediment loading from bank sources, and identified areas that may require restoration efforts and management controls during any remediation activities. For a detailed explanation on BEHI and NBS methodology, refer to *Watershed Assessment of River Stability and Sediment Supply (WARSSS)* (Rosgen, 2006).

During the Meander Survey and Soil Bank Loss study, aerial photographs from 1952 to 2000 were used to document the movement of the river and estimate the amount of bank migration. Additionally, short term changes in the volume of bank loss were measured following a bankfull flow event. Based on this study, the estimated range of erosion rates in Reach 5A was determined to be 0 to 0.9 ft/yr with an average value of 0.3 ft/yr. Likewise, the erosion rates for Reach 5B were estimated to by 0.1 to 0.8 ft/yr with an average rate of 0.5 ft/yr. During the study period, two meander cut-offs occurred resulting in a net loss of river surface area (Woodlot, 2002). The results of the Meander Survey and Soil Bank Loss study were used for bank erosion rates in the EFDC Monitored Natural Recovery (MNR) simulation for the Housatonic River. During the MNR simulation, a value of 1,328 MT/yr (1,464 tons/yr) of eroding solids from riverbanks was used, which resulted in the delivery of 14 kilograms (kg) (30.8 pounds [lbs]) of polychlorinated biphenyls (PCBs) to the water column and an additional 11 kg (24.3 lbs) of PCBs to the riverbed on an average annual basis. Based on this, PCBs from eroding riverbanks represent 45 percent of the overall mass of PCBs entering the river (EPA, 2011).

As part of the BEHI/NBS analysis, the banks were divided and inventoried according to changes of physical bank characteristics (e.g., bank angle, rooting depth, bank stratification) and the applied shear stresses. BEHI/NBS assessments obtained along a reach were converted to estimated sediment load in tons/yr. The bank migration rates were predicted based on published bank erosion rates as related to the BEHI/NBS ratings from North Carolina and Colorado (Rosgen, 2006).

The total bank erosion predicted from the 41,000 linear feet (ft) of the Housatonic River evaluated (in Reaches 5A and 5B) was estimated to be on the order of 7.300 tons/yr. This equates to an average bank erosion rate of 0.16 tons/ft/yr or 0.32 ft/yr in these reaches (Stantec, 2009). A reference geomorphic bank erosion rate for most stable alluvial reference reaches is less than approximately 0.005 ft/yr (Rosgen, 2006). Based on this reference rate, these reaches are considered to be in a state of accelerated bank erosion. One important finding of this study is that the areas of high bank erosion are generally out of phase with the planform of the river, which is an indicator of channel instability. In alluvial systems, areas of highest erosion are related to lateral scour pools on the outside and lower third of the meander bend (Leopold, 1992). On the reaches studied on the Housatonic River, many of the extreme and very high bank erosion rates are located upstream of point bars on the inside banks, which is indicative of channel migration and horizontal instability (Stantec, 2009).

The Housatonic River is currently recovering from historical impacts and modifications. Although the River will eventually reach a stable state through natural changes over time, such change will necessarily include accelerated erosion of the floodplain and stream banks, which are contaminated with PCBs.

4. TYPICAL CHANNEL RESTORATION CROSS SECTIONS

The goals of channel restoration for the Housatonic River include maintaining the natural geomorphic function of the river, as well as the natural beauty and biological function of the Housatonic ecosystem. It is possible to design the remediation/restoration in a manner that meets the restoration goals while improving the geomorphic function of the river. As noted above, significant portions of the Housatonic River are out of phase with the channel planform, indicating channel instability. In a natural river, riffles are located within the straighter crossover section between two bends, and pools are located on the outside of bends in the river (Harman and Jennings, 1999).

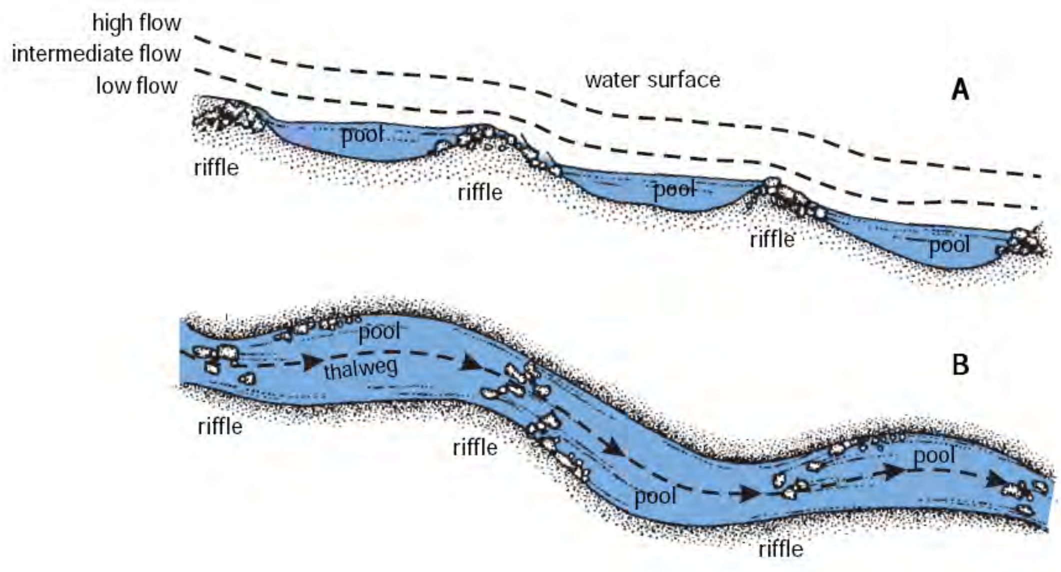

Figure 3: (A) Bed and Water Surface Slope at Baseflow and Stormflow; (B) Riffle/Pool Sequence

Remediation and subsequent restoration should consider the channel's geomorphic function. Additionally, modifying planform instabilities, including very tight radii of curvature (typically less than two times the bankfull width of the channel), should be considered and evaluated in the restoration plan. Figure 4 below depicts a typical riffle cross section that can be constructed over a capped area following removal of contaminants. In the illustrated example, a deformable soil layer composed of clean fill is placed over the isolation cap along the banks. An appropriate channel substrate is placed on top of the cap over the channel bed.

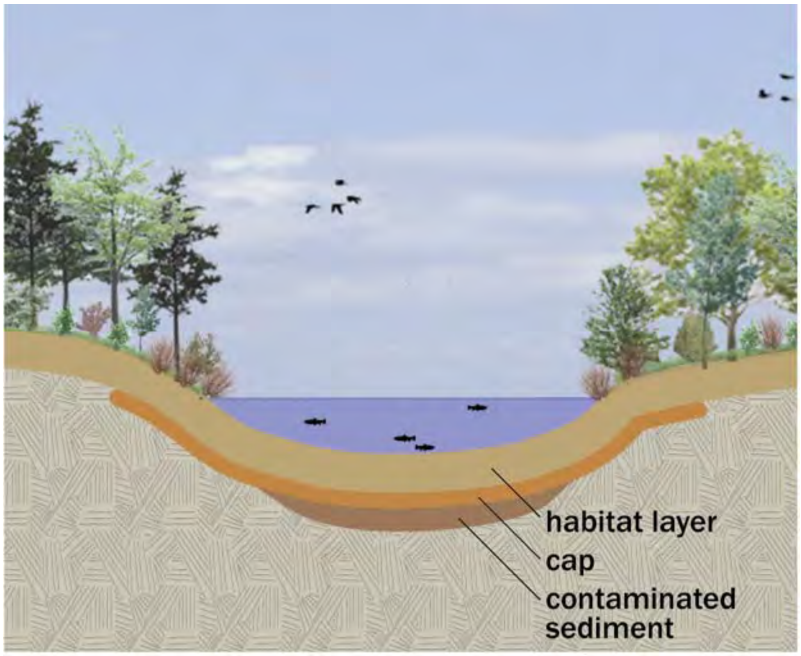

Figure 4: Riffle Cross Section

5. APPROACHES TO BANK RESTORATION ALONG THE HOUSATONIC RIVER

Bank restoration can be achieved through the use of natural materials such as woody debris, soil bioengineering, and log and rock structures, as well as by adjusting the slope of stream banks and revegetating the riparian zone (USACE, 2003). Stream bank stabilization should take into consideration the unique conditions that will be present after contaminant removal, as well as reference conditions from a stable stream channel (i.e., reference reach), and often involves restoring stream dimension and profile to improve channel stability. This can be accomplished by (1) constructing a channel of proper dimension, (2) adding grade control structures, and (3) regrading the floodplain (Rosgen, 1997). To meet the restoration objectives of this project, it is important that any bank restoration methods employ, where appropriate, the use of living systems to enhance the ecosystem and provide for natural ecologic functions.

Regrading a floodplain involves lowering bank heights by excavating a bankfull bench adjacent to the channel. A bankfull bench is a graded terrace at the bankfull elevation. The bankfull bench allows flood flows to access the adjacent floodplain, thereby reducing in-channel shear stresses. In general, the Housatonic River is an incising river system, meaning that the river has moderate access to its floodplain. One method to reduce future bank erosion is to excavate a bankfull bench along the Housatonic River and reduce bank heights by approximately 2 to 3 ft, thus improving floodplain access. The use of riparian plantings would enhance stream bank stability while providing important habitat.

Bank stabilization should be examined from the engineering, geomorphic, and biological perspectives. Engineering considerations include the ability of the stream banks to resist erosion, hydraulic conveyance of the channel, scour, and deflection of erosive forces to other locations along the reach. Geomorphic considerations include location of the proposed structures, channel-floodplain interaction, sediment competence and capacity, bankfull cross-section, width-to-depth ratio, sediment supply, location of depositional areas, bar formations, and locations of scour. Biological considerations include selection and survivability of planted riparian species, growing seasons, and fish and macro-invertebrate habitat.

Examples of some of the techniques used to provide bank stability are illustrated below.

5.1 WOODY DEBRIS TOE PROTECTION

Woody debris toe protection is an innovative structure that incorporates readily available on-site materials that would otherwise be sent off-site for disposal. Woody debris toe protection can be used for both temporary and long-term bank stabilization on the outside of stream meanders. The woody debris structure is planted with live stakes, bare roots, and transplants, as well as sod if available. Large woody debris is placed at an elevation such that the wood remains submerged, providing important fish habitat and significantly reducing the decay time of the wood.

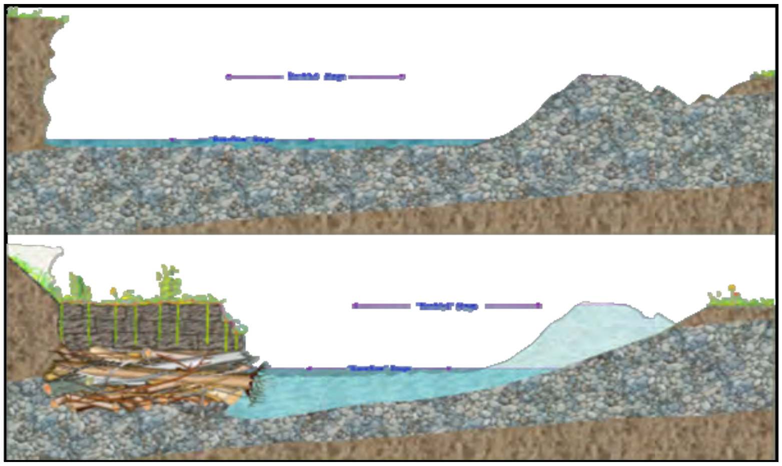

Figure 5: Woody Debris Toe Protection Detail (courtesy of Wildland Hydrology)

Figure 6: Woody Debris Toe Protection During Installation

5.2 SOIL BIOENGINEERING TECHNIQUES

Live cuttings and other soil bioengineering techniques can readily be used to restore and stabilize stream banks (USDA, 1995). Live cuttings consist of cut branches from appropriate tree and shrub species. These cuttings are typically obtained while the plants are dormant. Typical soil bioengineering techniques include live staking, live branch layering, and brush mattresses.

5.3 J-HOOKS/LOG VANES

J-hooks and log vanes are used for energy dissipation, flow redirection, and creation of downstream scour. These structures help create a large range of velocity and depth combinations throughout the project site, thus increasing biodiversity (Rosgen, 2006). J-hook vanes are composed primarily of large boulders, whereas log vanes are composed of logs typically removed from the site to be restored. A schematic of a j-hook/log vane, as well a photograph of a typical installation, are shown below.

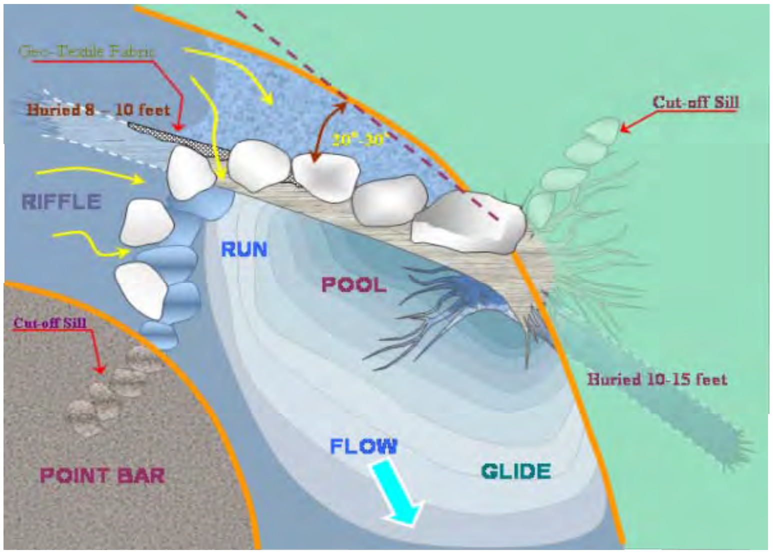

Figure 7: J-Hook Log Vane (courtesy of Wildland Hydrology)

Figure 8: Example of a Log Vane

5.4 RIFFLE HABITAT

Riffles serve a very important role for both the geomorphic and ecologic functions within a river system. A riffle is the hydraulic control for a river, helping to maintain sediment transport functions. If a riffle cross-section is under-sized for the sediment being delivered to the system, the stream can experience down-cutting. Likewise, if a riffle cross-section is over-sized, the stream can be subject to aggradation. From an ecological function perspective, riffles provide bed diversity and important habitat for macro-invertebrates.

Typically, riffles can be constructed of rock, wood or a combination of each. Examples of a log/rock constructed riffle (pictures taken immediately after construction and several years after construction) are included in Figure 9 below.

Figure 9: Examples of Log/Rock Constructed Riffle

6. EFFECTIVENESS OF BANK STABILITY TECHNIQUES

There are many examples of sites where these bank stabilization techniques have been implemented successfully (EPA, 2011), and numerous publications on the use of bioengineering techniques for bank erosion control and habitat enhancement (e.g., USACE, 1997; Sotir and Fischenich, 2001; Sylte and Fischenich, 2000; Allen and Fischenich, 2000; Allen and Fischenich, 1999; Li and Eddleman, 2002; and VDCR, 2004).

On the Connecticut River in Massachusetts, the Franklin Regional Council of Governments implemented the successful stabilization of more than 10,000 linear feet of river bank using several techniques, including fascines, live planting and seeding, hard toe structures, and coir rolls (FRCOG, 1999, 2003, 2007). On Town Branch Creek in Russellville, Kentucky, the Kentucky Department of Environmental Protection oversaw the removal and restoration of 3.5 miles of stream bank soils in three phases between 1997 and 2001 (Land and Water, 2009). For Phases II and III, several techniques, such as j-hook rock vanes, tree crowns, and submerged wooden shelters, were successfully used to stabilize banks and promote habitat restoration.

A combination of stabilization techniques was used successfully at the Army Research Laboratory Site in Watertown, MA. These stabilization techniques included coir fascines for toe stabilization and brush layers and live stakes for the upper slope treatment (Bioengineering, 2012a). On the Manhan River in Easthampton, MA, 600 linear feet of banks were stabilized for the emergency protection of a natural gas pipeline. Both vegetation and structural materials were used to stabilize the bank and re-direct flows toward the channel center (Bioengineering, 2012b).

In 1998, General Electric conducted a remedial action to restore portions of the upper riverbank along the West Branch of the Housatonic River in Pittsfield, Massachusetts. The restoration included placement of topsoil, a layer of biodegradable erosion control blanket, coconut fascines and various seed mixtures, tree, shrubs, and herbaceous species. General Electric completed a second remedial action in 2008/2009 that stabilized and restored sections of the lower riverbank and channel in the West Branch using aquatic structures, such as current deflectors, boulders, boulder clusters, large woody debris, and root wads. In addition, coir logs and plant plugs were used on the toe of the slope as bank stabilization features. Post-construction monitoring reports indicate that the restoration and stabilization techniques are performing successfully with minimal maintenance requirements (GE, 2010 and 2011).

7. UNCERTAINTIES IN LONG-TERM EFFECTIVENESS

Bank stabilization techniques are generally categorized into traditional methods, such as hard armoring and bioengineering (sometimes also referred to as biotechnical engineering) techniques (Li and Eddleman, 2002). Each technique has advantages and disadvantages in terms of applicability, cost, and effectiveness, each of which must be considered on a project-by-project basis. In addition, each technique will have limitations based on numerous site factors. For these reasons, and to reduce the potential for failure, it is necessary to implement an inter-disciplinary (engineering, geomorphic, and biological) approach to design and construction of a long-term effective bank stabilization solution. The inter-disciplinary approach can be effective at reducing uncertainties by designing the appropriate stabilization techniques for the project in consideration of both current and anticipated future conditions, e.g., a 100-year flow event. Moreover, establishing an effective post-construction monitoring and maintenance program can further prevent stabilization failures and potentially more severe impacts resulting from such failures (USACE, 1997).

Changes in watershed use or responses may impact the long-term effectiveness of any bank stabilization technique. Commonly observed responses include extensive hillslope erosion that leads to floodplain and channel aggradation during deforestation, followed by channel incision and bank erosion upon reforestation and/or the implementation of upland erosion control measures. The downstream movement of sediment created by aggradational and degradational processes occurring over long periods of time can lead to significant local post-construction channel instabilities (Miller and Kochel, 2009).

Reducing uncertainty in the long-term effectiveness of bank stabilization can be achieved with proper planning in selection of the stabilization technique and materials, incorporating site considerations (e.g., hydrological regime and regional watershed uses) with design considerations and appropriate construction techniques. Uncertainties associated with the various materials, design, and construction methods used can result in a range of positive and adverse environmental impacts. Through proper planning and design, negative impacts can be minimized and positive impacts maximized. A robust operation and maintenance program implemented early in a project will further reduce uncertainties in long-term effectiveness (Sylte and Fischenich, 2000; Fischenich, 2001).

8. CONCLUSIONS

The Housatonic River has been highly impacted over the past two centuries and currently exhibits accelerated bank erosion and other signs of instability, including a profile that is out of phase with the channel planform. Based on data collected from the River, the stream is eroding at a rate on the order of 0.3 to 0.5 ft/yr, which is significantly higher than stable reference streams. This erosion is contributing 45% of the PCB load. Accelerated bank erosion decreases water quality, can cause channels to over-widen, and can be detrimental to aquatic habitat and stream-side vegetation.

Restoration of rivers and stream banks is a common practice used throughout the United States and has evolved significantly over the past 50 years. In the past, many bank stabilization techniques focused on the use of hard armoring with concrete, gabion baskets, or riprap to achieve bank stabilization. Effective long-term bank stabilization can be readily achieved through the use of vegetation and other natural materials as evidenced from the bank restoration techniques presented in this paper. Advantages of these techniques over more traditional hard armoring approaches include increased water quality, temperature reduction, increased biological function, and aesthetics.

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ATTACHMENT 12
RIVER AND FLOODPLAIN RESTORATION

APPENDIX D

RIVER AND FLOODPLAIN RESTORATION

1. INTRODUCTION

This appendix provides a brief summary of the practice of ecological restoration and some of its key components, as well as its historical evolution, potential benefits, and examples of completed projects. Floodplain restoration is also highlighted in relation to river restoration efforts. Prominent themes in the river restoration literature highlight possible approaches to restoration along the Housatonic River Rest of River following any remediation.

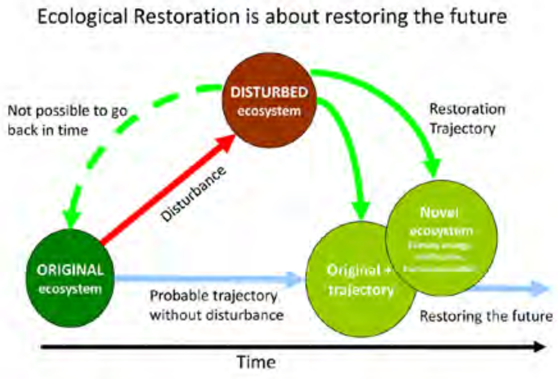
2. ECOLOGICAL RESTORATION

Ecological restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER, 2004). Around the world, ecological restoration has gained recognition as a valuable tool to repair landscapes that have been impacted by a history of human activities. In ecological communities that have been degraded, ecological restoration can be an effective way to accelerate the development of a more desirable set of physical and biological conditions to support a targeted ecosystem.

2.1 RESTORATION TRAJECTORY – RESTORING THE FUTURE

When an ecosystem is impacted, it can either be left to recover naturally, or humans can intervene and accelerate its recovery through active restoration. If the site is left alone, nature may restore it over many decades or sometimes centuries. However, the site may not recover to its former state, but take a new trajectory because contemporary constraints and conditions may cause it to develop along an altered trajectory, possibly one with degraded ecological processes and services.

Ecological restoration initiates or accelerates the recovery of an ecosystem along an intended trajectory that supports critical ecological processes, integrity, and sustainability. It enables abiotic support from the physical environment, suitable flows and exchanges of organisms and materials with the surrounding landscape, and the reestablishment of cultural interactions upon which the integrity of some ecosystems depends (SER, 2004). Active ecological restoration "sets the stage" for natural, passive restoration processes to take over, and can reduce the time needed for recovery from many decades to that of years.



Restoration Trajectory - Courtesy of Biohabitats, Inc.

The goal of ecological restoration is not to reproduce a static historical ecosystem state. Through proper analysis of ecological, cultural, and historical reference information, restoration planning can develop solutions that incorporate the contemporary constraints and influences to the system and direct the ecosystem toward improved health and integrity.

2.2 ELEMENTS OF A SUCCESSFUL RESTORATION PLAN

Ecological restoration is a complex process that involves numerous tasks. *The SER International Primer on Ecological Restoration* (SER, 2004) states that, at a minimum, the following tasks are needed in restoration planning:

- *A clear rationale as to why restoration is needed.*
  This rationale may be defined in ecological, economical, cultural, aesthetic, educational, and scientific terms.
- *An ecological description of the site designated for restoration.*
  Describe the ecosystem that was degraded, damaged, or destroyed, including the names of characteristic species, species communities, hydrology, and geomorphology.
- *A statement of goals and objectives of the restoration project.*
  Identify clear, achievable goals that are defined and understood by all stakeholders involved based on a shared vision.
- *A designation and description of the reference.*
  The reference ecosystem represents the future condition or target on which the restoration is designed and which can serve later as a basis for project evaluation.
- *An explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials.*
  Many species at a project site may be adversely affected by external conditions and off-site activities in the surrounding landscape. A functioning ecosystem is an interconnected network of habitats, which together, allow for movement of organisms and materials and enhance population survival.
- *Explicit plans, schedules, and budgets for site preparation, installation, and post-installation activities include a strategy for prompt mid-course corrections.*
  Restoration can be a complex undertaking that integrates a wide range of disciplines including ecology, aquatic biology, hydrology and hydraulics, geomorphology, engineering, planning, communications, and social science to develop a restoration plan. While implementing the restoration plan, progress should be monitored and communicated to the stakeholders involved.
- *Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated.*
  A performance standard is a specific state of ecosystem recovery, such as a minimum percent of herbaceous coverage that indicates or demonstrates that an objective has been attained. Some of these standards need to be monitored over time.
- *Strategies for long-term protection and maintenance of the restored ecosystem.*
  Although the restored ecosystem should become self-sustaining, plans should be

established to provide maintenance and protection from outside influences that may impact the natural communities.

2.3 RIVER RESTORATION PLANNING

In accordance with the guidelines listed above, the following major elements, which are essential in a proper river restoration planning process, should:

- Include an analysis of both historical and existing conditions of the river and floodplain. This can help inform the restoration conceptual design by serving as a reference condition.
- Result in reestablishing river and floodplain processes, such as moving nutrients and sediment through the environment. Watershed hydrology and river hydraulics, along with the geology and soils of the valley, define the shape and form of the channel and floodplain and must be well understood. Incorporation of these multidisciplinary elements is essential to developing successful plans.
- Embrace the diversity, complexity, and resiliency found in natural systems, providing for regional landscape linkages, including connecting the riparian wetland to the river. The composition and structure of vegetation provides the basis for riparian habitat. The morphology of the channel provides the basis for in-stream habitat.
- Include a clear trajectory toward success that ensures the future health and integrity of the river, and its supported aquatic and riparian communities, without requiring external assistance. This requires the restoration plan to design for inputs, some of which may be dynamic in space and time such as hydrology and sediment supply.
- Include adaptive management, providing built-in flexibility to facilitate alternative actions for addressing under-performance and achieving desired outcomes. Adaptive management is a key process by which restoration projects are managed and openly acknowledges uncertainty about how ecological systems function and how they respond to management actions. It is designed to improve our understanding of how a system works so we can achieve management objectives.

2.4 HISTORY OF RIVER RESTORATION

Rivers of North America have been manipulated since the original settlement by Native Americans and by European settlers. Practices such as straightening, smoothing, armoring, canalization, gravel mining, dams, diversions, and riparian deforestation have supported agricultural and industrial demands and urbanization, but disrupted natural river form and processes. River restoration, as the field exists today, grew from the need to ameliorate the impacts from these practices, but has been quickly evolving and improving, especially in the past few decades. A brief history of this evolution is described below, many aspects of which are covered in additional detail in Lave (2008).

After hundreds of years of anthropogenic changes to the landscape and its drainageways, numerous efforts to rehabilitate stream systems were undertaken in the 1930s through 1970s. Some of these early stream manipulation and rehabilitation efforts focused primarily on the placement of in-stream structures to benefit fish habitat, whereas others emphasized channelization for flood control, given the new jurisdiction granted under the 1936 Flood Control Act.

Modern fluvial geomorphology—the study of river processes and how they shape the landscape—emerged from the early field studies of Luna Leopold and M. Gordon Wolman in the 1950s and 1960s (e.g., Leopold et al., 1992), as well as natural hydraulic geometry work being developed based on these investigations (Leopold and Maddock, 1953).

In parallel with ongoing geomorphic studies, the latter half of the 20th century brought increasing awareness of the declining health of rivers, catalyzed in part with the passing of key federal legislation like the National Environmental Protection Act (1962), the Wild and Scenic Rivers Act (1968), the Clean Water Act (1972), and the Endangered Species Act (1973).

A growing environmental awareness and concern for the channelization resulting from traditional hydraulic engineering in the 1960s and 1970s led to some of the early coordinated efforts to define new design approaches. Early coordinated stream restoration efforts (e.g., from the 1980s) tended to focus on patching local sections of channel to address localized problems, such as bank erosion. Furthermore, early restoration efforts emphasized a generic desire for a greater amount and diversity of aquatic habitat. Underpinning stream efforts during this time has been the “build it, and they will come” philosophy. Practitioners tended to focus on installation of bank and bed protection and enhancement structures with the belief that adding specific types of structures and/or additional heterogeneity of water depths and velocities would be a proxy for improving stream ecology. Some of these efforts focused on improving fish habitat and bank stabilization, but emphasized natural materials, including bioengineering techniques.

The past three decades have seen a boom in the development of river restoration guidelines from various agencies. Some of these documents were generated by government agencies with a growing number of constructed projects, and longer term intentions for expanding stream restoration activities (e.g., NRCS, 2001; NRCS, 2007; USFWS, 2008; among many others). Complementary to these broad design guidelines, specific technical guidelines also were provided in the literature, such as with regard to river hydraulics (e.g., Fischenich and Dudley, 2000).

These decades also saw the emergence of river restoration as an industry with early consulting firms dedicated to river restoration as a core service. The number of projects being installed escalated, and some of these projects provided cautionary tales. Early missteps in the field of river restoration most frequently resulted when practitioners mischaracterized systems based on overly simplistic understanding of operative stream processes (Smith, 1997; Kondolf et al., 2001). As one example, the classic sinuous form of meandering channels represented a compelling cultural ideal for much early stream restoration design. Some restoration programs focused on restoring this archetypal meandering channel form, sometimes in settings where there was no historical evidence to support it (Kondolf, 2006). These types of efforts were not always successful because the restoration approach did not account for dominant geomorphic and ecologic processes guiding riverine dynamics, or the *cause* of habitat degradation.

This narrowly focused culture led some researchers and practitioners to become increasingly vocal and identify a range of considerations missing from the restoration dialogue. A thread woven through much of the river restoration literature during the 1990s and 2000s focused on a debate within the river restoration community regarding how prescriptive an approach stream assessment and restoration should assume (Lave, 2009). Today analytical, empirical, and analog design tools are available for river restoration (Shields et al., 2003). Recent design efforts have combined approaches to draw on the strengths of each, weave together multiple lines of evidence, and adapt a design to the specific characteristics noted in a project area. Given the uniqueness of every site and project, the industry has chosen not to advance one standardized set of design guidelines.

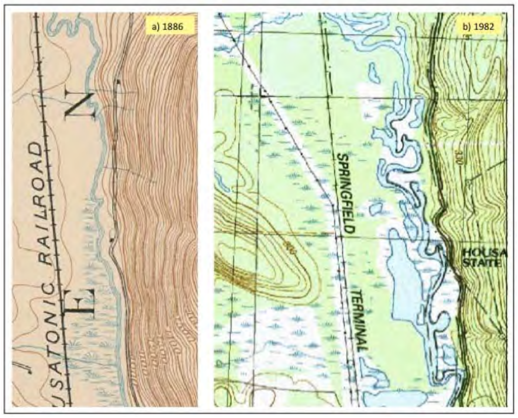
Over the last decade, the number of river restoration projects has increased exponentially (as cited in Bernhardt et al., 2005). The focus of river restoration projects has also evolved as human populations come to understand that healthy, self-sustaining rivers provide critical ecological and social goods and services upon which human life depends. Today, river restoration efforts are conceived to mitigate floods, provide clean drinking water, remove excessive levels of nutrients and contaminated sediments, support fisheries and wildlife, enhance property values, and offer recreational outlets.

To serve these purposes, much progress has been made in current restoration efforts to emphasize a solid understanding of river processes and how they influence river form, integrate river restoration with the broader ecological landscape and cultural and recreational attributes, account for projected changes (e.g., hydrologic, invasive species), and establish a more resilient and self-sustaining system (see Appendices B and C). Palmer et al. (2005) suggests the following five criteria for the next generation of ecologically successful river restoration projects:

1. A guiding image exists: a dynamic ecological endpoint is identified a priori and used to guide the restoration (within present regional context).
2. Ecosystems are improved: the ecological conditions of the river are measurably enhanced and move toward the guiding image.
3. Resiliency is increased: the river ecosystem is more self-sustaining than before.
4. No lasting harm is done: implementing the restoration does not inflict irreparable harm.
5. Ecological assessment is completed: some level of pre- and post-project assessment is conducted and the information is shared.

2.5 CONSIDERATION OF TEMPORAL SCALE

The Housatonic River appears, to the casual observer, as a pristine natural river system that has evolved by meandering over millennia. Some fear that disrupting these natural processes will result in irreparable harm to the ecosystem. However, analysis of historical documents and maps of the river reveals a history of alterations in the river associated with a number of human activities. Historical maps reveal almost the entire Rest of River Reach was artificially straightened prior to 1886 (Field, 2011). At right, a map from 1886 shows a straightened section of the river that now has



1886 and 1982 Map Comparison - Courtesy of University of New Hampshire Library Digital Collections Initiative and USGS developed a natural meander pattern, as shown on a 1982 USGS map (see Appendix A).

An altered river channel is inherently unstable due to factors such as the increase in channel gradient and stream power associated with a shortened stream length if the river is straightened. Over time, straightened river channels may undergo a series of channel adjustments that ultimately lead to the return to a stable meandering riverbed and banks that approximate the pre-disturbance condition. Many reaches of the river now appear undisturbed and exhibit a stable meander pattern within the wide floodplain. However, other reaches show symptoms of moderate instability, such as deeply incising cross sections that are becoming further disconnected from the floodplain, sections of unstable planform geometry, and homogeneous sand substrate providing poor habitat for aquatic invertebrates and fish (NHESP, 2010). This is an indication that the Housatonic River is still recovering from past physical disturbances. If left on its present trajectory, it is uncertain whether the river would attain full recovery for some parameters (e.g., floodplain reconnection).

One question regarding any remediation and restoration activities along the Housatonic River is how such activities will affect the physical appearance and the various habitat communities of the river corridor, and the time-frame for recovery. While the physical appearance and aesthetic quality of a restoration project are important considerations, they are not the primary tenets motivating design development. The primary goal of ecological restoration is to return the functions of an ecosystem, such that energy, nutrients, and moisture are available in the physical environment to support intended organisms and their interactions with the environment. Restoring ecosystem functions creates an environment that supports all biota, including species of special concern.

Remediation and restoration of the river and floodplain at this scale cannot be accomplished to any meaningful level without impacts to the present state of the river and floodplain. However, if proper ecological restoration addresses remediation and impacts of the restoration process, it will initiate an accelerated recovery of the ecosystem that would not only restore impacts caused by the remediation, but also address the river's historical morphological instabilities. Therefore, over the longer term, restoration activities would create processes sustaining diverse river and floodplain communities and an aesthetically pleasing landscape and associated recreational opportunities that have been enjoyed in the past along the river and floodplain.

2.6 RESTORATION TECHNIQUES SUPPORTING DIVERSE HABITATS

To fully restore the functions and values of a river and floodplain, the basis of a river restoration must embrace a whole systems approach. The goal of this whole systems approach is a fully functioning ecosystem that maintains the connection between the river and its unique, diverse and vital floodplain features. This involves a comprehensive understanding of the geomorphology, including dimension, pattern, and profile of natural, stable channels that can occur in specific valley types and landforms and restoring these conditions. As discussed in the previous section on historical river restoration efforts, unsuccessful stabilization projects often involve "patching in place" solutions rather than performing an assessment and treating not only the symptoms but the cause of the problems. Successful restoration solutions often are directed at emulating natural stable channels and reestablishment of the floodplain at various elevations.

Any remediation will likely introduce a new set of design constraints to the restoration of the site, such as limited belt width of meander pattern. An approach to restoration and remediation that incorporates whole systems thinking will likely be able to take into account the majority of the historical as well as the new design constraints.

Various restoration techniques play a role in a whole systems approach by providing short-term support for a longer-term ecological trajectory. Many well established techniques support a range of habitats for both rivers and floodplains, based on the desired function, setting, and site constraint. Specific techniques target the riverbed, riverbank, riparian buffer, and wetlands and vernal pools.

2.6.1 River

Riverbank restoration techniques center around various methods used to stabilize banks, either by affecting flows to reduce the force of water against the bank, or by providing strength and protection to the bank through armoring.

In-channel structures, such as deflectors and vanes, direct flow away from the banks, altering the secondary currents and promoting deposition at the toe of the bank (NRCS, 2007). Bank protection can be accomplished using boulder structures, coarse woody debris, bioengineering, bank grading, benches, and terraces. Often the stabilization involves riparian vegetation reestablishment or a change in management. Regardless, there is a time element that is needed to establish rooting depth, density, and strength to help maintain bank stability (NRCS, 2007).


Boulder Bank Protection -
Courtesy of Stantec

Bank protection is generally ineffective over the long term if the channel bed continues to degrade (NRCS, 2007). Riverbed restoration techniques center around grade control structures that not only provide stability to the river, but add varied habitat for fish and macroinvertebrates.

2.6.2 Floodplain

Floodplain restoration focuses on restoring the processes that form, connect, and sustain the diverse floodplain habitats. This may include raising the channel invert or lowering the floodplain elevation to reestablish the connection of water and sediment movement between the river and its floodplain. Periodic flooding and the related processes of erosion and deposition determine the shape of the floodplain, depth and composition of soils, type and density of vegetation, presence and extent of wetlands, richness and diversity of wildlife habitats, and depth to the groundwater. Floodplain restoration techniques often include supplemental plantings to the establishment of native plant communities and amendments to soils.


River and Floodplain Connection -
Courtesy of Biohabitats, Inc.

Vernal pools, or ephemeral wetlands, are seasonal or temporary wetlands with an intermittent source of hydrology that result from the scouring process of rivers (e.g., abandoned meander scrolls) or through various disturbances to the floodplain (e.g., fallen trees). Restoration of vernal pools requires proper site locations for various target species. Depressions that vary in depth, size, and location may be graded into the floodplain to offer a complex set of habitats to support different organisms and stages of lifecycles, as well as to maintain a natural appearance. To ensure sufficient hydrology is maintained in the pools, various techniques may be used, such as establishing a connection to the seasonal water table or compaction of an organic layer or native soils.

Planting a variety of grasses, sedges, forbs, and woody shrubs and small trees around the edges of the vernal pools will provide shading, cover, and forage for wildlife species using the pools. As a larger tree canopy develops, shedding leaves will provide a reliable source of organic matter, and will provide long-term stability to the ecology of the pool complexes. Coarse woody debris can be placed in the pools to provide additional habitat for the invertebrate and vertebrate community.

2.6.3 Successful Restoration Examples

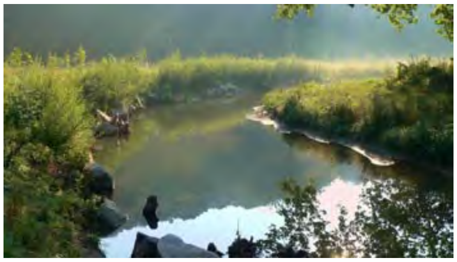
Many examples of successful ecological restoration projects exist across various settings and scale. Demonstrated successes following restoration of impacted sites throughout the world have shown that it is possible to restore both the ecological function of areas and appearance after they are disrupted.

Of particular relevance to the Housatonic River are restoration projects that have featured large rivers with a floodplain connection and/or rivers with soil remediation. Although there is no river that exactly matches the characteristics of the Housatonic River, the following projects are successful examples of these types of river restoration efforts.

Restored Provo River - Courtesy of Utah Reclamation, Mitigation and Conservation Commission

- Provo River, UT – The Provo River case study is one of many large-scale restorations on river systems similar in size to the Housatonic River, but it did not involve remediation of hazardous substances. The purpose of the Provo River Restoration Project (PRRP) was to restore the river form and ecological function to provide for fish, wildlife, and recreational angling losses caused by federal water reclamation projects in Utah. The project began construction in 1999 in several phased reach restoration sections. The restoration consisted of creating a multiple-thread, meandering river channel; reconnecting the river to existing remnants of the historical secondary channels; and constructing small side channels to recreate aquatic features. Existing levees were set back to create and reconnect floodplain, and streamside vegetation was planted to enhance the riparian communities and support healthy fisheries. An 800- to 2,200-foot-wide corridor along the entire reach of the restored middle Provo River is now protected for wildlife habitat and public access for anglers. With major construction activities completed by 2007 along 12 miles of river, the project has significantly improved this large river system through ecological restoration practices that have increased the quality and diversity of multiple habitats for numerous species, as well as provided access for anglers and other recreational users (URMCC, 2011).

- Kissimmee River, FL – This effort dates to 1992 when the U.S. Congress authorized this joint state-federal project. When restoration is complete in 2015, more than 40 square miles of river-floodplain ecosystem will have been restored, including almost 20,000 acres of wetlands and 44 miles of historic river channel (Mossa et al., 2009).
- Big Spring Creek, MT – The Montana Department of Fish, Wildlife, and Parks (MDFWP) reconstructed a meandering segment of Big Spring Creek that had been straightened decades earlier. The goal was to restore a section of channelized stream through a public access site to provide high quality fish habitat and angling opportunities, as well as create new wetlands and enhance existing wetlands by reconnecting the floodplain with the channel. A 2,800-foot long reach of stream was lengthened to almost 4,000 feet and now provides aquatic, wetland, and riparian habitat (Inter-fluve, 2011).
- Nine-Mile Run River Restoration Project, PA – The U.S. Army Corps of Engineers (USACE) Pittsburgh District, partnered with the City of Pittsburgh to restore over 1 mile of aquatic habitat along Nine Mile Run. The restoration was accomplished by reconnecting the river to its floodplain, eliminating leachate from an adjacent slag dump, reducing fish migration barriers, creating meanders and step pools, stabilizing eroding slopes using vegetation or soil bioengineering, managing invasive vegetative species, and enhancing/enlarging wetlands.


Restored Nine Mile Run - Copyright John Moyer

- Loring Air Force Base (AFB) Contaminated Wetland and Stream Remediation and Restoration, ME – This 2.5-mile stream and 35-acre wetland restoration resulted in decreasing PCB concentrations while recreating native aquatic and riparian habitats. After only 6 years, large areas of remediation were virtually indistinguishable from the areas prior to disturbance.


Restored Wetland at Loring AFB – Courtesy Stantec

- Clark Fork River, MT – The natural resources of the Clark Fork River were greatly degraded by the release of hazardous substances into its surface water, river bed sediment, and floodplain. The source of the substances is historical mining waste containing toxic metals that injured fish and macroinvertebrate populations along 43 miles of river (MNRDP, 2008). In 1992, EPA designated the Clark Fork River, from Warm Springs Ponds to the Milltown Reservoir, as a Superfund site (EPA, 2011). After years of study and planning, including continuous community involvement to hear landowners' concerns, the state developed a restoration plan with goals to restore

> the aquatic resources and terrestrial habitats of the river and floodplain, maximize the long-term beneficial effects and cost-effectiveness of restoration activities, and improve natural aesthetic values of the Clark Fork River (MNRDP, 2008). Remediation and restoration activities have begun, with contaminated soil being removed and replaced with clean soil, and streambanks stabilized and replanted with native vegetation (CFRTAC, 2009). Monitoring of the river is occurring during and after construction, as well as extensive outreach to landowners along the river to ensure cooperation, coordination, and concurrence with the restoration work (MNRDP, 2008).

Rivers are unique ecological systems, and each is different from all others in numerous ways. Some of the major differences between the examples cited and the Housatonic River include, for river systems such as Nine-Mile Run and the Clark Fork River, the near total lack of aquatic life before the restoration project was initiated. Therefore, these rivers presented unusual restoration challenges and these projects were successful in spite of the challenges. The Loring AFB restoration was conducted on a smaller scale than the entire Rest of River, but was typical in the magnitude of individual restoration projects that would be conducted as the remediation of the Rest of River proceeds in segments from upstream to downstream. Although each of these examples involved initial conditions and challenges that are different from those that would be encountered in restoring the Rest of River and its floodplain following remediation, these projects nonetheless demonstrate successes in river restoration from a geomorphological standpoint and provide design features within the restoration plan that create and provide enhancement to a diversity of floodplain processes and habitats. Indeed, the diversity evident in this range of examples provides assurance that restoration can be conducted successfully despite the nature of a system and its condition. The goal of the Rest of River restoration plans would be to apply the knowledge gained on successful restoration projects conducted on these and other diverse river systems to the unique challenges and opportunities for success that exist at the Rest of River site.

2.6.4 Attributes of a Restored Ecosystem

Once an impaired ecosystem has been restored, there are certain attributes that indicate it has recovered and will sustain itself structurally and functionally. The nine attributes of a restored ecosystem as stated in the *SER International Primer on Ecological Restoration* (SER, 2004) are as follows:

1. The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.

2. The restored ecosystem consists of indigenous species to the greatest practicable extent. In restored cultural ecosystems, allowances can be made for exotic domesticated species and for non-invasive ruderal and segetal species that presumably co-evolved with them. Ruderals are plants that colonize disturbed sites, whereas segetals typically grow intermixed with crop species.

3. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented, or, if they are not, the missing groups have the potential to colonize by natural means.

4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.
5. The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent.
6. The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.
7. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.
8. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.
9. The restored ecosystem is self-sustaining to the same degree as its reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure, and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change.

3. SUMMARY

Over the past few decades, the practice of river restoration has become well established. The field of ecological restoration provides guidance for a successful restoration plan for any ecological setting, and there are specific guidelines to support a river restoration planning process. Ecological restoration and remediation activities cause significant disturbance to an existing impaired ecosystem. However, ecological restoration accelerates the longer term recovery of an ecosystem along an intended trajectory that supports critical ecological processes, integrity, and sustainability.

There are numerous examples of successful river restoration projects across a range of spatial and temporal scales. A variety of techniques can be integrated into river restoration design to target the riverbed, riverbank, riparian buffer, and wetlands and vernal pool habitats. Ongoing collaboration among practitioners in the disciplines of geomorphology, hydrology, ecology, biogeochemistry, and engineering—in conjunction with lessons learned in early generations of river restoration projects—provide a foundation for current river restoration efforts.

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