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.

- Reach 5C

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.

- Backwaters

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.

- Reach 6 (Woods Pond)

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 $1x10^{-5}$ 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 $1x10^{-4}$ 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

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

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 $1x10^{-4}$ 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 $1x10^{-6}$ 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 $1x10^{-4}$ for the RME individual. In addition, the RME $1x10^{-5}$ 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] 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	10^-6 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
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		>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	0.0019	>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		>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	0.0064	>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 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	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
Human Consumption of Fish (Bass Fillets, Deterministic RME)																		
5A		>250	149	156	146	188	151	>250	>52		>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	0.019	>250	>250	>250	>250	>250	>250	>250	>52	0.19	>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		>250	103	108	102	127	108	>250	>52		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	0.064	>250	>250	>250	>250	>250	>250	>250	>52	0.64	>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 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	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
Human Consumption of Fish (Bass Fillets, Deterministic RME)																		
5A		>250	137	144	134	172	140	>250	>52		>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	0.026	>250	>250	>250	>250	>250	>250	>250	>52	0.062	>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		>250	106	111	105	131	111	>250	>52		>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	0.059	>250	>250	>250	>250	>250	>250	>250	>52	0.12	>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

Average Fish (fillet) Concentrations (mg/kg) [1,2]

River Reach	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
5B	9.3	3	0.23	0.22	0.15	0.27	6.6	3.48
5C	7.4	1.8	0.17	0.16	0.11	0.18	5.8	0.82
5D	9.5	6.3	0.36	0.35	0.29	0.41	11	1.1
6 (WP)	8.6	0.71	0.18	0.17	0.13	0.16	3.7	0.74
7A	6.4	1.3	0.42	0.4	0.34	0.42	4.2	1.12
7B	5.7	2.1	1.6	0.41	0.1	0.21	4.2	0.67
7C	6.3	1.8	1	0.2	0.12	0.2	4.4	0.81
7D	5.5	1.4	0.79	0.7	0.63	0.75	3.7	1.37
7E	4.1	1	0.57	0.34	0.18	0.22	2.8	0.64
7F	3.2	0.82	0.49	0.45	0.38	0.45	2.2	0.82
7G	3.5	1.3	1	0.4	0.15	0.22	2.6	0.38
7H	2.8	0.72	0.43	0.39	0.35	0.39	1.9	0.69
8 (RP)	3.6	1.6	0.34	0.22	0.17	0.24	2.7	0.37
BBD	0.16	0.04	0.01	0.009	0.006	0.009	0.1	0.022
LL	0.11	0.03	0.009	0.006	0.005	0.006	0.08	0.015
LZ	0.08	0.02	0.006	0.005	0.004	0.004	0.05	0.011
LH	0.08	0.02	0.006	0.004	0.003	0.004	0.05	0.010
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
5B	9.3	3	0.23	0.22	0.15	0.27	6.6	3.48
5C	7.4	1.8	0.17	0.16	0.11	0.18	5.8	0.82
5D	9.5	6.3	0.36	0.35	0.29	0.41	11	1.1
6 (WP)	8.6	0.71	0.18	0.17	0.13	0.16	3.7	0.74
7A	6.4	1.3	0.42	0.4	0.34	0.42	4.2	1.12
7B	5.7	2.1	1.6	0.41	0.1	0.21	4.2	0.67
7C	6.3	1.8	1	0.2	0.12	0.2	4.4	0.81
7D	5.5	1.4	0.79	0.7	0.63	0.75	3.7	1.37
7E	4.1	1	0.57	0.34	0.18	0.22	2.8	0.64
7F	3.2	0.82	0.49	0.45	0.38	0.45	2.2	0.82
7G	3.5	1.3	1	0.4	0.15	0.22	2.6	0.38
7H	2.8	0.72	0.43	0.39	0.35	0.39	1.9	0.69
8 (RP)	3.6	1.6	0.34	0.22	0.17	0.24	2.7	0.37
BBD	0.16	0.04	0.01	0.009	0.006	0.009	0.1	0.022
LL	0.11	0.03	0.009	0.006	0.005	0.006	0.08	0.015
LZ	0.08	0.02	0.006	0.005	0.004	0.004	0.05	0.011
LH	0.08	0.02	0.006	0.004	0.003	0.004	0.05	0.010

10^{-6} Cancer Risk

River Reach	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
Deterministic CTE									
5A	0.049	>250	113	118	111	141	117	>250	>52
5B		>250	>250	118	109	137	113	>250	>52
5C		>250	>250	111	102	125	102	>250	>52
5D		>250	171	>250	>250	>250	IT	>250	>52
6 (WP)		>250	>250	130	119	136	99	>250	>52
7A		>250	>250	>250	227	>250	240	>250	>52
7B		>250	>250	>250	>250	134	186	>250	>52
7C		>250	>250	>250	129	138	122	>250	>52
7D		>250	>250	>250	>250	>250	>250	>250	>52
7E		>250	239	>250	159	197	148	>250	>52
7F		>250	>250	>250	249	>250	>250	>250	>52
7G		>250	>250	>250	>250	203	178	>250	>52
7H		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)		>250	>250	>250	200	234	205	>250	>52
BBD		148	37	22	23	54	19	138	22
LL		119	23	21	22	36	17	99	18
LZ		89	17	19	20	31	15	58	15
LH		85	17	19	20	31	15	54	14
Probabilistic CTE (50th percentile)									
5A	0.057	>250	108	112	106	133	112	>250	>52
5B		>250	>250	111	103	129	107	>250	>52
5C		>250	>250	104	96	116	96	>250	>52
5D		>250	167	>250	>250	>250	IT	>250	>52
6 (WP)		>250	>250	121	111	127	93	198	>52
7A		>250	>250	>250	214	>250	226	>250	>52
7B		>250	>250	>250	>250	122	172	>250	>52
7C		>250	>250	>250	120	128	114	>250	>52
7D		>250	>250	>250	>250	>250	>250	>250	>52
7E		>250	229	>250	151	182	138	>250	>52
7F		>250	>250	>250	235	>250	>250	>250	>52
7G		>250	>250	>250	>250	186	165	>250	>52
7H		>250	>250	>250	>250	>250	>250	>250	>52
8 (RP)		>250	>250	>250	185	215	190	>250	>52
BBD		135	26	21	22	39	17	120	20
LL		106	19	20	21	32	16	81	16
LZ		75	14	18	20	26	14	41	14
LH		72	13	18	19	22	14	37	13

10^{-5} Cancer Risk

River Reach	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
Deterministic CTE									
5A	0.49	>250	22	22	22	23	35	205	26
5B		>250	241	18	18	21	22	>250	>52
5C		>250	142	20	20	32	15	>250	>52
5D		>250	115	21	21	31	16	>250	>52
6 (WP)		>250	134	22	23	42	16	209	>52
7A		>250	142	36	33	44	37	>250	>52
7B		>250	>250	>250	23	43	16	>250	>52
7C		>250	234	227	24	45	17	>250	>52
7D		>250	174	124	94	127	114	>250	>52
7E		>250	96	69	24	45	17	>250	>52
7F		231	102	51	41	48	39	>250	>52
7G		>250	196	193	24	46	17	>250	31
7H		214	99	34	26	47	22	>250	>52
8 (RP)		>250	231	23	25	53	19	>250	30
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0
Probabilistic CTE (50th percentile)									
5A	0.57	249	18	18	18	18	23	194	21
5B		>250	225	17	17	21	18	>250	>52
5C		>250	131	19	20	31	14	>250	>52
5D		>250	111	21	21	31	15	341	>52
6 (WP)		>250	103	22	23	41	16	52	>52
7A		>250	128	25	25	43	25	246	>52
7B		>250	250	>250	23	43	16	>250	>52
7C		>250	213	192	24	44	17	>250	>52
7D		>250	155	101	76	98	91	>250	>52
7E		243	86	52	23	44	16	>250	>52
7F		216	87	36	32	46	30	>250	>52
7G		>250	173	164	24	46	17	>250	28
7H		199	80	24	24	46	17	>250	>52
8 (RP)		246	208	23	24	53	18	>250	23
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0

10^{-4} Cancer Risk

River Reach	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
Deterministic CTE									
5A	4.9	82	8	8	8	10	8	36	9
5B		123	12	10	10	14	9	81	16
5C		98	10	14	14	17	10	69	11
5D		136	58	17	17	27	12	108	12
6 (WP)		132	11	18	19	37	12	25	12
7A		78	9	10	10	12	11	26	12
7B		69	9	10	10	12	11	26	11
7C		78	10	10	10	13	12	36	12
7D		64	9	9	10	12	11	11	12
7E		34	9	7	9	11	11	9	11
7F		9	8	6	8	10	10	8	11
7G		10	8	6	8	11	10	8	9
7H		7	7	5	7	8	9	6	10
8 (RP)		10	8	6	8	11	11	8	9
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0
Probabilistic CTE (50th percentile)									
5A	5.7	71	7	7	7	9	7	26	9
5B		107	11	10	10	13	9	65	13
5C		81	10	11	11	14	9	54	10
5D		122	54	17	17	27	11	122	12
6 (WP)		113	11	17	19	37	11	10	12
7A		63	9	9	9	11	11	11	12
7B		52	9	9	9	11	11	11	10
7C		62	9	9	9	12	11	12	12
7D		38	9	8	9	11	11	9	11
7E		11	8	6	8	10	10	8	10
7F		7	7	5	7	8	9	7	10
7G		8	7	5	7	9	9	7	8
7H		4	5	3	5	7	8	3	9
8 (RP)		7	7	5	7	9	10	6	8
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0

Non-Cancer: Child

River Reach	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
Deterministic CTE									
5A	0.19	>250	62	64	62	74	68	>250	>52
5B		>250	>250	59	56	70	63	>250	>52
5C		>250	207	44	44	48	51	>250	>52
5D		>250	138	>250	>250	117	IT	>250	>52
6 (WP)		>250	>250	50	48	51	44	>250	>52
7A		>250	233	138	112	166	120	>250	>52
7B		>250	>250	>250	>250	46	60	>250	>52
7C		>250	>250	>250	53	52	52	>250	>52
7D		>250	>250	>250	210	>250	>250	>250	>52
7E		>250	154	173	83	64	61	>250	>52
7F		>250	195	165	128	182	140	>250	>52
7G		>250	>250	>250	154	52	63	>250	>52
7H		>250	219	174	139	226	147	>250	>52
8 (RP)		>250	>250	>250	65	63	72	>250	>52
BBD		31	11	11	18	15	13	17	10
LL		26	9	8	9	11	11	9	8
LZ		6	6	4	6	7	9	6	0
LH		5	5	4	5	6	8	4	0
Probabilistic CTE (50th percentile)									
5A	0.71	232	14	14	14	16	16	179	15
5B		>250	202	16	16	20	14	>250	>52
5C		>250	116	19	19	31	14	>250	>52
5D		>250	105	20	21	31	15	320	>52
6 (WP)		>250	53	22	23	41	15	180	>52
7A		>250	107	24	24	42	17	225	>52
7B		>250	217	238	22	42	15	>250	35
7C		>250	182	141	23	44	16	>250	>52
7D		>250	129	68	51	60	58	>250	>52
7E		222	73	27	23	44	15	212	35
7F		195	65	24	24	44	17	236	>52
7G		231	140	122	23	45	16	>250	15
7H		178	52	22	23	45	16	>250	38
8 (RP)		222	174	22	24	52	18	>250	18
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0

Non-Cancer: Adult

River Reach	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
Deterministic CTE									
5A	0.43	>250	26	26	26	39	38	214	33
5B		>250	>250	21	20	23	34	>250	>52
5C		>250	151	20	21	32	16	>250	>52
5D		>250	118	22	22	32	24	>250	>52
6 (WP)		>250	161	23	24	42	17	219	>52
7A		>250	155	48	41	48	48	>250	>52
7B		>250	>250	>250	23	43	16	>250	>52
7C		>250	>250	>250	24	45	18	>250	>52
7D		>250	189	144	110	153	134	>250	>52
7E		>250	104	84	24	45	17	>250	>52
7F		244	114	68	55	61	56	>250	>52
7G		>250	216	218	24	47	18	>250	35
7H		226	116	51	37	48	35	>250	>52
8 (RP)		>250	>250	24	25	54	19	>250	33
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0
Probabilistic CTE (50th percentile)									
5A	1.5	174	11	11	11	13	10	125	12
5B		>250	124	14	14	18	11	203	>52
5C		226	65	18	18	28	12	193	14
5D		249	87	19	19	29	13	249	35
6 (WP)		>250	14	20	21	40	14	122	15
7A		192	26	21	22	39	14	152	18
7B		201	103	63	21	41	14	193	14
7C		202	76	23	22	42	14	177	16
7D		206	38	22	22	42	15	180	33
7E		149	23	21	21	40	14	124	14
7F		122	19	20	21	33	14	113	16
7G		145	34	21	21	42	14	158	13
7H		106	15	19	20	32	13	99	14
8 (RP)		141	58	20	22	50	16	182	15
BBD		0	0	0	0	0	0	0	0
LL		0	0	0	0	0	0	0	0
LZ		0	0	0	0	0	0	0	0
LH		0	0	0	0	0	0	0	0

Key:

(white box) = *post-remediation EPC is higher than IMPG*

(shaded box) = *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

[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.

[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.

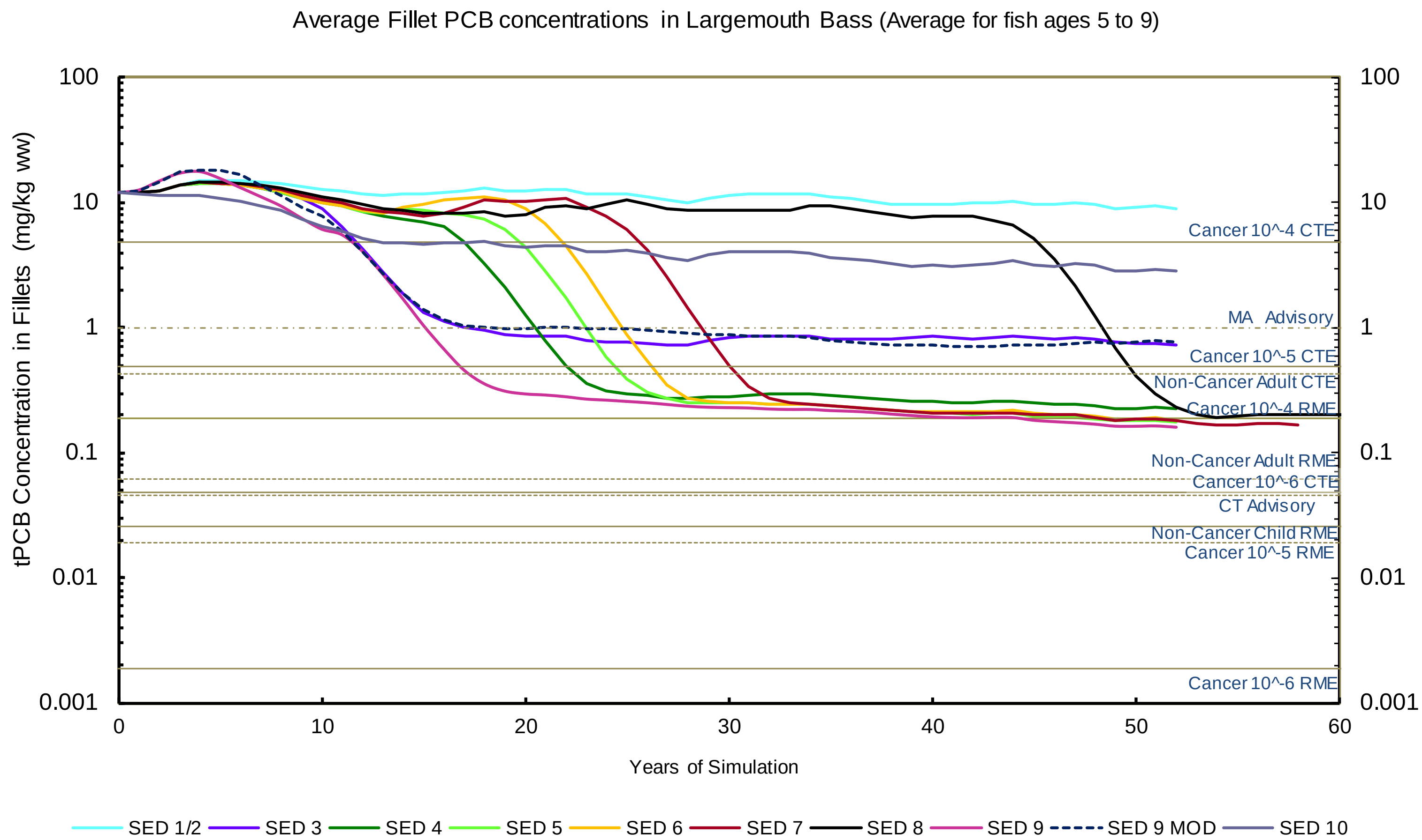
For example, in Reach 6 (Woods Pond) (see Figure 1), reduction in fillet tissue PCB concentrations corresponding to the CTE $1x10^{-5}$ cancer risk would not be achieved by SED 2/FP 1 and SED 10/FP 9 during the 52-year simulation period and, based on the trajectories, for many years thereafter. SED 3/FP 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.

[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.

Riverbank Habitat: 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

Reduction of Toxicity: 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.

Reduction of Mobility: 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.

Impacts on Aquatic Riverine Habitat: 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.

Impacts on Riverbank Habitat: 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]

[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.

[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

[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-

[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

[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 3[3]	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 1
USE OF CHANNEL REALIGNMENT ALONG THE HOUSATONIC RIVER FOR RESTORATION AND REMEDIATION OF PCB CONTAMINATION

USE OF CHANNEL REALIGNMENT ALONG THE HOUSATONIC RIVER FOR RESTORATION AND REMEDIATION OF PCB CONTAMINATION

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1. INTRODUCTION

This paper provides an overview of the use of channel realignment for geomorphic restoration of disturbed river systems, and how that information may relate to the remediation of PCB contamination in the Housatonic River. There are four main goals of this effort:

1. Document the current understanding of channel realignment as a stream restoration tool.
2. Document the limitations of bank stabilization alone as a restoration alternative following remediation.
3. Describe the additional restoration opportunities provided by channel realignment.
4. Present the advantages and disadvantages of channel realignment as a tool for geomorphic and ecological restoration.

The information in this paper integrates sciences such as fluvial geomorphology, engineering, toxicology, hydraulics, sedimentology, biology, and ecology, as well as applied construction and remediation technology. The ultimate goal for this paper is to build an understanding of restoration processes using principles of geomorphology to help the assessment of potential strategies for the remediation and ecological restoration of the Housatonic River.

2. OVERVIEW OF GEOMORPHIC CONDITIONS ALONG THE HOUSATONIC RIVER

Over the past few hundred 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 plan form and dimension. Evidence of past plan form adjustments along the Housatonic River is displayed in Figure 1, where a chute cutoff formed along the River, and created an oxbow wetland. As a result of this chute cutoff, the sinuosity (ratio of channel length to the valley length) of this particular reach decreased from a value of 2.6 to 1.7. Often chute cut-offs and other plan form channel adjustments occur at locations where the ratio of the radius of curvature of the channel relative to the bankfull width of the channel is less than 2. There are many locations on the Housatonic River where tight bends exhibit low radius of curvature ratios (Rc), as exhibited in Figure 1.

Cutoffs are an inherent part of meandering behavior (Hooke 2004) and help streams maintain a stable state by preventing the length and sinuosity of the channel from becoming too great and developing an unstable plan form configuration (Camporeale et al. 2008). Empirical studies of meander geometry show the radius of curvature of meander bends trends toward 2.4 times the bankfull channel width (Garcia 2008), implying there is an equilibrium dimension to which meandering rivers evolve (Lagasse 2004).

Figure 1: Housatonic River Reach 5B Meandering Cutoffs and Oxbows

Additional evidence of an accelerated plan form evolution is seen on the Housatonic River upstream and downstream of New Lenox Road (Figure 2). An analysis of historical topographic maps and aerial photographs reveals that the majority of the Housatonic River from the confluence of the East and West Branches downstream to Woods Pond was artificially straightened in the past. Most of this straightening likely occurred in association with railroad construction and agricultural practices in the Housatonic River valley completed in the 1850s, and was often accompanied by removal of the woody vegetation along the stream banks. Even before the railroad was built, the majority of the floodplain had been deforested during colonization in the 17th and 18th centuries. The river, which appears to be a naturally sinuous system, has been undergoing a process of active readjustment to these historical channel-altering disturbances.

Figure 2: Reach 5B Comparison of 1886 Plan Form and Current Plan Form

3. GEOMORPHIC LIMITATIONS OF BANK STABILIZATION AND RESTORATION APPROACHES

As described above, the Housatonic River corridor has been highly disturbed, which has caused active channel adjustments resulting in very sinuous and tight meander bends. Figure 3 displays a section of Reach 5A that has a sinuosity of 2.0 and radii of curvature as tight as 1.4 times the width of the channel. In stream reaches such as this, the plan form has areas of greatly accelerated bank erosion that will lead to future chute cut-offs, oxbows and other channel avulsions. Such geomorphic changes and erosion would likely result in future releases of PCB contaminated soils that are not removed during remediation.

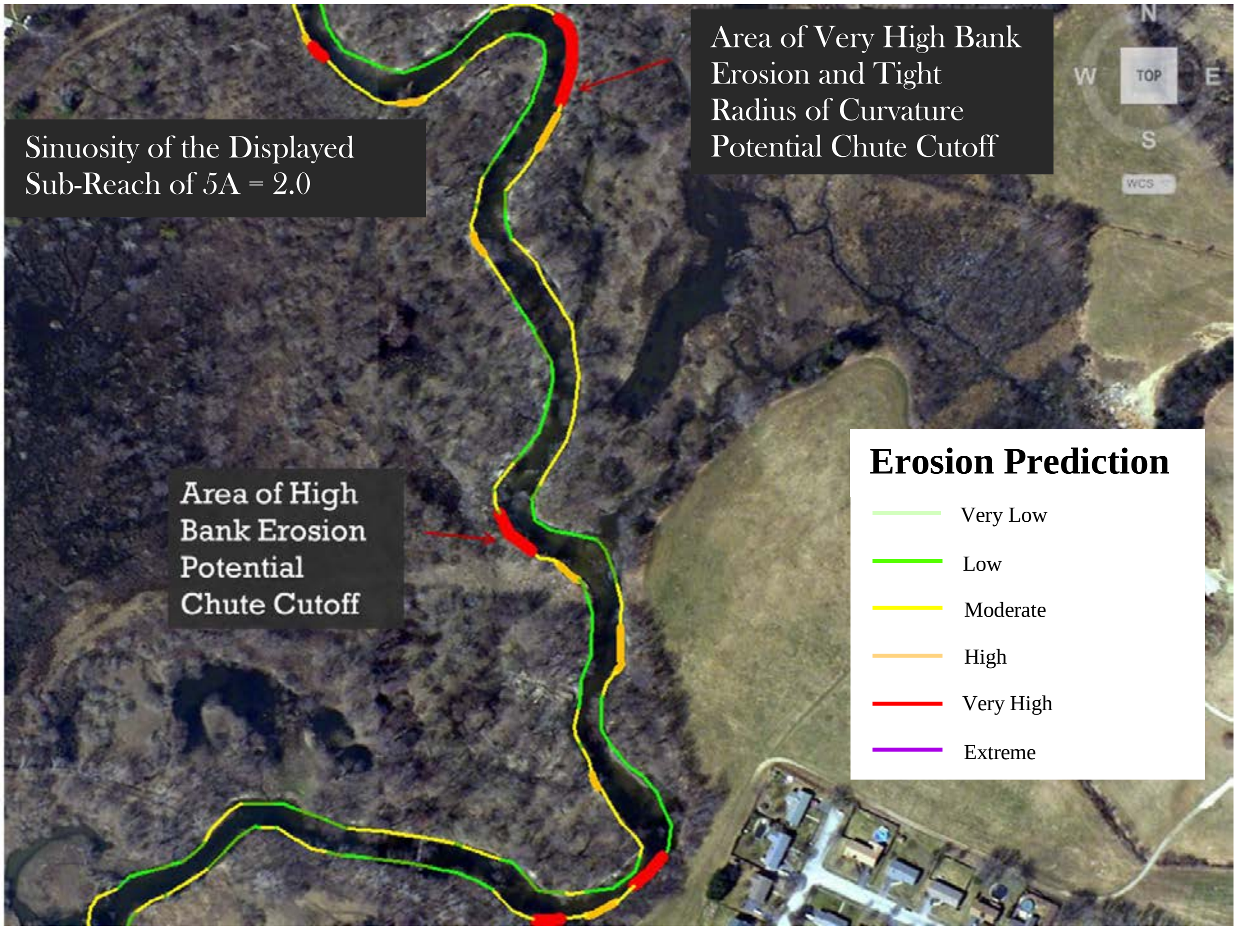

Figure 3: Housatonic River Reach 5B - Unstable Plan Form with Tight Radii of Curvature and a High Sinuosity

Understanding fluvial processes is imperative for successful river management and channel restoration design (Holmes, 1993). Without an understanding of fluvial geomorphology, and the impacts of catchment developments, it is likely that inappropriate enhancements will be proposed and executed only to be destroyed by natural river processes. Specifically, the application of bank stabilization techniques without this geomorphic context is unlikely to be successful. In areas of tight meander bends, chute cutoffs will be able to circumvent bank treatments.

If the existing channel is in an unstable morphology, then there will be areas of increased near-bank shear forces (the force applied to the bank by flowing water) due to the tight radii of curvature of the current plan form. Realignment is one restoration approach that can reduce the potential for bank erosion to the lowest possible value for long term stability.

4. THEORY OF CHANNEL REALIGNMENT TO PROVIDE GEOMORPHIC RESTORATION

Geomorphic restoration of rivers requires an understanding of both hydraulic engineering and geomorphology. By bringing together geomorphic principles and engineering methods, river restoration can be completed while following a geomorphic-engineering framework for channel restoration design in meandering rivers. By accounting for natural systems variability, the design framework is an appropriate methodology for generating restoration design solutions that mimic the natural channel morphologies and environmental attributes in undisturbed systems, while meeting multifunctional goals of channel stability and enhanced ecologic function. There are various methodologies and approaches that will be briefly referred to in this paper. In finding a solution for restoration of a natural meandering river, the practitioner is forced to use empirical-statistical, analytical and analogue methods. Both the empirical and analogue methods use reference reach data from other similar watercourses as a basis for design parameters on an impaired reach. It is not currently in the limits of understanding of geomorphic river engineering to use only analytical equations to solve the complex problems of a disturbed natural river.

Natural rivers in dynamic equilibrium possess a high degree of morphological diversity, in terms of cross-sectional, longitudinal, and plan form variability. The physical characteristics of a river channel include the shape and size of the channel cross section, the configuration of the bed along the path of the channel, sediment deposits and other in-stream features, the longitudinal profile, and the channel pattern (Simons, 1979). In addition, biological factors, such as riparian vegetation, have significant influence on the system. For straight alluvial streams, Lane (1937) identified a list of factors that may enter into a determination of stable channel shapes:

i) Hydraulic Factors - slope, roughness, hydraulic radius, mean velocity, velocity distribution, and temperature

ii) Channel Shape - width, depth, and chemical and physical side factors

iii) Nature of Material Transported - size, shape, specific gravity, dispersion, quantity, and bank and sub-grade material

iv) Miscellaneous Factors - alignment, uniformity of flow, and aging

The number of morphological equations required to obtain a determinate solution of the fluvial system is controlled by the number of dependent variables that define the hydraulic geometry of the system. Hey (1978, 1988) identified nine degrees of freedom for natural channels with sinuous plan forms based on:

i) Cross-Sectional Shape - wetted perimeter, hydraulic radius, maximum depth

ii) Slope

iii) Plan Shape - sinuosity, meander arc length

iv) Velocity

v) Bed Forms - bankfull dune wavelength, bankfull dune height

The controlling, or independent, variables are discharge, input sediment load, bed and bank sediment size, bank vegetation, and valley slope. With only three established process equations available (continuity, flow resistance, and sediment transport), the system is indeterminate unless empirical methods and other assumptions that include analog relationships are applied. Analogue solutions for channel restoration can include a historical reconstruction of the disturbed reach or the use of a stable geomorphic reference reach for a natural analogue.

There are numerous practitioners and educators that use various combinations of analytical, empirical and analogue relationships to define a slightly different approach to natural river restoration design for meandering alluvial channels. It is not the purpose of this paper to prescribe one approach or a specific suite of tools for the Housatonic River.

Channel realignment can be a valuable design approach when morphological parameters of a disturbed reach fall outside a range likely to provide long-term stability in the context of a particular project. There are numerous interrelated morphological parameters, including width, depth, radius of curvature, sinuosity, riffle slope, and pool-to-pool spacing. Effective channel restoration would consider channel realignment in concert with cross-sectional, plan form, and longitudinal variables. Further, the placement of bank stabilization and habitat structures would be developed after establishing the channel morphology design. Such structures could be used to add additional bank and/or bed protection at critical design locations, redirect flow away from vulnerable banks, and enhance terrestrial and aquatic habitat.

5. POTENTIAL APPLICATION OF REALIGNMENT ON THE HOUSATONIC RIVER

There are many areas of the current alignment of the Housatonic River in reaches 5A and 5B that are not within the stable range of pattern and profile morphology compared to other stable reference channels in New York and Massachusetts. For a simplification of this application of channel realignment, three of the numerous morphological parameters were evaluated. The three morphological parameters are listed with an appropriate range for a stable reference reach in Table 1. The morphological parameters and associated ranges are for stable reference reaches of similar channel type, valley type, channel size, and sediment supply. These morphological parameters in Table 1 are dimensionless and normalized by a unit length of the Bankfull Width or Valley Length.

Table 1: Reference Dimensionless Morphological Parameters

Morphological Parameter	Minimum Value	Maximum Value
Ratio of Radius of Curvature to Bankfull Width	2.0	4.0
Ratio of Pool to Pool Spacing to Bankfull Width	4.5	6.0
Sinuosity Ratio of Channel Length to Valley Length	1.2	2.0

Channel realignment was considered for all areas of the Housatonic River in Reaches 5A and 5B that did not meet these three morphological parameters. It was assumed that the remainder of reach that met these three parameters could have the banks restored or stabilized with bank stabilization techniques. All of the numerous morphological parameters should be compared to the existing conditions as well as a reference condition to decide the appropriate length of the Housatonic that should be realigned to achieve geomorphic restoration. This task cannot be done until a geomorphic assessment and river survey is completed on Reaches 5A and 5B.

5.1 BENEFITS OF CHANNEL REALIGNMENT FOR THE HOUSATONIC RIVER

5.1.1 Creation of New Oxbows and Wetlands

The current rate of oxbow formation is likely greater than under natural conditions given the past disturbance described above. The river exhibits characteristics that indicate it is not in an equilibrium condition after such disturbance, so the rates of change as the river returns to an equilibrium condition are greater than a channel that is near equilibrium. Remediation and restoration will result in a slower rate of oxbow creation. However, as part of the channel realignment, there can be additional oxbows and wetlands created in the existing channel that will become abandoned after realignment and geomorphic restoration. Figure 4 displays the horizontal position of potential oxbow wetlands that could be created with the process of channel realignment. The off-channel oxbows and wetlands would be depositional zones and may not require removal of sediments. The transport of the PCBs in the oxbows and wetlands could be reduced by capping the contaminated bed material with clean fill material.

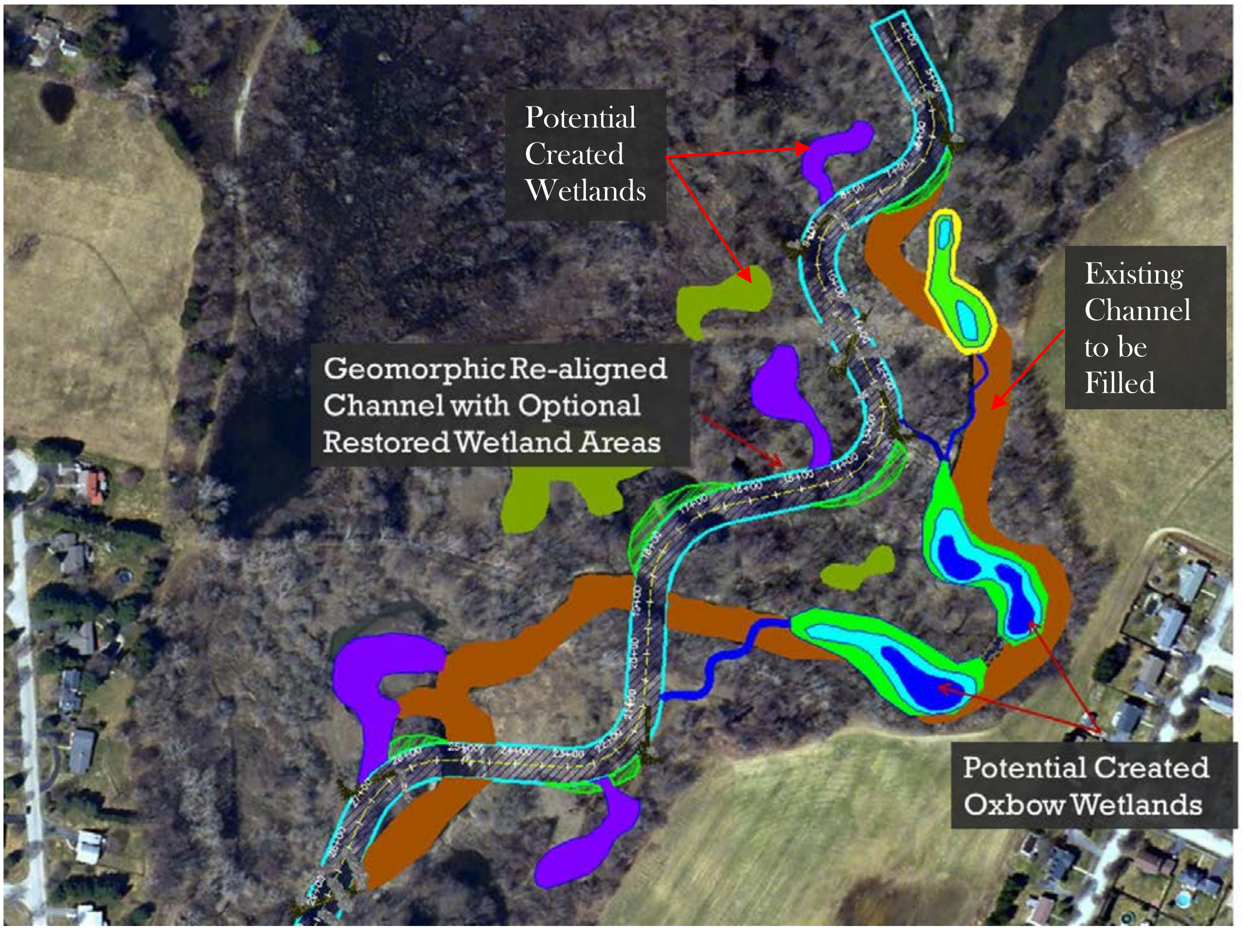

Figure 4: Example of Potential Oxbows and Wetlands in Reach 5A

5.1.2 Floodplain Fill and Capping of the Existing Channel

With a realignment approach to restoration, the existing channel location could potentially be used as a disposal location for contaminated sediments. In addition, the realigned channel can be graded through some amount of clean material that could be used as capping material. The channel could then be restored without armoring if the excavation is through clean fill. The combination of placement of floodplain fill from on-site as well as realignment through areas of clean sediments could result in less material taken off-site to achieve the same desired cleanup level. Less material transported off-site would reduce the disturbance to existing wetlands for access roads and the effort that would be needed to transport the contaminated sediments off-site.

5.1.3 Construction in the Dry Off-Line

The construction of the realigned restored channel can be done off-line in the dry. This construction technique would allow for a more surgical approach to remediation and restoration. An entire sub-reach of the realigned channel could be constructed in the dry, then the water would be diverted to the realigned channel and using common engineering methods the existing channel would be dry for cleanup and remediation. The existing channel could become a created wetland feature or an on-site disposal location for sediments. The offline construction in the dry may reduce construction duration and cost.

5.1.4 Sediment and Erosion Control During Construction

Construction of an off-line realigned channel will allow for easier management and control of sediment and erosion during construction.

5.2 DISADVANTAGES OF CHANNEL REALIGNMENT FOR THE HOUSATONIC RIVER

5.2.1 Vegetation Disturbance and Impact

Channel realignment will require the removal of a significant amount of vegetation on the floodplain; however, efforts could be made to incorporate these activities into floodplain remediation. It would be possible to incorporate some of the removed vegetation into in-stream grade control, bank stabilization, and habitat structures. It is also possible that the most ecologically or aesthetically important trees or stands of trees or habitats of concern can be mapped and avoided during the design and construction. It should be noted that the majority of the Housatonic River floodplain has been deforested in the past since colonization in the 17^{th} and 18^{th} centuries and have returned without the benefit of active restoration. Trees and other vegetation are very important to any restoration project and will need to be re-established as part of the channel restoration.

5.2.2 Change in the Character of the Housatonic

The Housatonic River currently has a character that will be changed with channel realignment. The realignment would result in a less sinuous channel and a shorter reach length. The character of the River is a subjective parameter that would most likely change with each person’s opinion.

5.2.3 Additional Testing and Sampling During Construction

Channel realignment and geomorphic restoration to achieve the desired risk reduction would require additional excavation that would need additional testing of sediments in the channel and floodplain soils in areas of interest.

5.2.4 Change in Property Lines due to Channel Realignment

Property lines that were defined by the River centerline would need to be reestablished and surveyed if the River was realigned.

6. SUMMARY OF POTENTIAL CHANNEL REALIGNMENT ON THE HOUSATONIC RIVER

Based on this assessment, 9,500 linear feet of the Housatonic River in Reaches 5A and 5B fall outside of the range of the three reference ratios of radius of curvature, pool-to-pool spacing, and sinuosity. This length equals 20 to25% of the total 41,000 linear feet that were assessed from the confluence of the East and West Branches to below New Lenox Road into Reach 5B. The 9,500 linear feet should be considered as a minimum length for consideration of channel realignment. A more-detailed geomorphic assessment would need to be carried out to determine if realignment is appropriate for sections of stream outside of this minimum estimate of 9,500 linear feet.

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ATTACHMENT 2
CHANNEL DYNAMICS AND ECOLOGICAL CONDITIONS IN THE HOUSATONIC RIVER PRIMARY STUDY AREA

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February 2, 2012

Scott Campbell
Weston Solutions
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Re: Channel Dynamics and Ecological Conditions White Paper

Dear Mr. Campbell,

Biohabitats is pleased to submit the attached white paper titled "Channel Dynamics and Ecological Conditions in the Housatonic River Primary Study Area." The paper presents principles of stream meandering, reviews data related to the Housatonic River in the Primary Study Area (PSA), and describes wetlands in the PSA and associated Massachusetts Endangered Species Act (MESA) species.

The white paper reflects the joint efforts of Biohabitats, Stantec, and Field Geology Services, as well as input from the EPA and its wider technical consulting team members.

We appreciate the opportunity to work as a member of your team on this project.

Sincerely,

BIOHABITATS, INC.

Ellen M. McClure

Ellen M. McClure, C.E.
Senior Fluvial Geomorphologist

cc: Susan Svirsky, EPA

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1. INTRODUCTION

This paper summarizes the current understanding of stream meander migration theory. There are three main objectives of this effort:

1. Document the current understanding of stream meanders and the role they play in the formation of floodplain geomorphological features such as point bars, scroll bars, cutoffs, floodplain/oxbow wetlands, backwaters, sloughs, and vernal pools.

2. Present the current data on how the Housatonic River channel in the Primary Study Area (PSA) relates to other river systems in the region, the history of channel migration in the PSA, and the rates of channel change.

3. Describe, to the extent possible, the wetlands in the PSA and how those wetlands relate to the Massachusetts Endangered Species Act (MESA) species in the PSA.

2. MEANDER THEORY AND MEANDER FORMATION LITERATURE REVIEW

Alluvial rivers, rivers with the freedom to migrate across a self-formed floodplain, have a propensity for developing a meandering planform (Leopold, 1994). A meandering river can ultimately develop from a straight channel alignment as small perturbations, such as sediment input from a tributary, result in large-scale meanders (Xu et al., 2011). As meanders develop, they eventually reach a quasi-equilibrium state with the meander wavelength, amplitude, corridor width, and radius of curvature staying relatively stable despite continuing meander growth and channel migration (Xu et al., 2011; Figure 1). Although the time needed to reach an equilibrium state will vary by river, the river tends towards a condition where a minimum rate of energy dissipation occurs along its length (Xu et al., 2011). As such, sharp right angle bends along alluvial rivers do not persist, because energy expenditure along the length of the channel is focused at one point - the sharp bend. Ultimately, given such a sharp bend, a river adjusts through erosion and deposition to form a smooth meander where the amount of turning, and therefore energy expenditure, at any given point in the bend is equal to all other points.

Empirical studies of meander dimensions document several relationships that hold for rivers of all sizes, such as a value of 11 for the ratio between meander wavelength and channel width (Leopold, 2004). The consistency of meandering relationships suggests meandering is a transient process that tends, as sinuosity increases, toward a planform equilibrium (Garcia, 2008).

A common process on meandering rivers is the cutting off of meander bends and creation of oxbow ponds (Figure 1). Cutoffs are an inherent part of meandering behavior (Hooke, 2004) and help a river maintain a stable state by preventing the channel length and sinuosity from becoming too great and developing an unstable planform configuration (Camporeale et al., 2008). Two cutoff mechanisms are widely recognized: neck cutoffs and chute cutoffs (Constantine et al., 2010). Neck cutoffs occur through bank collapse when the banks of two adjacent meanders erode towards each other and eventually meet. A chute cutoff results when a new channel carves across the inside bend of a meander and becomes the dominant conveyor of river discharge. The processes of meander evolution ultimately enhance the likelihood of cutoffs developing by these two mechanisms. Empirical studies of meander geometry show the radius of curvature of meander bends generally falls within a range near 2.4 times the bankfull channel width (Garcia, 2008), implying this is an equilibrium dimension to which meandering rivers evolve (Lagasse, 2004).

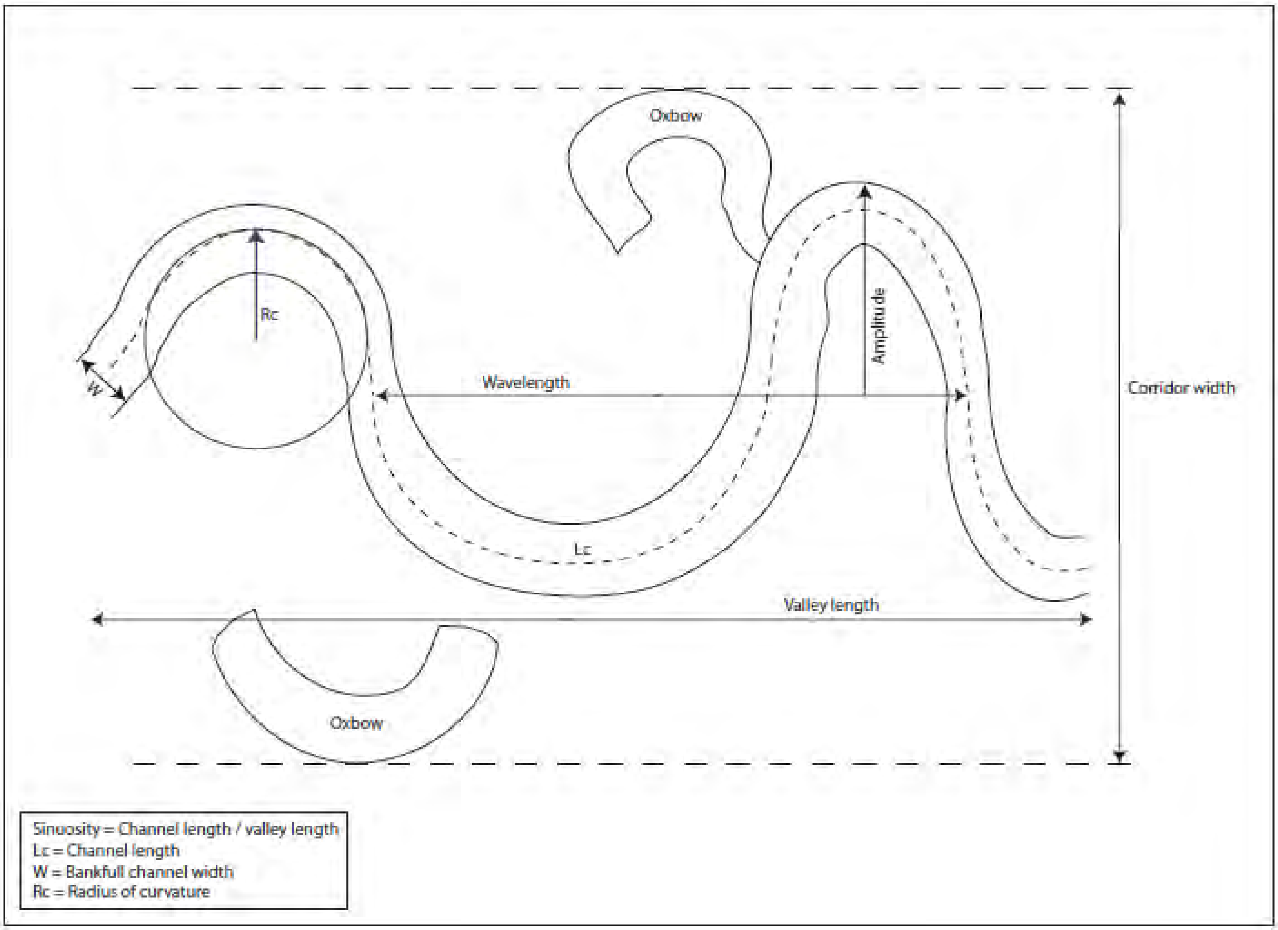

Figure 1 Definition of Meandering Planform Characteristics

Numerous studies also demonstrate that accelerated bank erosion rates on meandering rivers occur in meander bends with a radius of curvature between 2 to 3 times the bankfull channel width (Begin, 1981; Nanson and Hickin, 1986; Hooke, 1997). Consequently, as a meandering river approaches an equilibrium condition, the rate of bank erosion, a process that ultimately results in neck cutoffs, increases. This relationship also illustrates that geomorphic stability does not imply channel position is static through time, because a river in dynamic equilibrium can migrate across its floodplain through bank erosion on the outside bend of meanders while maintaining the same channel dimensions due to an equivalent amount of deposition on point bars on the inside bend of meanders. A similar inherent tendency in meander development also increases the probability of chute cutoffs developing. As channel sinuosity increases through meander growth, the corresponding decrease in channel slope leads to channel aggradation (i.e., deposition) (Knighton, 1998) and ultimately increases the amount of overbank flow available to carve a chute cutoff channel across the inside of a meander bend (Thompson, 2003).

Numerical modeling indicates channel sinuosity will increase along a meandering river until a critical sinuosity of 3.14 (pi) is reached (Stolum, 1996). Once this critical value is reached or exceeded, a cluster of cutoffs, both in space and time, is likely to occur. While the idealized sinuosity value of 3.14 is rarely reached on real rivers, empirical evidence does suggest clusters of cutoffs do occur once a critical sinuosity value is reached (Hooke, 2003). Channel adjustments resulting from the decrease in channel length associated with a single cutoff tend to promote the development of additional nearby cutoffs shortly after the initial one occurs (Stolum, 1996). As a result of multiple cutoffs, the channel sinuosity will fall below the critical sinuosity and a period of meander growth will subsequently ensue, so the channel can once again tend towards the critical sinuosity (Hooke, 2003). Consequently, meanders oscillate in sinuosity, through alternating periods dominated by meander growth and cutoffs, respectively, to maintain a critical sinuosity or equilibrium condition.

While intrinsic meandering dynamics control cutoffs and the formation of oxbows, the location and frequency of cutoffs are also controlled by external conditions. Vegetated floodplains are less likely to experience cutoffs because of the added floodplain resistance that slows the rate of erosion (Constantine et al., 2010). Similarly, floodplain stratigraphy also controls cutoff development. Clay plugs resulting from the infilling of older oxbows are more resistant to erosion than the surrounding floodplain deposits, potentially reducing the rate of meander migration and frequency of cutoffs. Maximum meander migration on the lower Mississippi River, where clay plugs are common, occurs on meander bends with a radius of curvature of less than 2 rather than between 2 and 3 times the channel width as observed on other rivers with homogeneous floodplain stratigraphy (Hudson and Kesel, 2000). Fine-grained sediment loads that might result from erosion of cohesive bank materials, such as clay, favor the development of meandering channels with a higher sinuosity (Schumm and Khan, 1972). Channel sinuosity, and in turn the likelihood of oxbow formation, is also controlled by valley gradient, with higher sinuosities associated with lower gradients (Schumm, 1979). High discharges accompanying floods are often the triggering event that causes cutoffs, although intrinsic meandering dynamics ultimately control the location and number of such cutoffs (Hooke, 2004). Finally, human activities can alter the rate of meander migration and oxbow development. Watersheds with dams and channels that have been armored show decreased rates of channel migration, although the planform dimensions (e.g., wavelength, amplitude, and radius of curvature) may remain unchanged (Ollero, 2010; Magdaleno and Fernandez-Yuste, 2011).

Natural events (e.g., large floods) and human activities (e.g., channel straightening) can sometimes greatly alter the channel configuration such that the river is temporarily removed from an equilibrium condition. Following the channel-altering disturbance, the river will undergo a series of adjustments that will bring the channel back into equilibrium (Petts, 1994). The adjustments will initially be very rapid but the magnitude and rate of change will decline as the river once again approaches equilibrium (Figure 2). In some instances when the disturbance permanently alters the watershed conditions, such as through urbanization, the river will not return to the former equilibrium state but will achieve a new equilibrium condition with channel dimensions different from those associated with the earlier equilibrium state.

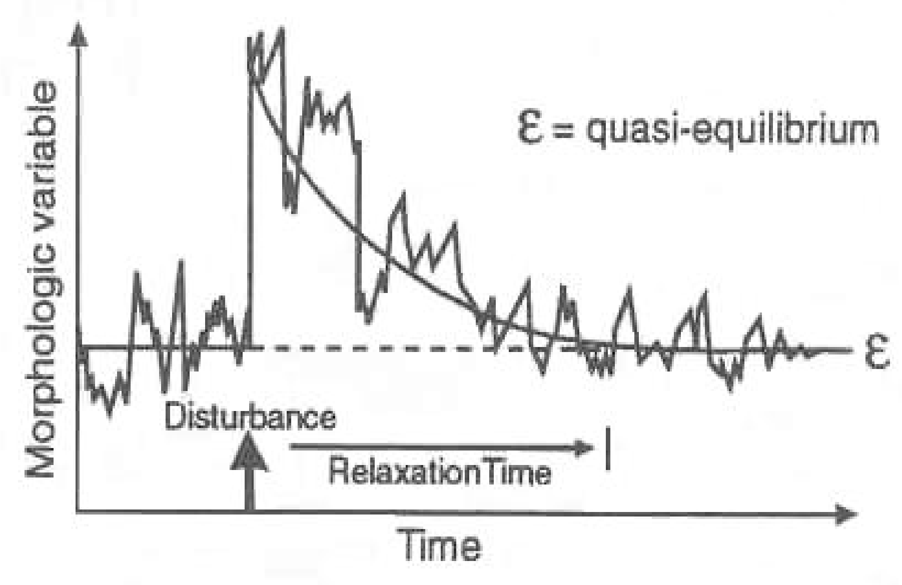

Figure 2 Magnitude of Channel Adjustments Through Time Following a Disturbance Relative to a Quasi-Equilibrium Condition

Source: From Petts (1994)

A meander cutoff represents a small channel disturbance that results in local channel adjustments. Following a cutoff, the newly created channel undergoes incision that migrates upstream as a headcut due to the shortened stream length and increased slope (Hooke, 1995).

Vertical accretion of sediment occurs most dramatically at the upstream end of the oxbow created by the cutoff as overbank flows enter the now-abandoned channel (Hooke, 1995; Lagasse, 2004). The changes following a cutoff are initially very rapid, but the rate of change declines with time (Hooke, 1995) such that oxbows can persist for hundreds of years before becoming completely infilled with sediment (Lagasse, 2004).

Many of the basic principles of meandering rivers, point bar development, and floodplain formation come from studies of rivers in the mid-Atlantic region of the United States (Wolman, 1955; Wolman and Leopold, 1957). Recent studies show that these rivers actually flow through impoundment sediments deposited behind old mill dams and do not represent meandering rivers flowing through self-formed floodplains (Walter and Merritts, 2008). Consequently, the presence of a meandering planform cannot immediately be assumed to develop from a standard sequence of processes or events. Alternate models of meander formation must be considered when studying any given river system and a full understanding of the history of the river considered in the development of such models.

3. ROLE OF MEANDER MIGRATION IN CREATING AND MAINTAINING BIOLOGICAL DIVERSITY

Meander migration, and the resulting channel cutoffs and oxbow lake/wetland formation are well-documented and reasonably understood phenomena (Howard, 2009). Meander migration is a complex interaction of many variables. Channel geometry, high-stage flows, sediment load and transport, bank material resistance and type of vegetation on the banks all factor into the process, making it very dynamic across the range of variables involved. The meander migration process generally erodes material from one area of the channel and deposits material in another through the erosion, sediment transport and sediment deposition processes. Meander migration is often most pronounced during high flow or flooding events.

As the erosion/deposition of material in meander migration takes place, the geometry and planform of the channel changes. The channel moves, and changes shape. Areas that once were channel banks and associated riverine floodplain are removed, and new areas, where eroded material is deposited, are created, often in predictable locations such as oxbow lakes, point bars and scroll bars.

The movement of the planform of the channel and associated formation of channel cutoffs, oxbow lakes, point bars and scroll bars creates topographic variations within the active floodplain. As variations in topography in the floodplain become more pronounced, they in turn create a wider range of hydrologic regimes within the floodplain, depending on the elevation, proximity to the active channel, and depth to groundwater in any given location.

The combination of the range of floodplain elevations and hydro-periods created by meander migration, and the resultant oxbow lake and bar formations, have been shown to dictate vegetation patterns and potentially provide diverse floral and faunal communities in an array of wetland and upland habitats (Nanson, 1979; Hupp and Osterkamp, 1996; Ward et al., 2002). Henry and Amoros (1995) state that the "most widely valued function of wetlands, particularly for riverine wetlands, is their contribution to the maintenance of regional biodiversity." Florsheim et al. (2008) state that bank erosion and the consequent meandering of rivers is beneficial, because it "is a geomorphic process that promotes riparian vegetation succession and creates dynamic habitats crucial for aquatic and riparian plants and animals."

4. COMPARISON OF REACH 5 AND 6 RIVER GEOMETRY WITH OTHER REGIONAL RIVERS

The meandering characteristics of the Housatonic River are not unique in the northeastern United States; other rivers in the region share similar meandering characteristics (Table 1; Figure 3; Appendix A). For this study, portions of nine meandering rivers displaying the most well-developed meandering conditions on those rivers were compared to determine if the meandering traits of the Housatonic River were more strongly developed than elsewhere. The measured meandering parameters were normalized to channel width in order make meaningful comparisons between the rivers of varying size (Figure 3). Of the nine meandering rivers selected, the sinuosity (as defined in Figure 1) was greatest on the Housatonic River, but only slightly higher than the Saco River and Fort River. When comparing other meandering traits, such as radius of curvature and meander amplitude, values for the Housatonic River fall within the range of values measured for the nine northeastern rivers (Table 1; Figure 3). For the two parameters best reflecting the amount and lateral extent of floodplain wetlands associated with meandering rivers (i.e., length of oxbow per valley mile and the width of the meander corridor), the values for the Housatonic River fall below the trend line for the nine rivers (Figure 3). Consequently, habitat features, such as oxbows, should be considered better developed on other rivers in the northeastern United States than on the Housatonic River.

Table 1 Meandering Characteristics of the Housatonic River and Other Rivers in New England and New York

Watershed	Drainage Area (mi^2)*	Location	Sinuosity	Channel width (ft)	Meander wavelength (ft)/channel width (ft)	Radius of curvature (ft)/channel width (ft)	Meander amplitude (ft)/channel width (ft)	Length of oxbows (ft)/valley mile	Corridor width (ft)/channel width (ft)
Sawmill River	32	Montague, MA	1.83	40	7.5	2.5	3.8	1320	13.8
Fort River	56	Hadley, MA	2.13	50	10	2.4	4	2560	15
Baker River	143	Rumney, NH	1.54	100	9	2.7	4	4197	15
Housatonic River	148	Pittsfield, MA	2.27	90	5.6	1.9	3.1	3761	11.1
Batten Kill	149	Arlington, VT	1.36	70	10.7	1.9	3.2	3210	10
Poultney River	175	Fair Haven, VT	2	60	6.7	1.8	2.9	7329	16.7
Contoocook River	221	Deering, NH	1.74	80	8.1	2	4.7	5659	20
Kinderhook Creek	316	Kinderhook, NY	1.45	140	7.1	2.1	2.7	6102	15
Saco River	444	Fryeburg, ME	2.25	300	13.3	3	9.2	8865	21.7

* Drainage area at site of interest.

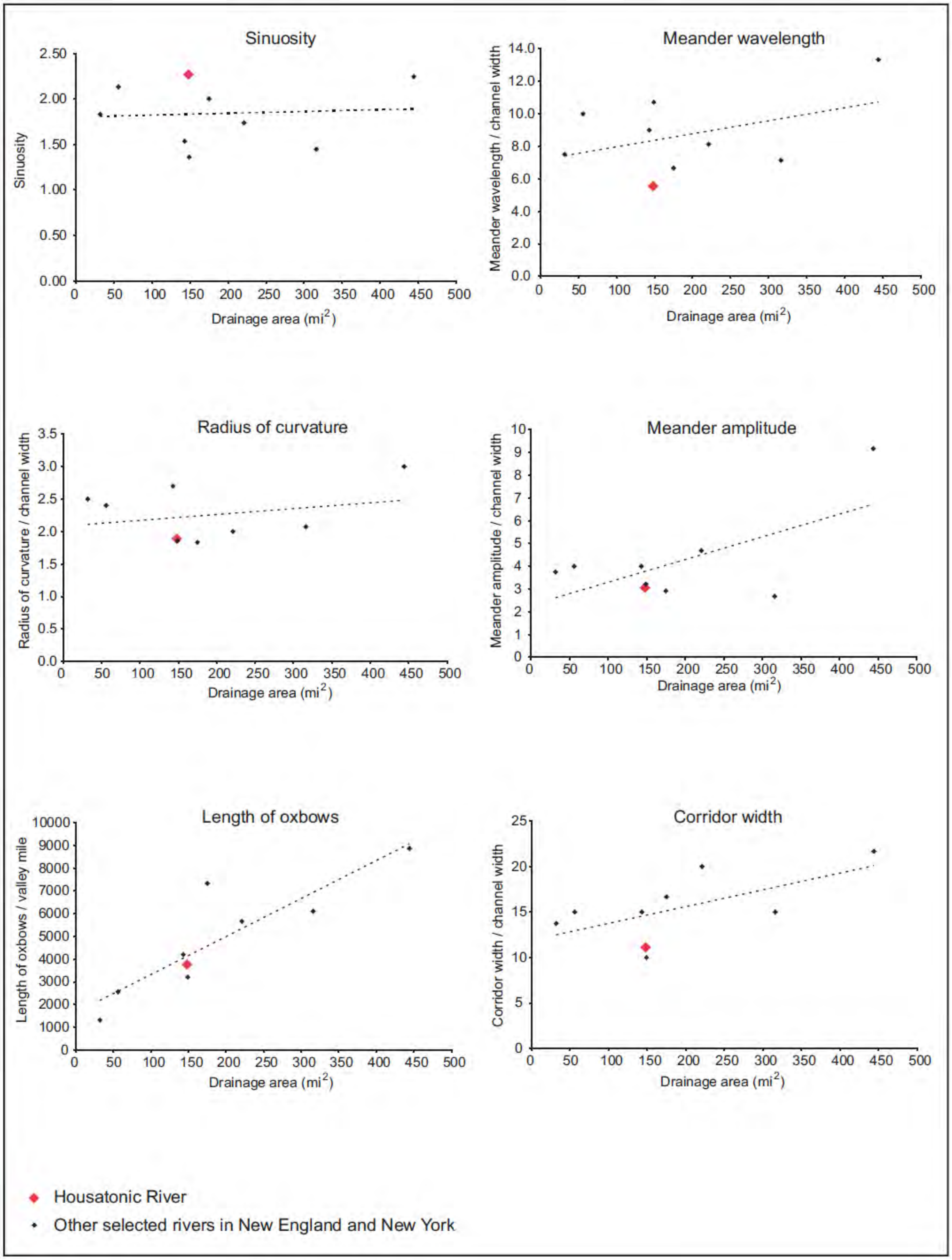

Figure 3 Meandering Characteristics of the Housatonic River and Other Rivers in New England and New York

5. HISTORY OF THE HOUSATONIC RIVER CHANNEL IN REACHES 5 AND 6

As was the case for rivers throughout New England, much of the Housatonic River was artificially straightened in the past (WESTON, 2011). Topographic maps and aerial photographs, both recent and historic, can be used to identify where channel straightening has occurred by looking for three hallmarks of artificial straightening: 1) straight segments longer than the wavelength of adjacent meanders; 2) straight segments that "hug" the valley sides despite an adjoining wide floodplain on which meanders could form; and 3) the presence of former meanders adjacent to straight channel segments (WESTON, 2011). Such evidence is seen on the Housatonic River (Figure 4) and an analysis of topographic maps and aerial photographs reveals at least 92 percent of the Housatonic River from the confluence of the East and West Branches downstream to Woods Pond was artificially straightened. Much of this straightening may have occurred in association with railroad construction completed in the 1850s, but agricultural practices and other land uses from perhaps even earlier likely were important contributors as well. Whatever the exact date of channel manipulations, the straightening was certainly completed prior to the time of the 1886 survey used to complete the historic topographic map of 1893 (Web citation 1). Whatever the exact reason for and timing of the straightening, the large-scale manipulation of the river channel represents a major disturbance that would have shifted the channel away from the quasi-equilibrium condition existing at the time of straightening (Figure 2).

In response to the artificial channel straightening and removal from a quasi-equilibrium state, the Housatonic River has undergone a period of channel adjustment that has resulted in the natural reformation of meanders along much of its length. By 1945, at least 55 percent of the straightened channel had redeveloped a meandering planform (Web citations 2 and 3). The redevelopment of meanders along artificially straightened channels has been documented elsewhere in New England (Field, 2007) and other parts of the world (Ollero, 2010). Meanders have reformed along artificially straightened channels by two primary mechanisms: 1) breakouts and 2) build outs (WESTON, 2011). First, sediment, ice, or wood can clog the channel, allowing flows to breakout rapidly across the floodplain and carve a new meander. Second, sediment building out into the channel at the mouths of tributaries can force the river flow into the opposite bank, with the ensuing bank erosion leading to the formation of a new meander. The creation of single simple meanders through these processes has occurred on the Housatonic River as documented through comparisons of historic and recent topographic maps (Figure 5). Complexes of multiple meanders have also evolved from straightened reaches (Figure 4b) and may have grown from a single breakout or build-out meander that served as the minor initial perturbation required to develop the more complex meandering planform (Xu et al., 2011). In some instances, the reformed meanders may be simply reoccupying old meanders abandoned during the channel straightening.

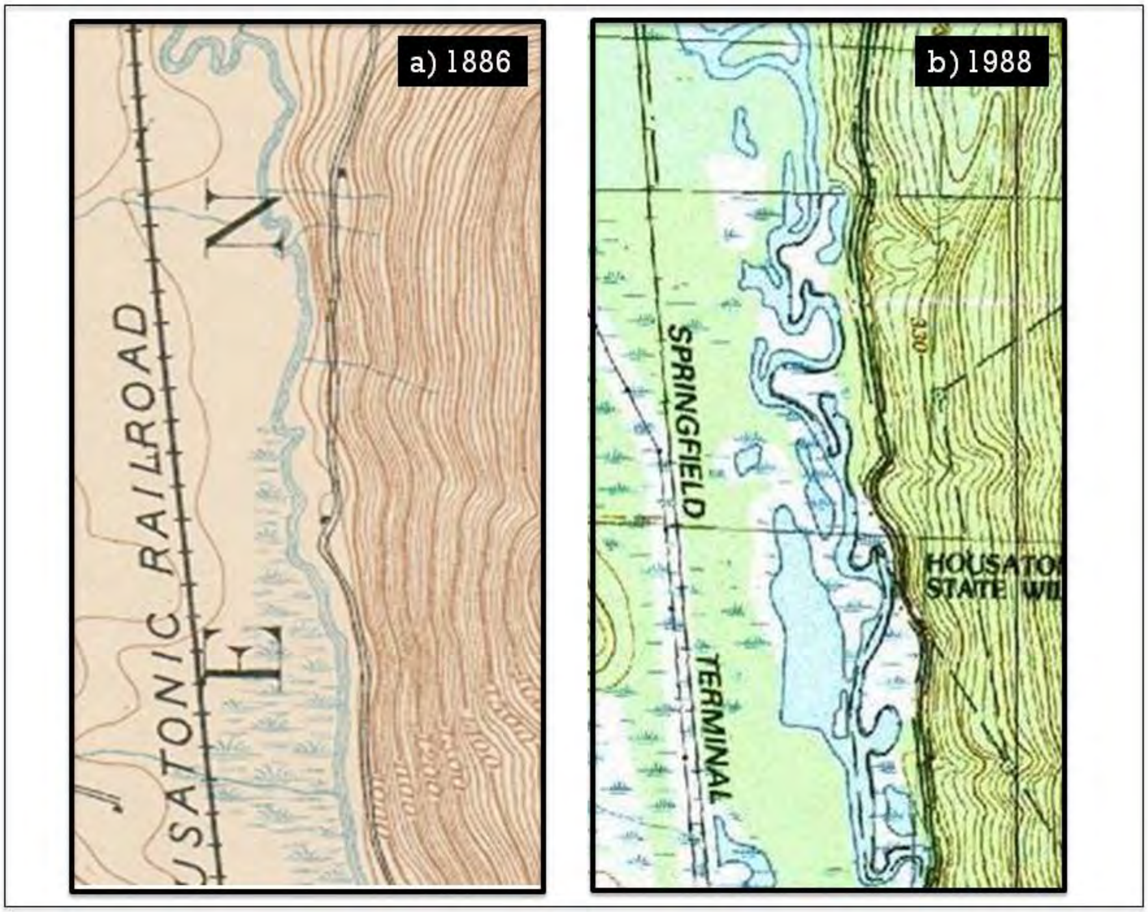

Figure 4 Topographic Maps from a) 1886 and b) 1988 Showing Reestablishment of Meanders along an Artificially Straightened Reach of the Housatonic River just Upstream of Woods Pond

Note: Evidence for straightening includes channel "hugging" the valley side, straight reaches longer than the natural meander wavelength seen at upper end of the 1886 map, and presence of abandoned meanders adjacent to the straightened channel seen on the 1988 map.

Long reaches of the river remain in a straightened configuration and are presumably not sensitive to the breakout or build-out processes of meander reformation. The areas most sensitive to the development of meanders are upstream of valley constrictions where floodwaters are impounded and flows more easily escape the channel, breakout across the floodplain, and carve a new meander. On the Housatonic River between the confluence of the East and West Branches and Woods Pond, several natural and artificial valley constrictions are present. A natural valley constriction is formed by a high ridge of glacial deposits that extends across most of the valley bottom just upstream of the Pittsfield Wastewater Treatment Plant (WWTP). Among other locations, artificial valley constrictions have been created where: 1) the sewer pipe crosses the

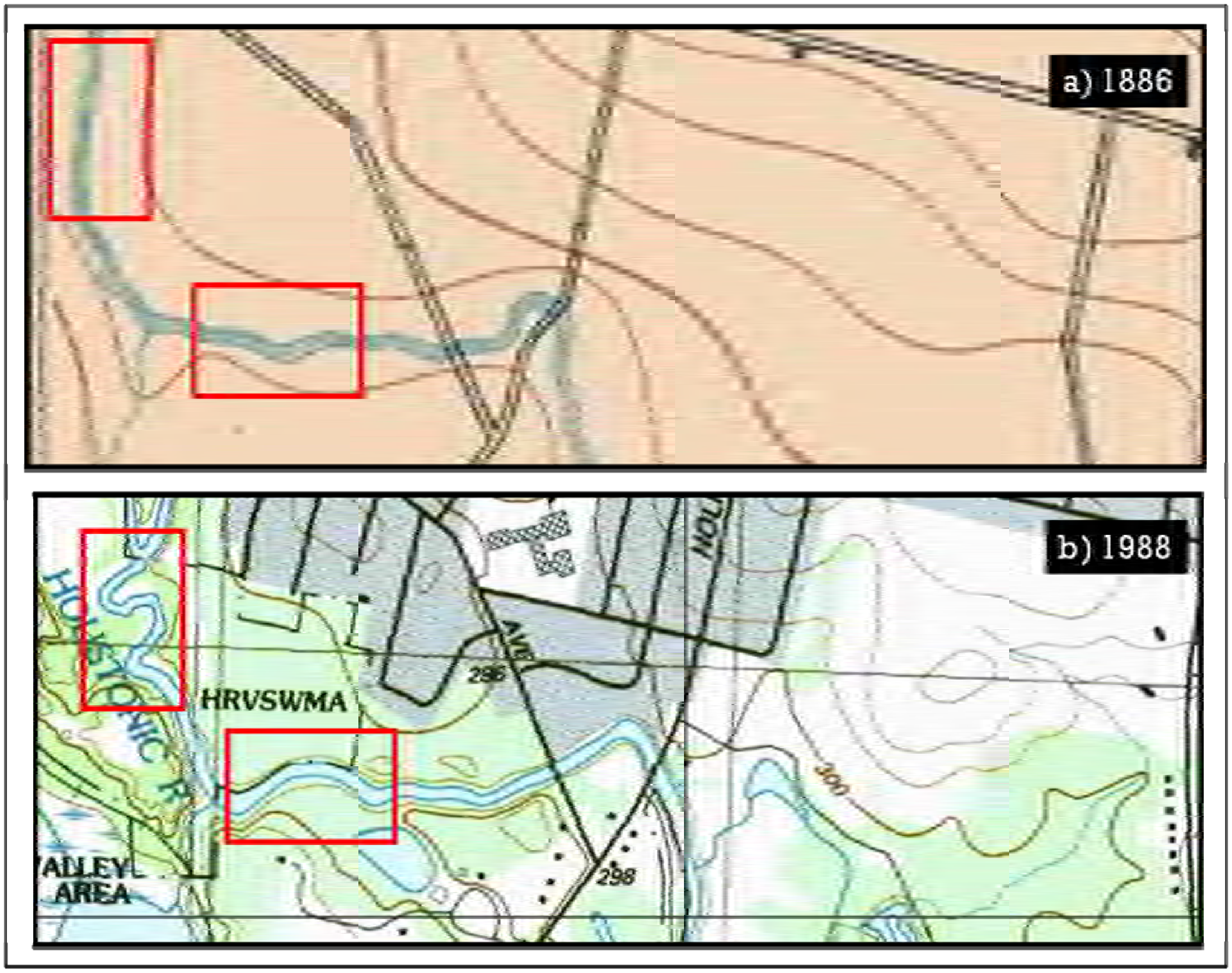

Figure 5 Topographic Maps from a) 1886 and b) 1988 Showing the Reformation of Meanders Along an Artificially Straightened Section of the Housatonic River just Downstream of the Confluence of the East and West Branches

Note: Red boxes are in the same location on both maps.

river 0.7 mi upstream of the WWTP, 2) the elevated road grade crosses the floodplain at New Lenox Road, 3) the railroad grade narrows the floodplain quite significantly across from and continuing downstream of the Roaring Branch confluence, and 4) flow is backwatered behind the Woods Pond Dam. Some of the most dramatic meandering on the Housatonic River has formed immediately upstream of these constrictions, but unless the river "hugs" the valley sides (Figure 4), the meandering is too well developed to definitively determine if these meanders have redeveloped from an artificially straightened channel.

Since 1945, no new meanders have formed along the Housatonic River between the confluence and Woods Pond (although oxbows have been created, see below). The meanders have continued to grow, with migration occurring through erosion of the outside bends at a rate no greater than 0.9 ft/yr since 1952 (WESTON, 2006). It should be noted that the average erosion rate for the entire channel in Reaches 5A and 5B is on the order of 0.3 ft/yr (Stantec, 2009). The lack of new meander formation along reaches that remain artificially straightened might be the result of meanders having already reformed in the most sensitive areas (e.g., upstream of valley constrictions, near the confluences of larger tributaries) and a lack of sufficient wood and sediment to clog the channel and force the creation of new meanders in less-sensitive areas. Sediment loads in New England rivers were high following widespread land clearance in the 1800s and generated considerable channel change (Brakenridge et al., 1988; Bierman et al., 1997; Bierman et al., 2005), but sediment loads were greatly reduced by the 1940s as forests redeveloped in the upper watersheds. Despite the regrowth of the forests, wood loads have remained low in most New England rivers because of the periodic removal of wood from river channels, a management practice that continued on the Housatonic River until at least the 1970s (WESTON, 2011). The lack of further meander formation may also indicate the Housatonic River is more closely approaching a quasi-equilibrium state where the frequency of significant channel adjustments would be expected to decline (Figure 2; Petts, 1994).

The history of channel straightening and manipulation clearly demonstrates that the Housatonic River is not a pristine fluvial system that has naturally meandered, undisturbed, across its floodplain for thousands of years. Rather than resulting in permanent change, the river has adjusted to the channel straightening in order to restore a quasi-equilibrium. The recreation of well-developed meanders in less than a century along much of the straightened river channel indicates the capacity of the river to recover from large-scale perturbations in a relatively short time frame.

6. RATE OF OXBOW CREATION AND INFILLING

Although many of the oxbows present along the Housatonic River today were likely created when long sections of the river channel were abandoned during artificial straightening, oxbow formation also occurs naturally and eight oxbows have formed in the last 70 years, as determined from historical aerial photographs, between the confluence of the East and West Branches and Woods Pond (Appendix B). A similar number of oxbows occurred in the same time period elsewhere on the Housatonic River (Pierce, 2006), perhaps resulting from continuity in the setting or some autogenic equilibrium tendency. Because the oxbows remain as a low spot on the floodplain after they are cut off from the main channel, they represent an important component of the floodplain wetland complex. Oxbows also serve as sinks for sediment carried by floodwaters, so they eventually fill in to the level of the surrounding floodplain. Along a naturally meandering river in a state of quasi-equilibrium, new oxbows are created by cutoffs at a sufficient rate to replace the wetland habitat lost through the infilling of older oxbows. At what rate the oxbows fill is an important determinant of the location, distribution, and heterogeneity of wetland habitats on the floodplain. While the literature suggests hundreds of years are needed to fill in oxbows (Lagasse, 2004), an analysis of aerial photographs and topographic surveys was completed, and presented below, to ascertain how long oxbows persist on the Housatonic River floodplain.

The locations of all oxbows between the Confluence and Woods Pond were mapped through aerial imagery interpretation (Appendix B). Oxbows were identified by their arcuate form and/or their continuing connection to the current river channel. Other wetlands without these characteristics may also be oxbows but, being less definitive, were not included in the mapping. An analysis of historical aerial photographs extending back to 1942 allowed oxbows created in the last 70 years to be dated by bracketing their time of formation between two sets of aerial photographs (Appendix B). Once mapped, the length of each oxbow was measured and the total length of oxbows created in any given time period compiled. Since 1942, nearly one mile of oxbow has been created (Table 2), representing 16.0 percent of the total length of oxbows present. If a constant rate of oxbow formation is assumed through time, then all of the oxbows on the floodplain would have taken more than 435 years (=70 years/0.16) to form. However, a constant rate of oxbow formation cannot necessarily be assumed as many, if not most, of the oxbows were created as the channel was artificially straightened. After channel straightening, a long period of channel adjustment and meander reformation would need to occur before the channel sinuosity was, once again, high enough to promote cutoffs and oxbow formation. Consequently, over the long term, the total length of oxbows seen on the Housatonic floodplain, although not formed at a constant rate, may roughly equate to what would have formed under natural conditions.

Table 2 Lengths of Housatonic River Oxbows Formed in Different Time Periods

Date of Oxbow Formation	Length (mi)
Pre-1942	5.13
1942-1952	0.12
1952-1972	0.21
1972-1990	0.13
1990-2000	0.49
2000-2011	0.00
Total Length of River Segment	11.39
Total Length of Oxbows	6.08
Length of Oxbows Formed in 70 Years	0.95

The estimated 435 years required to form the total length of oxbows present must be considered a minimum value. The rate of cutoffs and oxbow formation in the last 70 years was likely much more rapid than on a natural undisturbed river for at least two reasons. First, in response to channel straightening, the river has likely been undergoing a period of accelerated adjustment as is typical of rivers following a major disruption (Figure 2; Petts, 1994). The Housatonic River first experienced a period of rapid meander reformation prior to 1945, but since that time may be experiencing a period of accelerated oxbow formation. Clusters of cutoffs are known to occur when a critical sinuosity value is reached or exceeded (Hooke, 2003), a condition that may have been attained on the Housatonic River once sufficient sinuosity had been regained through meander reformation. Second, many of the oxbows have formed in the last 70 years in proximity to recent human alterations in the channel (e.g., treatment plant outfall) or artificial valley constrictions (e.g., sewer pipe crossing). The disruption of hydraulic and geomorphic processes around these human impacts likely increased the probability of cutoffs occurring. For both reasons, the amount of oxbow formation in the last 70 years should be considered artificially high in response to both past and recent human activities. Consequently, the rate of oxbow formation before the 1940s was likely slower, so more than the estimated 435 years would have been necessary to form all of the oxbows observed in the PSA.

The time required to form all of the oxbows on the floodplain can also be equated with the time required to completely infill any given oxbow because earlier oxbows that have infilled would no longer be visible on the floodplain and, therefore, not counted in the total length of oxbows present. To independently corroborate that the oxbows are infilling over time periods in excess of 400 years, topographic cross sections were analyzed to establish to what extent existing oxbows of different ages have infilled. If the assumption is made that the bottom of the oxbow at the time of its formation was at the same elevation as the present channel bottom, the current difference in elevation of the oxbow bottom relative to the channel bottom represents the amount of infilling that has occurred since the formation of the oxbow. Fourteen sites were identified where cross section surveys had been conducted across oxbows and the adjacent active channel, so bottom elevations of both could be compared (Table 3).

Three of the surveyed oxbows formed in the last 70 years, so the date of the first aerial photograph showing the oxbow cutoff from the active channel provides the latest possible date for its formation. The remaining 11 surveyed oxbows formed prior to the earliest aerial photographs and are assumed to have been created 150 years ago when railroad construction and other activities in the valley likely led to channel straightening and abandonment of the former meandering channel. With the ages of each oxbow either directly established or assumed, an estimate can be made of the time required to completely infill the oxbows based on the percentage of infilling that has already occurred with the difference in elevation between the current channel bottom and the adjacent floodplain surface representing the baseline for comparison. Assuming a constant rate of infilling, or a linear relationship, the time required to completely infill the oxbows is approximately 350 years (Figure 6a).

However, the rate of change following a cutoff decreases with time (Hooke, 1995), so a logarithmic relationship better describes changes in the rate of infilling through time. When a logarithmic relationship is applied to the oxbow infilling data on the Housatonic River, more than 500 years would be expected to pass before 70 percent of any given oxbow is filled with floodplain sediment and organic matter (Figure 6b). A decrease in the rate of infilling through time can also be expected from changes in land use through time.

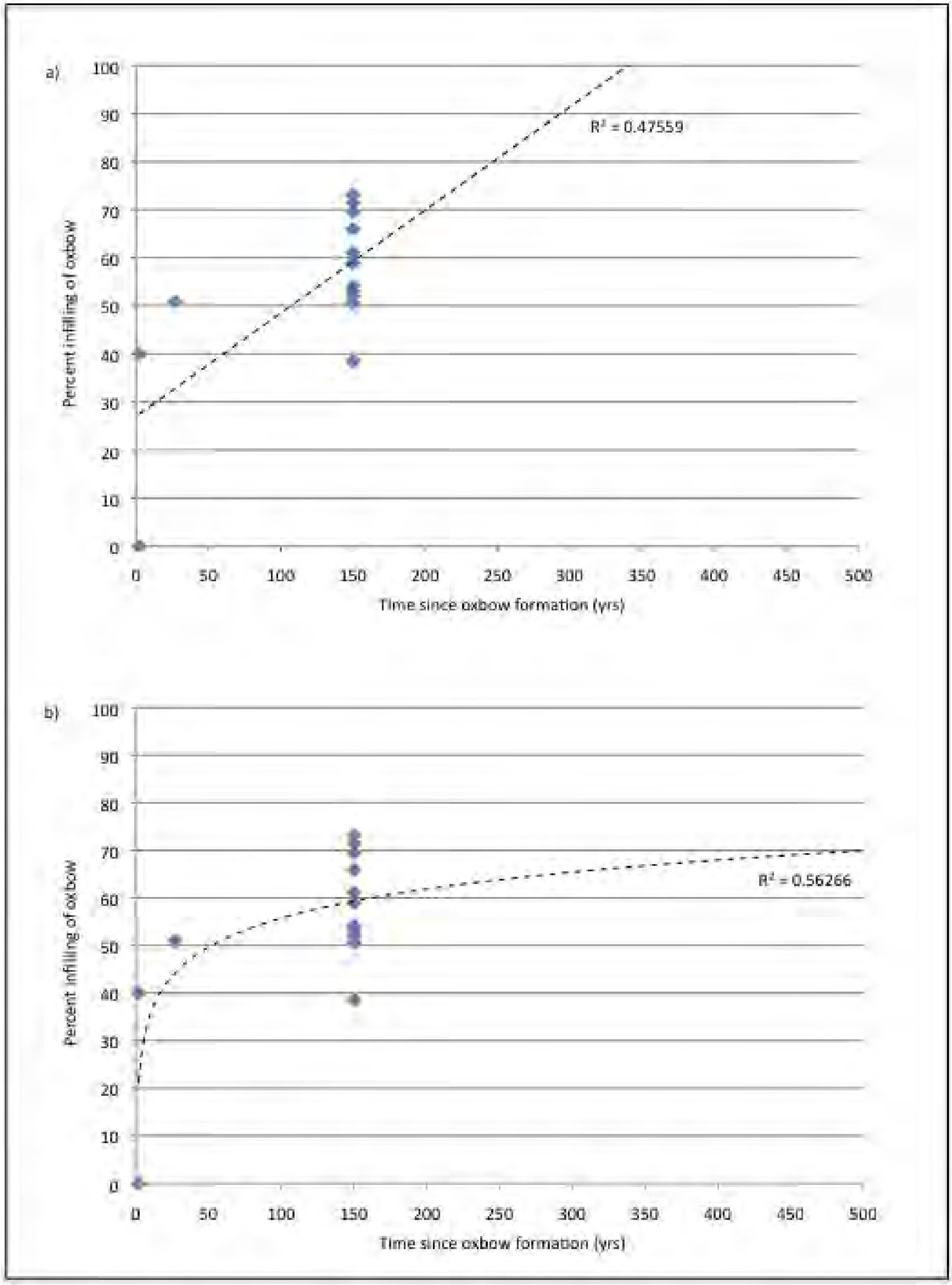

Figure 6 Estimates of Time to Infill Oxbows Based on a) Linear, or Constant, Rate of Infilling and B) Logarithmic, or Reduced, Rate of Infilling

Sediment loads have decreased over time due to a transition from agricultural to forested land use, so less sediment is available over time to contribute to the infilling of the oxbows. Although the data are limited and assumptions regarding the age of older oxbows uncertain, the topographic cross sections corroborate the findings of the floodplain mapping (Appendix B) that oxbows on the Housatonic River floodplain are infilling over several centuries and not decades.

Table 3 Elevations of Oxbows, Channel, and Adjacent Floodplain

Cross Section #	Years since oxbow formation	Oxbow bottom elevation (ft)	Channel bottom elevation (ft)	Floodplain elevation (ft)	Oxbow elevation above channel (ft)	Channel elevation below floodplain (ft)	Percent infilling
167 and 111	2	954.8	952.2	958.7	2.6	6.5	40
175 and 121	27	952.5	949.8	955.1	2.7	5.3	51
222 and 218	2	944.2	944.5	954.7	-0.3	10.2	0
274 and 100	150	948.8	937.2	953.9	11.6	16.7	69
278 and 74	150	947.1	940.3	949.6	6.8	9.3	73
284 and 58	150	945.4	939.6	950.5	5.8	10.9	53
286 and 42	150	942.9	938.2	950.4	4.7	12.2	39
292 and 29	150	944.5	935.4	949.2	9.1	13.8	66
R5 - 1	150	956.4	952.8	959.9	3.6	7.1	51
R5 - 2	150	956.3	950.8	959.8	5.5	9	61
R5 - 3	150	954.0	948.8	958.8	5.2	10	52
R5 - 4	150	949.5	943.6	954.5	5.9	10.9	54
R5 - 5	150	948.9	944.9	950.5	4	5.6	71
R5 - 6	150	946.1	940.8	949.8	5.3	9	59

Note: The R5 cross sections are numbered sequentially from upstream to downstream.

7. EXISTING ECOLOGICAL CONDITIONS

The entire Massachusetts length of the Housatonic River flows through the Western New England Marble Valleys ecoregion (NHESP, 2010). The calcium-rich marine sediments of the ancient seafloor were transformed to marble, and it is the underlying marble that makes the Housatonic watershed unique (Woodlot Alternatives, 2002).

The approximately 10 miles of river in Reaches 5 and 6 generally ranges from 45 to 100 feet in width, is bordered by extensive floodplains (up to 3,000 feet wide), and has a meandering pattern with point bars, cut banks, and the persistence of backwater sloughs, abandoned channels, and alluvial bars, as well as oxbows and backwaters throughout. Portions of the lower reaches of the floodplain are inundated by water impounded by Woods Pond Dam. Channel widths range from approximately 40 to 60 feet in the upper reaches near the confluence due to topography and development of the historic floodplain, and approximately 60 to 120 feet in the lower reaches that are not influenced significantly by Woods Pond Dam (i.e., flooding in the main channel and backwater wetlands increases width significantly near Woods Pond). Stream depths range from approximately 1.5 ft in urbanized areas to more than 8 ft under baseflow conditions, where natural meanders, cut banks, and point bars have developed. The substrate of the upper channel contains coarse gravels, cobbles, and small boulders, with occasional mid-stream bars of coarse sands. Downstream from the confluence, there are larger sand deposits in point bars.

Consideration of anthropogenic activities is of particular interest because of the land use history and the effect that past human activities have had in shaping ecological conditions and processes in the PSA (including meandering processes, downstream transport of contaminated sediment via accelerated bank erosion, and settlement in the floodplain during flooding events).

The Pittsfield Wastewater Treatment Plant (WWTP), which discharges its effluent near the midpoint of Reach 5, contributes an average flow of 0.5 cubic meters per second to the Housatonic River (Harrington Engineering and Construction, Inc., 1996).

Clearing of riparian areas for development purposes, including urban development in the upper 3.1 miles, has occurred in the floodplain throughout Reaches 5 and 6. Portions of the floodplain have been cleared for various purposes, primarily agriculture, residences, and various rights-of-way (e.g., roads, railroads, power lines). Agricultural disturbances are the major source of forest clearing within the riparian zone of the upper Housatonic River. Agricultural fields, including corn and hay fields, are a predominant land use within Reach 5 and have affected the size of the natural riparian habitats in the middle section of the Reach 5 and downstream sections near New Lenox Road. Much of the upper two-thirds of Reach 5 appears to have been cleared for agriculture at one time (Woodlot Alternatives, 2002).

Near and within areas that were previously disturbed, portions of the floodplain are inhabited by multiple non-native and invasive shrub, herb, grass, sedge, and aquatic species (Woodlot Alternatives, 2002). In Reach 5A, invasive species are prevalent in the floodplain where ornamental shrubs [Morrow's honeysuckle (*Lonicera morrowii*), common privet (*Ligustrum vulgare*), Chinese spindle-tree (*Euonymus fortunei*), European spindle-tree (*Euonymus europaea*), and winged burning bush (*Euonymus alatus*)] have escaped from adjacent urban areas. Other common invasive non-native herbs have also colonized floodplain forests [e.g., dame's rocket (*Hesperis matronalis*), goutweed (*Aegopodium podagraria*), garlic mustard (*Alliaria petiolata*) and moneywort (*Lysimachia nummularia*)]. Invasive species such as purple loosestrife (*Lythrum salicaria*), common reed (*Phragmites australis*), yellow iris *(Iris pseudacorus*), and reed canary grass (*Phalaris arundinacea*) occur, and in some areas, dominate the shoreline and marsh communities, including wet meadows and shrub swamps. Eurasian water-milfoil (*Myriophylum spicatum*), water chestnut (*Trapa natans*), and crisped pondweed (*Potamogeton crispus)* are also documented in Woods Pond and adjacent wetlands flooded by the impoundment created by the dam. Water chestnut has increased in abundance from a few plants in 1998-2000, and is now a dominant species within Woods Pond (John Lortie, personal communication).

7.1 OVERVIEW OF NATURAL COMMUNITIES IN REACH 5 AND 6

Significant portions of Reach 5 and 6 (sometimes referred to as the Primary Study Area or PSA) are open palustrine wetlands and riverine systems dominated by submersed, floating-leaved, and emergent herbaceous vegetation. Table 4 provides an acreage summary by type for each of the wetland communities in Reaches 5 and 6 based on natural community characterization in the

Ecological Characterization Report (Woodlot Alternatives, 2002). For the purpose of this analysis, the acreage of oxbow wetlands, which are present as part of several communities, albeit at a relatively small scale, were separated from the community types where they occur and treated as a separate calculation. The sizes of oxbow wetlands were subsequently calculated by natural community type (Table 5).

Table 4 Acreage Calculations for the Wetland Communities Within Reaches 5 and 6

Wetland Natural Community Type[1]	Acreage	% Wetlands
Black ash-red maple-tamarack calcareous seepage swamp	79.0	7.4
Deep emergent marsh	28.5	2.7
High-gradient stream	0.1	<0.1
High-terrace floodplain forest	10.7	1.0
Low gradient stream	250.2	23.6
Medium-gradient stream	8.4	0.8
Moderately alkaline lake/pond	22.1	2.1
Red maple swamp	102.7	9.7
Rich mesic forest	4.5	0.4
Riverine point bar and beach	1.0	<0.1
Shallow emergent marsh	59.1	5.6
Shrub swamp	157.8	14.7
Transitional floodplain forest	193.8	18.3
Wet meadow	41.6	3.9
Oxbows (present in multiple wetland communities)[2]	102.0	9.6[3]
Total	1061.5	100%

Notes:
1. Wetland natural community classification based on Swain and Kearsley (2000) as characterized in the Ecological Characterization. Oxbow wetlands are not a distinct community
2. Oxbow wetlands occur within multiple wetland communities, including upland fringes and are not a distinct wetland community recognized in Swain and Kearsley (2000).
3. Small inclusions of upland natural communities were mapped along the margin of some oxbow wetlands and are included in the overall area calculation, thus are represented in the percentage.

With the exception of Woods Pond, most of the river in Pittsfield, Lenox, and Lee is classified as a low-gradient stream (approximately 250.2 acres). A short section of Reach 5A (approximately 8.4 acres) and sections of the river downstream of the Woods Pond impoundment are considered medium-gradient streams. High-gradient streams (approximately 0.1 acre) flow off the west slope of October Mountain and enter Reach 5 as they cross Woodland Road near Woods Pond.

Deep emergent marshes (approximately 28.5 acres), which are usually inundated through the growing season and vegetated by robust herbs, are frequent along the river channel and backwater edges of the floodplain. Shallow emergent marshes (approximately 59.1 acres), which are areas with saturated soil or shallow water and lower herbs, are less frequent in the floodplain and most commonly observed within the vernal pools with longer hydroperiods. Riverine point bars and beaches (approximately 1.0 acre) occur occasionally along the Housatonic River, primarily near bends in the channel. Mud flats of limited size begin to appear typically later in the season as the water levels decline and expose previously flooded substrate. Several large wet meadows (approximately 41.6 acres) can be found in the floodplain; in these areas the species composition is often influenced by past farming practices. Woods Pond, a relatively shallow impoundment, and some of the larger backwater areas to the immediate north are considered to be a moderately alkaline lake/pond habitat (approximately 22.1 acres).

Table 5 Sizes of Oxbow Wetlands by Natural Community Type Within Reach 5 and 6

Oxbow Wetland Community Type[1]	Acreage
Agricultural field	0.9
Black ash-red maple-tamarack calcareous seepage swamp	0.4
Cultural grasslands	0.7
Deep emergent marsh	12.4
High-terrace floodplain forest	0.1
Low-gradient stream	17.0
Moderately alkaline lake/pond	9.3
Northern hardwoods-hemlock-white pine forest	1.2
Red maple swamp	1.1
Red oak-sugar maple transition forest	0.8
Riverine point bar and beach	0.3
Shallow emergent marsh	14.1
Shrub swamp	17.9
Transitional floodplain forest	21.3
Wet meadow	4.5
Total	102.0

Notes:

1. Small inclusions of upland natural communities were mapped along the margin of some oxbow wetlands and are included in the overall area calculation.

Within the floodplain, the structure of the palustrine communities is heavily influenced by wetland hydrology and river flooding (Woodlot Alternatives, 2002). Most of the existing landscape is forested, except where disturbance (i.e., forest clearing) or permanent flooding (i.e., river channel and backwater slough) prohibit tree growth. The forests can be categorized generally as one of two types—those areas that receive groundwater discharge and those that do not. Most of the floodplain forests do not receive groundwater discharge and are largely classified as transitional floodplain forests (approximately 193.8 acres). These forests are within the riparian corridor of the river and are subject to inundation during spring flooding and other high water events. Vernal pool habitat and oxbows are present throughout the transitional floodplain forest community. Vernal pools are relatively common in small seasonally inundated fishless depressions, whereas oxbow wetlands are created by chute or neck cutoffs, as described in Section 2.2.

In a few locations, the floodplain forests are situated on elevated berms and are referred to as high–terrace floodplain forests (approximately 10.7 acres). In the lower portion of the floodplain, the floodplain forests give way to black ash–red maple–tamarack calcareous seepage swamps (approximately 78.9 acres). These forested communities are low-lying wetlands that are enriched by high-pH groundwater discharge and the backwater effect of Woods Pond Dam.

Red maple swamps (approximately 102.7 acres), another type of forested wetland in the floodplain, are primarily found in the transition between the floodplain forests and calcareous seepage swamps. Shrub swamps (approximately 157.7 acres) are common along pool and river channel borders, but they are especially frequent as an intermediate successional stage in areas where pasture is reverting to forested floodplain.

Oxbow wetlands (approximately 102 acres) within the floodplain represent approximately 10 percent of the wetland mosaic. These oxbow wetlands differ spatially and temporally due to the degree of succession of the associated plant community since the date of the initial oxbow creation. Oxbow wetlands are most common in transitional floodplain forest (approximately 21.3 acres), shrub swamp (approximately 17.9 acres), and low-gradient stream (approximately 17.0 acres) communities (Table 5); however, they represent a relatively small area within these communities. Oxbow wetlands are additionally represented within the shallow emergent marsh (approximately 14.0 acres), deep emergent marsh (approximately 12.3 acres), moderately alkaline lake/pond (approximately 9.2 acres), and wet meadow (approximately 4.4 acres) communities. Oxbow wetlands represent approximately one percent or less of several additional communities; most likely along the edge of these communities.

Very little terrestrial or upland habitat is found in within the 10-year floodplain. Red oak–sugar maple transition forests (approximately 16.3 acres) are located in a few widely scattered locations. Cultural grasslands (approximately 54.3 acres), which are open, upland habitats periodically disturbed by mowing or grazing, occur near New Lenox Road. A few upland inclusions of northern hardwoods–hemlock–white pine forest (approximately 60.0 acres) also occur north of Yokun Brook. Most of the upland habitats occur adjacent to the floodplain as cultural grassland, northern hardwoods–hemlock–white pine forest, and rich mesic forest (approximately 4.9 acres).

7.2 OVERVIEW OF WETLAND FUNCTION AND VALUES IN REACH 5 AND 6

A wetland function-value assessment was performed for the PSA using the U.S. Army Corps of Engineers 1995 *Highway Methodology for Wetland Function-Value Evaluations* manual (TechLaw, 1998). Due to the underlying marble in the Housatonic River Valley, many of the wetlands in the valley provide high-level functions and values.

Upper Section of the Floodplain

The section from the Confluence to the farm fields and wet meadows south of New Lenox Road is generally characterized as suburban or agricultural with some floodplain wetlands (primarily Reaches 5A and 5B). The floodplain here is narrower than the lower half of the area and has undergone a higher degree of floodplain development. The surrounding land contains a combination of suburban development, agriculture, the Pittsfield Wastewater Treatment Plant, and conservation land (the Audubon Society's Canoe Meadows Wildlife Sanctuary and sections of the Commonwealth of Massachusetts' George L. Darey Wildlife Management Area).

The combination of land use changes over the years and a dynamic floodplain surficial geology creates a mosaic of wetland types that include open water river, palustrine open water, wet meadow, and emergent, scrub-shrub and forested wetlands. Features such as seasonal pools and abandoned sloughs or oxbows contain open water with unconsolidated substrates, as well as emergent vegetation, shrubs, and trees. Few macrophyte beds are found in this section due to lack of suitable still or slow-moving, open-water habitat.

There is dense vegetation along most of the wetland-river edges. The steeper stream banks have trees and shrubs rooted into the banks, while more low-angle bank areas tend to be densely vegetated with floodwater-resilient herbs, as well as shrubs and trees. Most of the agricultural land that slopes down to the floodplain has either been abandoned or has some naturally vegetated buffer to protect it from soil erosion. Erosion due to the migration of meanders is apparent in several areas of this section; but the narrower floodplain width, topography, and development are limiting factors for meandering processes. Vegetation may thwart this type of erosion and may influence the exact location of stream bank changes, but only temporarily as the river attempts to move toward recovery and re-establishment of equilibrium following from severe anthropogenic influences.

In addition to the abandoned channels, oxbows, and backwaters within the river, there is evidence of recent channel overwash, erosion of cut banks, and accretion and erosion of point bars. The floodplain wetlands also have a micro-topography of alluvial rills, mounds, and small plateaus created by historic and recent flood events.

The principal functions and values provided by wetlands from the Confluence to the farm fields and wet meadows on the south side of New Lenox Road include Floodflow Alteration, Fish and Shellfish Habitat, Sediment/Toxicant Retention, Production Export, Sediment/Shoreline Stabilization, Wildlife Habitat, Recreation, Educational/Scientific Value, Uniqueness/Heritage, Visual Quality/Aesthetics, and Endangered Species Habitat. The wetlands herein provide 11 of the 13 functions and values, and each is present at relatively high levels.

Lower Section of the PSA

This section extends from the farm fields and wet meadows south of New Lenox Road to Woods Pond Dam (Reaches 5B (in part), 5C and 6). Vegetation cover types surrounding this area include primarily forest land. A railroad right-of-way (ROW) runs along portions of the western edge of the area, but several tributary wetlands west of the railroad are included. There is also an abandoned trolley line that bisects the southwestern tributary wetlands from the floodplain. Much of the flashiness exhibited in upstream sections of the river has been dissipated by upstream floodplain wetlands. River bed sediments in this section primarily include silt and fine organic particles.

Most of the floodplain wetlands are within one foot of the typical Spring water surface elevation of the river. This section has the most complex micro-topography in the floodplain. From the fields at New Lenox Road, south to the backwaters of Woods Pond, there are abandoned oxbows interlaced with floodplain pools and backwater sloughs. Based on aerial photography interpretation and field observations, there appears to have been historical logging and ditching in these wetlands. Discrete zones of forest, shrub, and emergent vegetation are indicative of past flooding patterns and meander pathways. The Woods Pond impoundment has created backwaters upstream and laterally at this location, negating natural meandering processes in the inundated areas in contrast to the upper section.

Five major backwater ponds, and over a dozen smaller ones, provide still-water habitats for the development of macrophyte beds. These are all located in the southern half of this section, and include those connected directly to Woods Pond.

Emergent fringe wetlands are scattered around the edges of the main channel and along transitional land located between backwaters and the river channel or between meanders where frequent overwash occurs. These wetlands are primarily dominated by purple loosestrife. Some cattail-dominated areas surround the larger backwaters, but even these have a significant purple loosestrife component. The large wetland areas west of the railroad berm, in the southern part of this section, have a more diverse vegetative community.

The principal functions provided by wetlands located in the south end of farm fields along New Lenox Road to Wood Pond Dam include Groundwater Interchange, Floodflow Alteration, Fish and Shellfish Habitat, Sediment/Toxicant Retention, Nutrient Removal, Production Export, Sediment/Shoreline Stabilization, Wildlife Habitat, Recreation, Education/Scientific Value, Uniqueness/Heritage, Visual Quality/Aesthetics, and Endangered Species Habitat. Each of the 13 evaluated functions and values were found to be significant.

7.3 OVERVIEW OF MASSACHUSETTS ENDANGERED SPECIES ACT AND PRIORITY HABITAT IN REACH 5 AND 6 OF REST OF RIVER

The Massachusetts Endangered Species Act (MESA) regulations (321 CMR 10.00), promulgated by the Division of Fisheries and Wildlife and administered by the Natural Heritage and Endangered Species Program (NHESP), were designed to implement the MESA statute. Under MESA, state-listed species are listed as classified as Endangered, Threatened, and Special Concern. The regulations establish a process for determining whether there will be a “take” of state-listed species protected under MESA. In reference to animals, take means “to harass, harm, pursue, hunt, shoot, hound, kill, trap, capture, collect, process, disrupt the nesting, breeding, feeding or migratory activity or attempt to engage in any such conduct, or to assist such conduct." Disruption of nesting, breeding, feeding or migratory activity may result from, but is not limited to, the modification, degradation or destruction of Habitat. In reference to plants, take means "to collect, pick, kill, transplant, cut or process or attempt to engage or to assist in any such conduct."

The NHESP has mapped approximately 1,367.5 acres of Priority Habitat[1] for 25 identified state-listed rare species in Reaches 5 and 6, which are protected from a "take" under MESA. Approximately 98.4 % of the Rest of River is mapped as Priority Habitat. This Priority Habitat is an amalgamation of smaller Priority Habitats mapped for individual state-listed species. Approximately 547.1 acres of Priority Habitat is located within the upper section of the area (from the Confluence to New Lenox Road in Reach 5B); while 820.4 acres is mapped in the lower section (from New Lenox Road to Woods Pond Dam).

Table 6 provides a summary of individual species' Priority Habitat mapped by the NHESP. Note that individual species' mapping overlaps due to shared habitat use patterns. Per the definition of Priority Habitat, the NHESP uses "best scientific evidence available" and includes "necessary supporting habitat." As a result, Priority Habitat mapping can overestimate actual habitat used by state-listed species because the extent is often not verified on the ground and inferred from a variety of available sources of information. In addition, some state-listed species are lesser studied and exact management requirements are not fully understood.

On February 3, 2011, the NHESP proposed changes to the MESA list that may change the number of state-listed species about which the NHESP is concerned during remediation activities (NHESP 2011b). Triangle floater (*Alasmidonta undulata*), arrow clubtail (*Stylurus spiniceps*), and zebra clubtail (*Stylurus scudderi*) are proposed for delisting. Spine-crowned clubtail (*Gomphus abbreviatus*) is proposed to be downgraded from Endangered to Special Concern, crooked-stem aster (*Symphyotrichum prenanthoides)* downgraded from Threatened to Special Concern, and rapids clubtail (*Gomphus quadricolor*) upgraded from Threatened to Endangered. The proposed addition of new species to the MESA list is not anticipated. If the triangle floater, arrow clubtail, and zebra clubtail are delisted in the future, the Priority Habitat will not change measurably since their mapping largely overlaps with other state-listed species.

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[1] Priority Habitat is defined as the geographic extent of Habitat for state-listed species as delineated by the Division pursuant to the MESA regulations (321 CMR 10.12). Priority Habitat is delineated based on confirmed observations of state-listed species within the last 25 years and the best scientific evidence available, defined as "species occurrence records, population estimates, habitat descriptions, assessments, peer-reviewed scientific literature, documented consultation with experts and information contained in records from the NHESP or other credible scientific reports or species sighting information reasonably available to the Director." Priority Habitat mapping is based on examination of individual species occurrence records in the context of the following criteria: "the nature and/or significance of the occurrence as it relates to the conservation and protection of the species, including but not limited to evidence of breeding, persistence, life stages present, number of individuals, extent of necessary supporting habitat, and proximity to other occurrences." Priority Habitat mapping is updated on a four-year cycle.

Table 6 Priority Habitat Acreage Calculations for the 25 State-Listed Species, as Identified by the NHESP, Within the PSA

Scientific Name	Common Name	PSA Priority Habitat[1, 2, 3]			PSA Reach(es)
		Upper[4]	Lower	Total	
Sagittaria cuneata	Wapato	172.2	209.8	382.0	5A, 5B, 5C, 6
Carex tuckermanii	Tuckerman's sedge	0.9	0.0	0.9	5A
Quercus macrocarpa	Bur oak	0.0	369.2	369.2	5B, 5C, 6
Elymus villosus	Hairy wild rye	19.3	0.0	19.3	5A
Ranunculus pensylvanicus	Bristly buttercup	29.4	0.8	30.1	5A, 5C
Carex alopecoidea	Foxtail sedge	5.6	68.8	74.3	5B, 5C
Carex grayi	Gray's sedge	0.0	143.9	143.9	5C, 6
Symphyotrichum prenanthoides	Crooked-stem aster	0.0	12.6	12.6	5B, 5C
Claytonia virginica	Narrow-leaved spring beauty	17.6	1.7	19.2	5B, 5C
Eleocharis intermedia	Intermediate spike-sedge	158.7	109.5	268.3	5A, 5B, 5C
Pieris oleracea	Mustard white	410.7	699.2	1109.9	5A, 5B, 5C, 6
Papaipema sp. 2 nr. *pterisii*	Ostrich fern borer moth	178.0	0.0	178.0	5A
Gomphus quadricolor	Rapids clubtail	77.8	95.2	173.0	5B, 5C
Ophiogomphus carolus	Riffle snaketail	106.0	0.0	106.0	5A
Gomphus abbreviatus	Spine-crowned clubtail	250.0	0.0	250.0	5A, 5B
Stylurus spiniceps	Arrow clubtail	328.9	404.7	733.6	5A, 5B, 5C, 6
Ophiogomphus aspersus	Brook snaketail	152.8	0.0	152.8	5A
Stylurus scudderi	Zebra clubtail	327.8	396.8	724.6	5A, 5B, 5C, 6
Alasmidonta undulata	Triangle floater	19.4	0.0	19.4	5A
Glyptemys insculpta	Wood turtle	491.6	338.4	830.0	5A, 5B, 5C
Ambystoma jeffersonianum	Jefferson salamander	0.0	78.1	78.1	5B, 5C
Sorex palustris	Water shrew	0.0	38.9	38.9	5C
Botaurus lentiginosus	American bittern	162.6	202.4	365.0	5A, 5B, 5C
Gallinula chloropus	Common moorhen	16.6	390.6	407.1	5C, 6
Haliaeetus leucocephalus	Bald eagle	0.0	186.5	186.5	5C

Notes:

1. Individual species' Priority Habitat mapping data was provided through a data sharing agreement with NHESP dated February 24, 2010.
2. The current Priority Habitat mapping will remain effective through December 31, 2011, until the 14th Edition of the Natural Heritage Atlas (Atlas) is published. Changes to existing Priority Habitat in the PSA are possible based on new information available to the NHESP since the last Atlas.
3. On February 3, 2011, the NHESP proposed changes to the MESA list, in part, including delisting triangle floater, arrow clubtail, and zebra clubtail.
4. The PSA was divided into upper and lower sections at New Lenox Road (southern portion of Reach 5B).

The Priority Habitat is an amalgamation of individual habitats for multiple state-listed species, occurring at various spatial and temporal scales. Priority Habitats mapped for highly mobile animal species such as the wood turtle (*Glyptemys insculpta*), two dragonfly species, arrow clubtail, zebra clubtail, and mustard white (*Pieris oleracea*) encompass a large percentage of the PSA based on habitat usage patterns, whereas Priority Habitat for many state-listed plant species occurs in specific reaches at smaller spatial scales as localized occurrences (Stantec, 2010). Triangle floater, narrow-leaved spring beauty (*Claytonia virginica*), crooked-stem aster (*Symphyotrichum prenanthoides*), and hairy wild rye (*Elymus villosus*) each have Priority Habitat areas less than 20 acres within the PSA, while Tuckerman's sedge (*Carex tuckermanii*) has the lowest, with approximately 1 acre.

The existing railroad right-of-way (ROW) running parallel with and west of the Housatonic River within Reaches 5C and 6 has altered wetland hydrology within Reaches 5C and 6 and to some extent Reach 5B. The past disturbance resulting from ROW construction has influenced hydrology on both sides, and occasionally the ROW is used as the boundary of Priority Habitat mapping for several species. Species such as crooked stem aster and foxtail sedge (*Carex alopecoidea*), which are sedentary, have a Priority Habitat boundary terminating along the eastern limit of the ROW. Several more mobile species, including mustard white, bald eagle (*Haliaeetus leucocephalus*), Jefferson salamander (*Ambystoma jeffersonianum*), and wood turtle, have Priority Habitat mapped on both sides. Two of the five areas mapped as Priority Habitat for American bittern (*Botaurus lentiginosus*) and the largest of the three Priority Habitat areas for common moorhen (*Gallinula chloropus*) occur west of the ROW.

Conceivably, portions of, or most of these individual species' Priority Habitat areas, have been influenced and are likely maintained by the ROW. The habitats on the west side of the ROW are likely hydrologically disconnected from the river, and may have been created in part during excavation associated with ROW construction.

In addition, Priority Habitat mapped within the floodplain for several species extends beyond the 10-year floodplain defined as Rest of River [e.g., ostrich fern borer moth (*Papaipema* sp. 2 nr. *pterisii*), mustard white, hairy wild rye, rapids clubtail (*Gomphus abbreviatus*), Jefferson salamander, and American bittern] and is unlikely to be directly altered by remediation activities. In the case of foxtail sedge, approximately 45 percent of the Priority Habitat occurs outside the Rest of River.

While 25 identified state-listed species are found in the Rest of River, many of these species occur in other locations in the state. Actual state-listed species occurrence data in the NHESP database is exempt from disclosure as a public record (Massachusetts General Law c.66 s.17D of the Public Record Law), so state-listed species distribution ranges have been inferred from general occurrence descriptions by county in the publically available factsheets maintained by the NHESP (NHESP, 2011a) and prior General Electric (GE) reports (ARCADIS, Anchor QEA, and AECOM, 2010). Per the data publically available, two of the 25 state-listed species (1 butterfly and 1 plant) have known occurrences restricted to Berkshire County [mustard white and bur oak (*Quercus macrocarpa*)]. Three of the 25 state-listed species [3 plants: wapato (*Sagittaria cuneata*), foxtail sedge, and crooked-stem aster] have occurrences restricted to Berkshire and one additional western county (i.e., Hampshire, Franklin, or Hampden). One moth [ostrich fern-borer], two plants [Gray's sedge (*Carex grayi*) and intermediate spike-sedge (*Eleocharis intermedia*)], and two dragonflies [riffle snaketail (*Ophiogomphus carolus*) and rapids clubtail] are considered to have distribution in western Massachusetts (three or more western counties). The remaining 15 species have occurrences in western and central Massachusetts (3 plants, 2 dragonflies, 1 amphibian) or have a scattered statewide distribution (1 plant, 2 dragonflies, 1 mussel, and 1 reptile, 1 mammal and 3 birds). Overall, the anticipated number of individuals for each mapped occurrence is probably relatively low and may include a single or a few individuals. Plant occurrences are likely to contain more than a single individual.

7.4 STATE-LISTED SPECIES HABITAT USE IN REACH 5 AND 6

The 25 identified state-listed plant and animal species in the Rest of River are highly dependent upon and require habitat conditions within the current wetland mosaic in order to complete their life cycle (Table 7). Many are capable of inhabiting varying types of floodplain wetlands, river banks, pond shores and/or wetlands influenced by impoundment of Woods Pond. The river meandering process may create oxbow wetlands, but with similar wetland function and values to other habitat types. These other similar habitat conditions for many species are present within the wetland mosaic. None of the state-listed species are dependent upon or restricted to oxbow wetlands but utilize these habitats as part of their overall habitat use patterns within the wetland mosaic. Species occurring in backwater areas further from the river channel and/or lower section of the floodplain influenced by Woods Pond Dam are not dependent on the meandering process as it is no longer a dominant process under current conditions with the dam. As described in Section 7.1, the Rest of River provides a wetland mosaic with variable wetland communities, of which oxbow wetlands represent approximately 10 % of the habitat. Bank habitat conditions in the Rest of River are variable as result of seasonal overbank flooding and bank erosion due to river meandering. Many state-listed species are not strictly limited to bank habitats in the Rest of River, but species will utilize these areas as part of their overall habitat use patterns or banks are within the range of suitable habitat types. For example, wood turtles will shelter and may overwinter in the river under overhanging banks, whereas several state-listed plants may inhabit disturbed banks. In the case of the water shrew, its principal habitat use occurs along banks close to the river in subterranean burrows. In addition to wetland habitat use patterns, several of the more mobile animal species also require upland habitat as part of their life history strategy (e.g., adult dragonflies and wood turtles).

For the 10 state-listed plant species identified in the floodplain, all are affiliated with riverine systems that are prone to natural disturbance (e.g., seasonal flooding or low water conditions) and/or open areas/edges within floodplain wetlands. In the case of wapato (*Sagittaria cuneata*), which has the largest Priority Habitat for a plant species within the PSA, occurrences of this perennial may be emergent, floating, or fully submerged when present in floodplain wetlands, demonstrating its tolerance of a hydrological gradient. Intermediate spike-sedge (*Eleocharis intermedia*) has more specific habitat requirements, inhabiting muddy alkaline river banks and ponds during periods of low water when muddy substrates are exposed. In addition to the habitats describe above, crooked-stem aster (*Symphyotrichum prenanthoides*) and bristly buttercup (*Ranunculus pensylvanicus*) also inhabit managed wetlands (e.g., utility corridors and roadsides). Overall, these wetlands and their edges are indicative of early successional vegetative communities as a result of the natural and/or anthropogenic disturbance regimes. Such disturbances also create susceptibility to colonization by invasive plant species, which as noted in Section 7.1 are present throughout and dominate some PSA wetland communities. Rare species observation forms completed during the Ecological Characterization noted the threat of invasive plant species to state-listed species occurrences in multiple locations (Woodlot Alternatives, 2002).

Of the 15 identified state-listed wildlife species, many are wide-ranging and occupy different seasonal habitats (e.g., breeding and nesting) within the PSA. Water birds migrate seasonally to complete their life cycle (e.g., returning in spring/summer for breeding) and are not present year round in the floodplain, while others may travel outside the Rest of River. Dragonfly species may travel between or be present in adjacent watershed(s)s or up/downstream of Reach 5 and 6. The wood turtle, Jefferson salamander, and water shrew occur year round in the Rest of River, undergoing subterranean hibernation during winter months.

As part of the evaluation of habitat use patterns of state-listed species in Reach 5 and 6, it is also relevant to evaluate available data sources. The Ecological Characterization was conducted by skilled wildlife biologists and botanists during thousands of field survey hours from 1998-2000 to evaluate ecological resources within the Rest of River, particularly Reach 5 and 6. The 2008-2009 NHESP rare species surveys completed over thousands of hours of field surveys within the entire Housatonic River watershed (NHESP, 2010). It is possible that additional occurrences are represented in the current individual state-listed species' Priority Habitats to supplement those from the Ecological Characterization and other recent NHESP surveys (NHESP, 2010). As a note, surveys during the Ecological Characterization for state-listed plant species at historic or other previously known sites did not document species presence (Woodlot Alternatives, 2002).

Table 7 Habitat Descriptions for the 25 State-Listed Species of Concern, as Identified by the NHESP, in Reach 5 and 6

Scientific Name	Common Name	Habitat Description
Sagittaria cuneata	Wapato	Riverine floodplain habitats on muddy substrates along the shores of rivers, ponds, oxbows, and marshes, preferring shallow and very slow-moving alkaline waters.
Carex tuckermanii	Tuckerman's sedge	Deciduous forest swamps, stream borders, pond margins, oxbows, vernal pools, and wet meadows.

Table 7 Habitat Descriptions for the 25 State-Listed Species of Concern, as Identified by the NHESP, in Reach 5 and 6 (Continued)

Scientific Name	Common Name	Habitat Description
Quercus macrocarpa	Bur oak	Forested fens, forested swamps, floodplain forests influenced by calcareous (alkaline or basic) seepage water, and in mesic to wet sites in shady areas subject to seasonal flooding
Elymus villosus	Hairy wild rye	Floodplain forests (high terrace floodplain forests in particular), rich moist thickets, and rocky woodlands. Stream banks, marshes, and moist woods also provide suitable habitat.
Ranunculus pensylvanicus	Bristly buttercup	Colonizes variety of habitats via seed dispersal by water and wildlife. Suitable habitats include marshes, bogs, moist clearings, wet woods, stream banks, and ditches under open to filtered sunlight. Frequently inhabits disturbed river banks and managed wetland communities in utility corridors
Carex alopecoidea	Foxtail sedge	Floodplain meadows and thickets, generally in alkaline alluvial soils. Typically found in open swales within floodplain forests.
Carex grayi	Gray's sedge	Preferred habitat is floodplain forest along major rivers where the floodplain forest is subject to spring flooding, wet deciduous forests on alluvial soils, swampy woods, calcareous meadows, and remnant floodplain forests bordered by open pastures.
Symphyotrichum prenanthoides	Crooked-stem aster	Occurs in a variety of habitats, including exposed gravel and cobble substrates, rich alluvial soils in floodplain forests, thickets, and meadows, riverbanks and streamside seeps, partially wooded swamps, and roadside habitats under open to semi-open conditions.
Claytonia virginica	Narrow-leaved spring beauty	Inhabits rich, damp to moist deciduous woods, thickets, floodplain forests, and open clearings on alluvial soils seasonally flooded.
Eleocharis intermedia	Intermediate spike-sedge	Typically found on muddy, alkaline river banks and pond shores, usually during periods of low water that expose muddy shores.
Pieris oleracea	Mustard white	Typically found in understory and along edges of moist, rich, openings in deciduous woodlands including riparian floodplains. Nearby open areas including streamsides, shallow marshes, wet meadows, open fields and pastures also utilized. Two-leaved toothwort, cuckoo-flower, and other mustard family plants are essential larval host plants. Adults attracted to garlic mustard, common winter cress, and field pennycress as potential host plants.
Papaipema sp. 2 nr. *pterisii*	Ostrich fern borer	Primarily associated with mature floodplain forests and wooded swamps with moderate to dense stands of ostrich fern. Adults likely to be found in shaded to partially shaded forested floodplain habitats or red maple swamps containing the larval host plant species

Table 7 Habitat Descriptions for the 25 State-Listed Species of Concern, as Identified by the NHESP, in Reach 5 and 6 (Continued)

Scientific Name	Common Name	Habitat Description
Gomphus quadricolor	Rapids clubtail	Occurs in or near clear, cold streams and rivers that have intermittent segments of rocks and rapids. Larvae found in shallow pools (just below sediment surface) located downstream of rapids that often contain cattail or other emergent plants. Adults may travel far from waterway to feed, before returning to mate.
Ophiogomphus carolus	Riffle snaketail	Larvae prefer sandy substrates (and reside close to surface) in clear running water, and have a relatively high oxygen requirement among this family. Upon emergence, flies into adjacent woodland or shrubland to hide among vegetation and continue to develop. Adults may live rest of the summer far from the stream, often in dense woodland or shrubland.
Gomphus abbreviatus	Spine-crowned clubtail	Typically in or near medium to large rivers with sandy or rocky bottoms and silt deposits. Upon emergence, flies into adjacent woodland to hide in the tree tops. Adult males return to waterway to feed and mate. Adult males prefer sandy stretches of the shoreline or overhanging vegetation as perching sites. Adult females spend a majority of their lives in the forested areas away from the river, returning for a brief period to mate.
Stylurus spiniceps	Arrow clubtail	Larvae prefer silty to sandy substrates (near surface) in running water, with a moderate oxygen requirement. Upon emergence, flies to adjacent woodland to continue developing. After one to several weeks, adults return to waterway to feed and mate. Adults may live rest of the summer away from the waterway, often in dense woodland. Adults believed to spend most of time in treetops.
Ophiogomphus aspersus	Brook snaketail	Larvae prefer sandy substrates (near surface) in clear running water, with relatively high oxygen requirement. Upon emergence, flies to adjacent woodland or shrubland to continue developing. After one to several weeks, adults return to the waterway to feed and mate. Adults may live rest of the summer far from the waterway, often in dense woodland or shrubland.
Stylurus scudderi	Zebra clubtail	Larvae prefer silty to sandy substrates (near surface) in running water, with a moderate oxygen requirement. Upon emergence, flies into adjacent woodland to hide in the trees and continue to develop. After one to several weeks, adults return to the waterway to feed and mate. Adults may live rest of the summer away from waterway, often in dense woodland.
Alasmidonta undulata	Triangle floater	Prefers low gradient rivers with flowing water and sand and gravel substrate; may be found in lake habitats, and can survive in a wide variety of substrate types. Glochidia attach to multiple common fish species, where they grow and eventually fall to develop into adults on the bottom.

Table 7 Habitat Descriptions for the 25 State-Listed Species of Concern, as Identified by the NHESP, in Reach 5 and 6 (Continued)

Scientific Name	Common Name	Habitat Description
Glyptemys insculpta	Wood turtle	Requires clear, moving water, such as rivers, streams and creeks, also utilize variety of shallow wetlands, such as swamps, bogs, oxbows, and seasonal pools. Use variety of upland habitats and generally prefer mosaic of communities near water. Require wide range of habitats for food availability, thermoregulation, nesting and overwintering. They also use emergent logs or grassy, sandy, and muddy banks for basking.
Ambystoma jeffersonianum	Jefferson salamander	Primarily upland species, prefers well-drained deciduous or mixed forests in proximity to small shallow vernal pools or fishless ponds surrounded by vegetation. Adults hide beneath leaf litter, loose soil, stones, and rotting logs, or in subterranean burrows. Vernal pool habitat, full of detritus to conceal larvae, is necessary for reproduction, and submerged woody shrubs or grasses needed for egg mass attachment.
Sorex palustris	Water shrew	Found near rivers and streams with exposed banks, rocks, and downed logs along the waterways. Lives on river banks where moss-lined burrows are hidden between tangles of roots along undercut banks or boulders. Seldom found more than a few yards from the nearest water. Prefers forested habitat proximal to water.
Botaurus lentiginosus	American bittern	Inhabits freshwater and brackish wetlands, including marshes, meadows, bogs, and fens, where occurs in emergent vegetation like cattails, sedges, and rushes. Occasionally utilizes upland grasslands for foraging and nesting. Prefers wet meadows for nesting sites, but known to construct platforms of vegetation a foot above water or nest in uplands adjacent to wetlands. Also occasionally nest in upland fields next to water.
Gallinula chloropus	Common moorhen	Inhabits large freshwater marshes and ponds with cattails and other emergent vegetation. Generally takes cover in dense vegetation and feeds by wading or diving at the edges of open water. Preferred habitat is waterbodies at least one foot deep, with dense cattails and occasionally shrub swamps adjacent to open water with aquatic vegetation bed.
Haliaeetus leucocephalus	Bald eagle	Inhabits coastal areas, estuaries, and larger inland waters. Requires high amount of water-to-land edge with forest stands to nest and trees above the canopy for perching, an adequate supply of moderate-sized to large fish, an unimpeded view, and minimal human disturbance.

8. SUMMARY

This paper presents the current understanding of stream meandering processes along the Housatonic River, and the connection between associated habitat and species assemblages. The findings illustrate that the Housatonic has a complex history of planform change associated with anthropogenic influences and meandering processes. Meandering processes along the Housatonic tend to progress slowly in the riverine environment (e.g., 0.9 ft/yr along outside meander bends) and generate floodplain features (such as cutoffs and oxbows) over an extended time scale (i.e., centuries). There are 25 state-listed species in the PSA that use habitat throughout the PSA wetland mosaic.

Additional major points discussed in this paper are summarized below:

1. River meandering is a process by which some floodplain features are created, including channel cutoffs, oxbow lakes, point bars, and scroll bars, which are utilized by aquatic and riparian plants and animals.
2. The meandering character and planform pattern of the Housatonic River is not unique to rivers of the northeastern United States.
3. Anthropogenic activities along the Housatonic River have affected riverine processes, including meandering, and associated aquatic and terrestrial habitats over the past several centuries.
4. In Reach 5, channel straightening and other channel manipulations have dramatically altered the channel and accelerated meander development and chute/cutoff formation during this time, as the river has attempted to re-equilibrate to these disturbances. Rather than resulting in permanent change, the recreation of well-developed meanders in less than a century along much of the straightened river channel indicates the capacity of the river to develop a new quasi-equilibrium and recover from large-scale perturbations in a relatively short time frame.
5. Since 1952, meanders in Reach 5 have continued to migrate slowly (with erosion along the outside bends at a rate no greater than 0.9 ft/yr). It should be noted that the average erosion rate for the entire channel in Reaches 5A and 5B is on the order of 0.3 ft/yr based on a study completed in 2009. Since 1945, no new meanders have formed along the Housatonic River between the Confluence of the East and West Branch and Woods Pond.
6. Assuming similar hydrology and sediment supply and the absence of significant channel straightening in the future, future meandering rates are likely to be less than those observed historically.
7. Sedimentation within existing oxbows occurs on a time scale of centuries. Based on available historical records and assuming a constant rate of oxbow formation and infilling through time, it is estimated that the existing oxbows would become 70% infilled over

the next 500 years with perhaps several hundred more years beyond that necessary to completely infill individual oxbows and begin to lose associated wetland habitats.

8. Extensive field studies of the channel and floodplain environments along the Housatonic have characterized the presence and relative abundance of state-listed species. The existing state-listed species data collected by Woodlot Alternatives (2002) in Reach 5 and 6 and the NHESP (2010) from the watershed provide reliable documentation of actual habitat and species occurrences that are available for evaluating potential impacts during remediation of the Housatonic River.

9. The floodplain is a wetland mosaic with variable wetland communities, of which oxbow wetlands represent approximately 10% of community structure.

10. The state-listed species are not strictly dependent upon or restricted to oxbow wetlands or other geomorphic features associated with meandering, but utilize these habitats as part of their overall habitat use patterns within the wetland mosaic.

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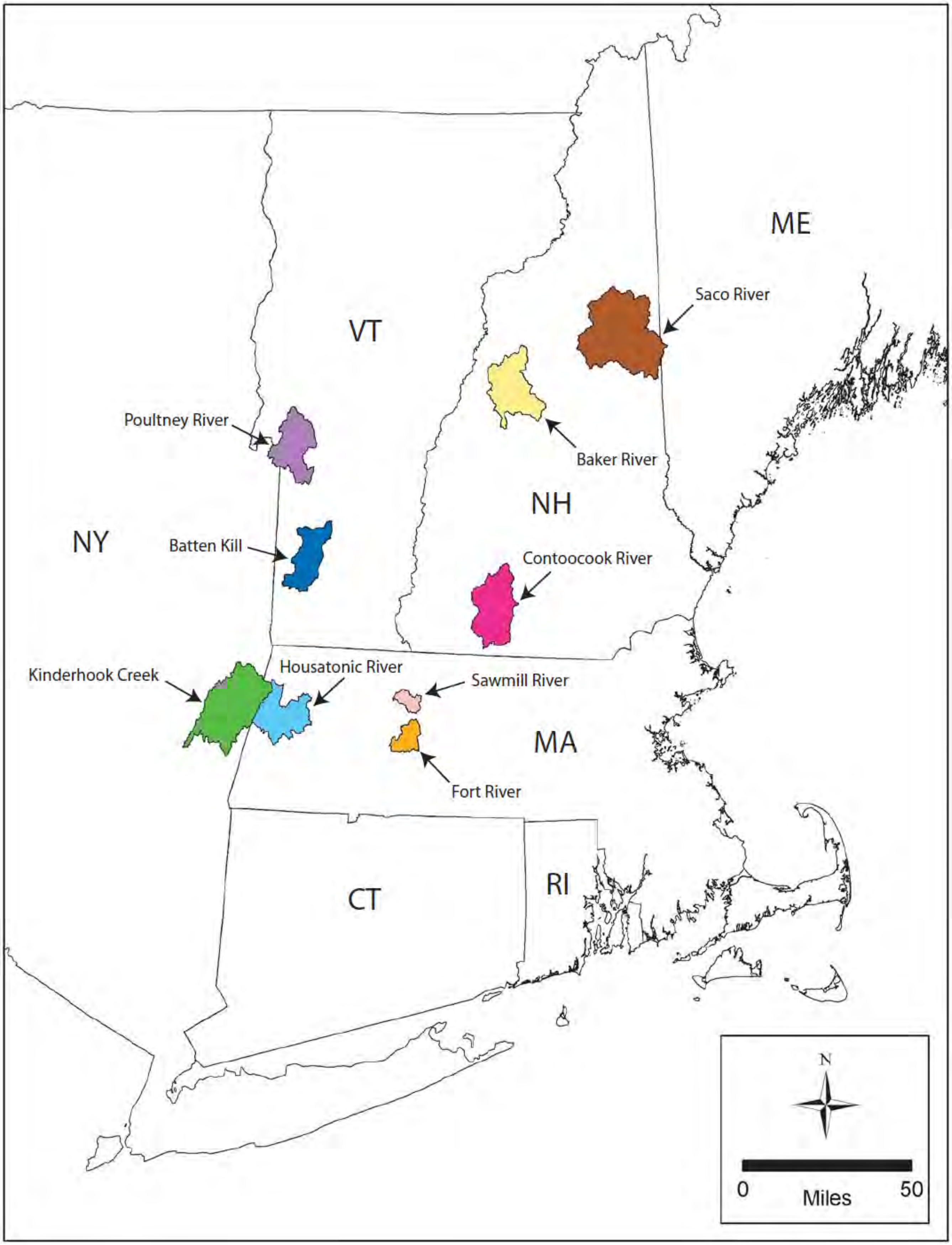
Web citation 1: http://docs.unh.edu/MA/beck93nw.jpg

Web citation 2: http://docs.unh.edu/MA/pite47sw.jpg

Web citation 3: http://docs.unh.edu/MA/estl48nw.jpg

APPENDIX A

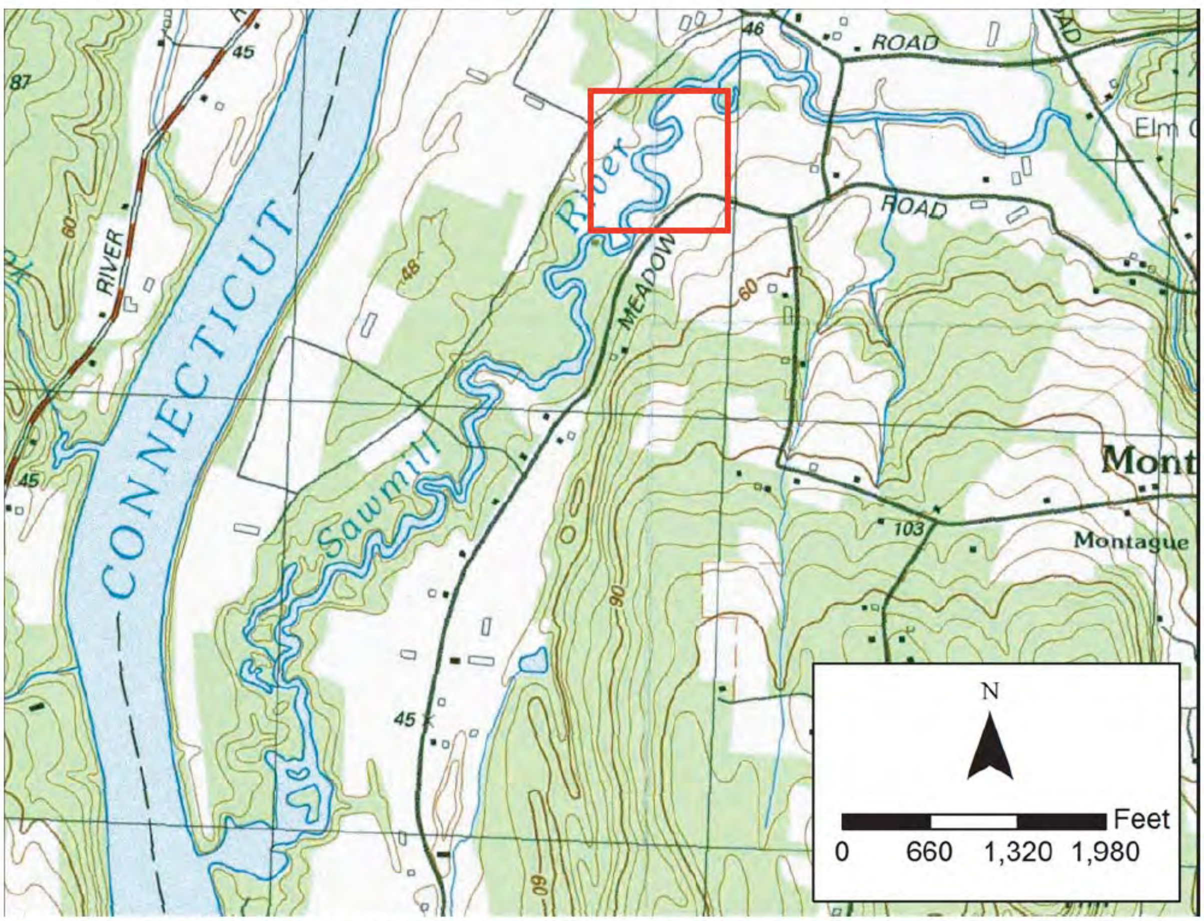
Location Maps and Meandering Characteristics of Selected Rivers in the Northeastern United States



ME
VT
NH
NY
MA
CT
RI
Saco River
Baker River
Poultney River
Batten Kill
Contoocook River
Kinderhook Creek
Housatonic River
Sawmill River
Fort River
N
0
Miles
50

Sawmill River (Montague, MA)

Drainage area: 32 sq mi
Sinuosity: 1.83
Channel width: 40 ft
Meander wavelength: 300 ft
Radius of curvature: 100 ft
Meander amplitude: 150 ft
Length of oxbows / valley mile: 1,320 ft
Corridor width: 550 ft

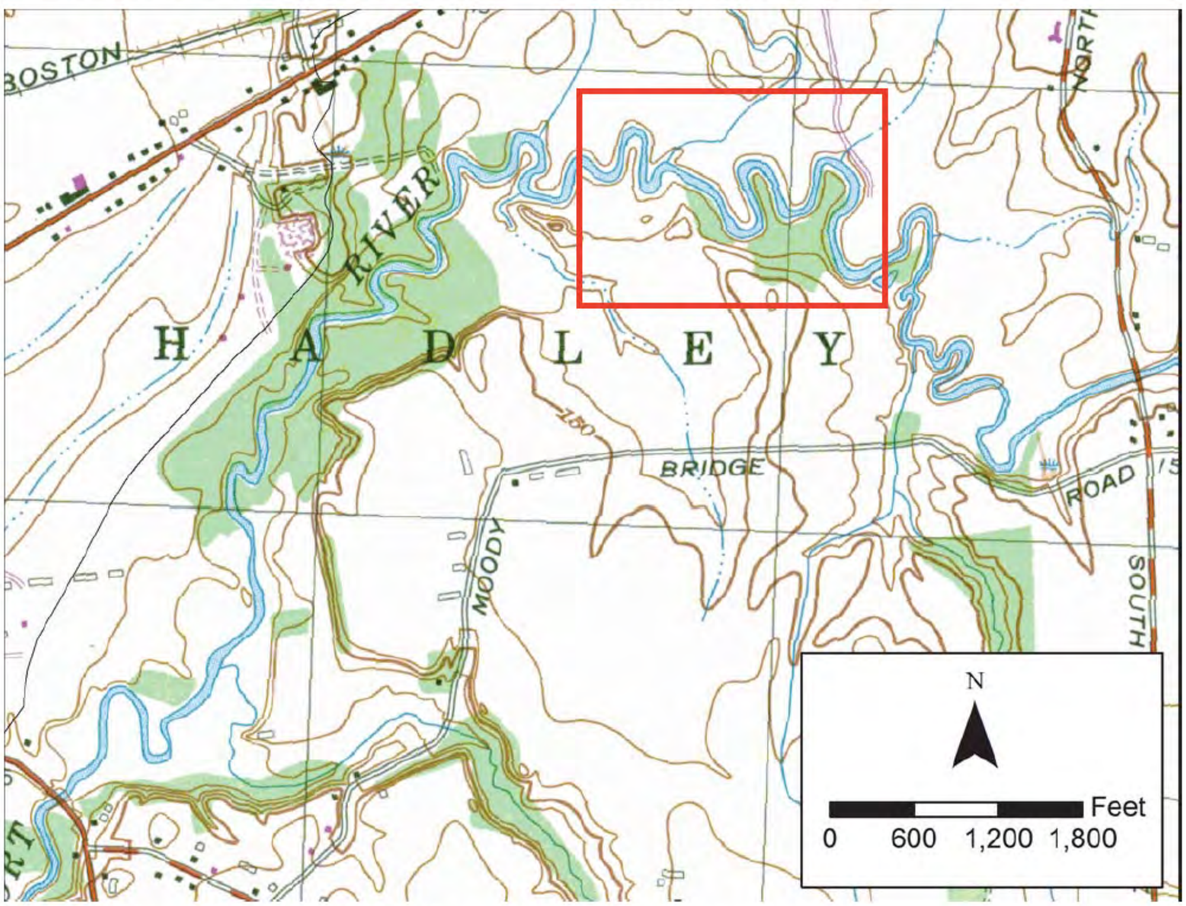


Note: Red box highlights area of detail shown in aerial photograph

Fort River (Hadley, MA)

Drainage area: 56 sq mi
Sinuosity: 2.13
Channel width: 50 ft
Meander wavelength: 500 ft

Radius of curvature: 120 ft
Meander amplitude: 200 ft
Length of oxbows / valley mile: 2,560 ft
Corridor width: 750 ft

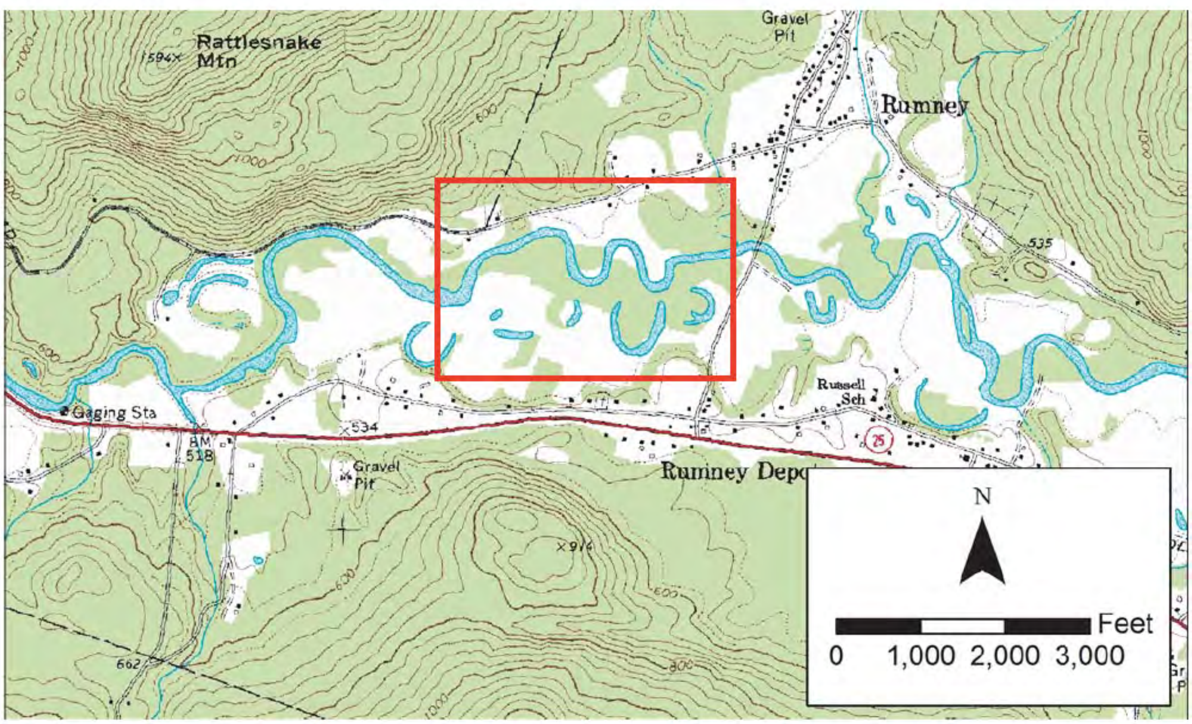


Note: Red box highlights area of detail shown in aerial photograph

Baker River (Rumney, NH)

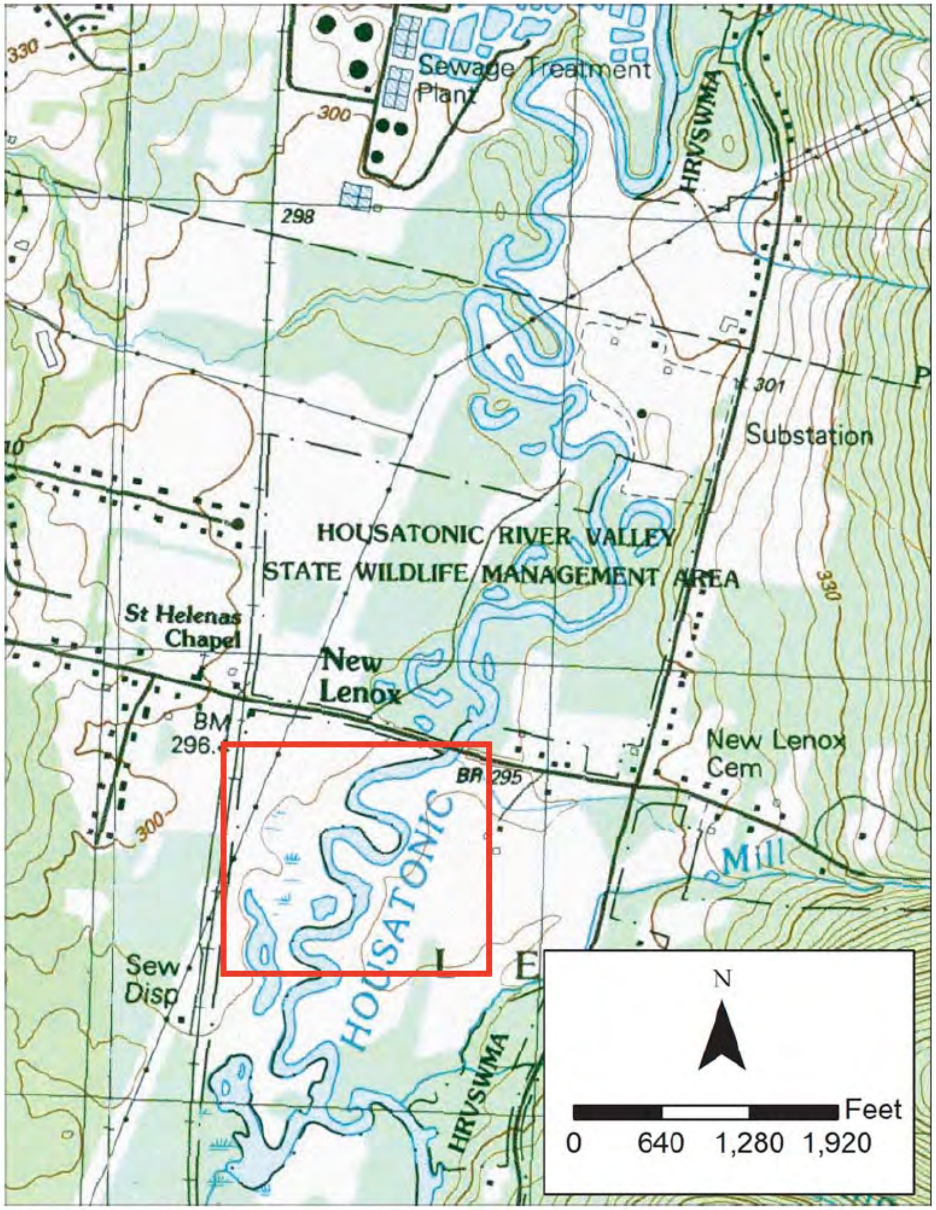
Drainage area: 143 sq mi
Sinuosity: 1.54
Channel width: 100 ft
Meander wavelength: 900 ft

Radius of curvature: 270 ft
Meander amplitude: 400 ft
Length of oxbows / valley mile: 4,197 ft
Corridor width: 1,500 ft



Note: Red box highlights area of detail shown in aerial photograph

Housatonic River (Pittsfield, MA)



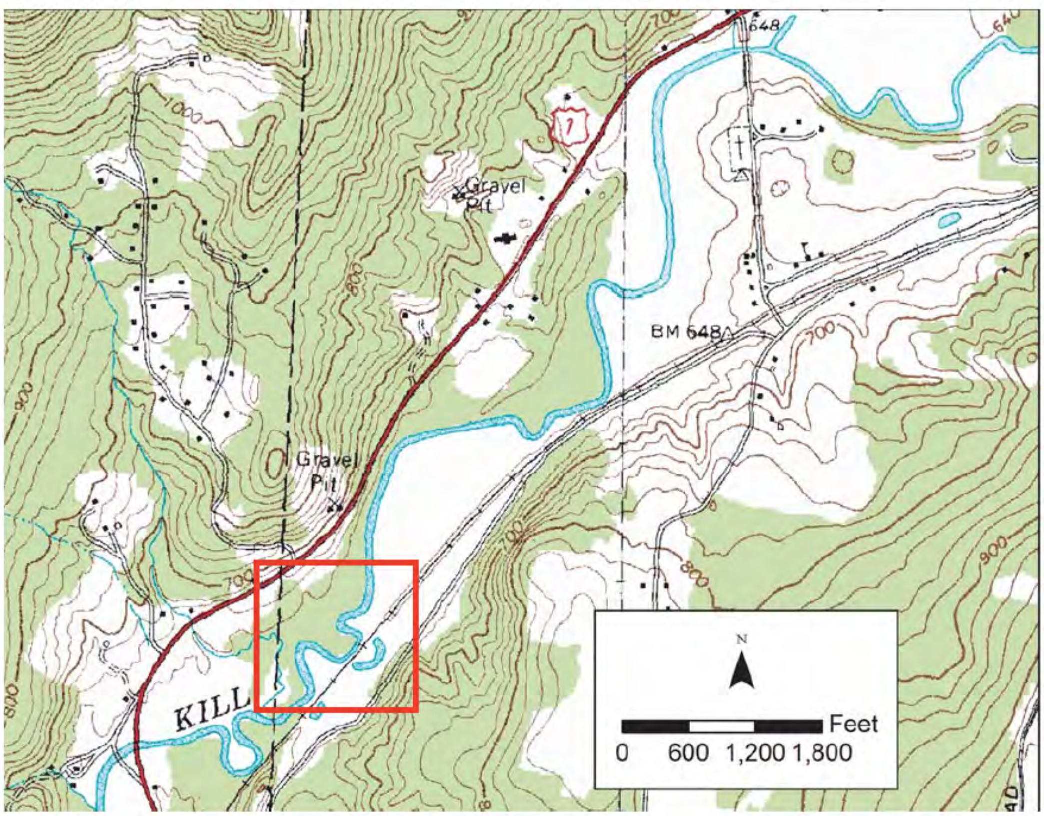
Note: Red box highlights area of detail shown in aerial photograph

Drainage area: 148 sq mi
Sinuosity: 2.27
Channel width: 90 ft
Meander wavelength: 500 ft
Radius of curvature: 170 ft
Meander amplitude: 275 ft
Length of oxbows / valley mile: 3,761 ft
Corridor width: 1,000 ft

Batten Kill (Arlington, VT)

Drainage area: 149 sq mi
Sinuosity: 1.36
Channel width: 70 ft
Meander wavelength: 750 ft

Radius of curvature: 130 ft
Meander amplitude: 225 ft
Length of oxbows / valley mile: 3,210 ft
Corridor width: 700 ft

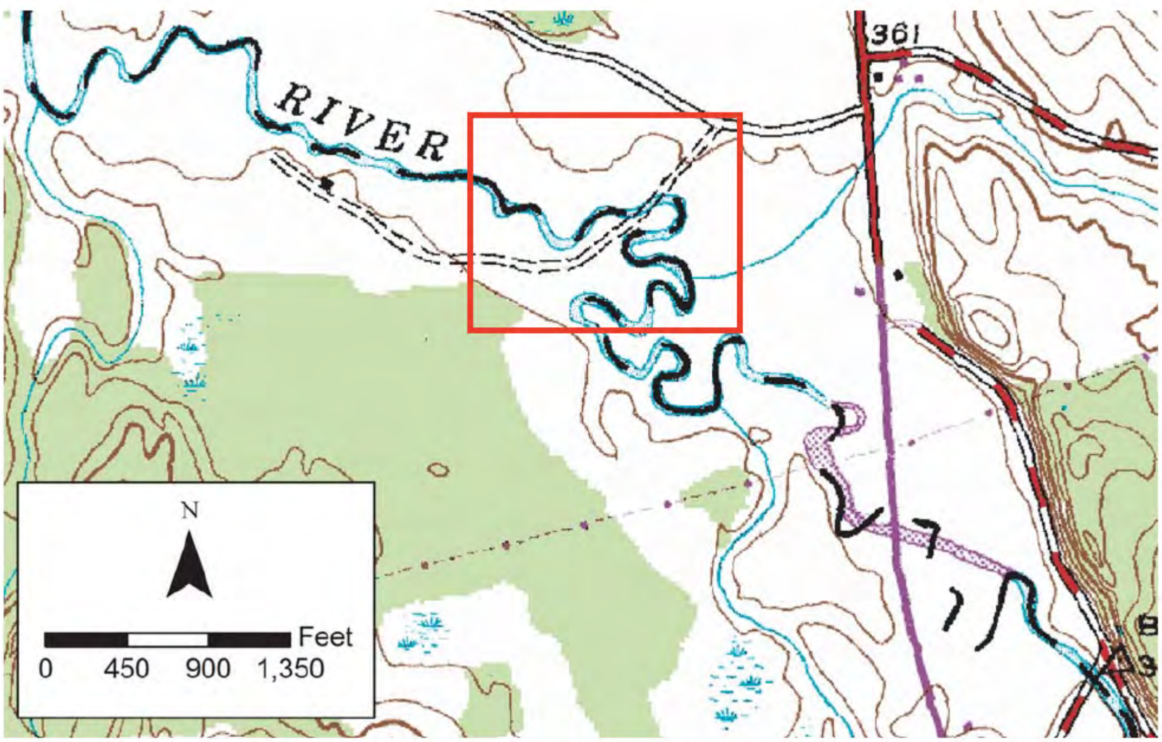


Note: Red box highlights area of detail shown in aerial photograph

Poultney River (Fair Haven, VT)

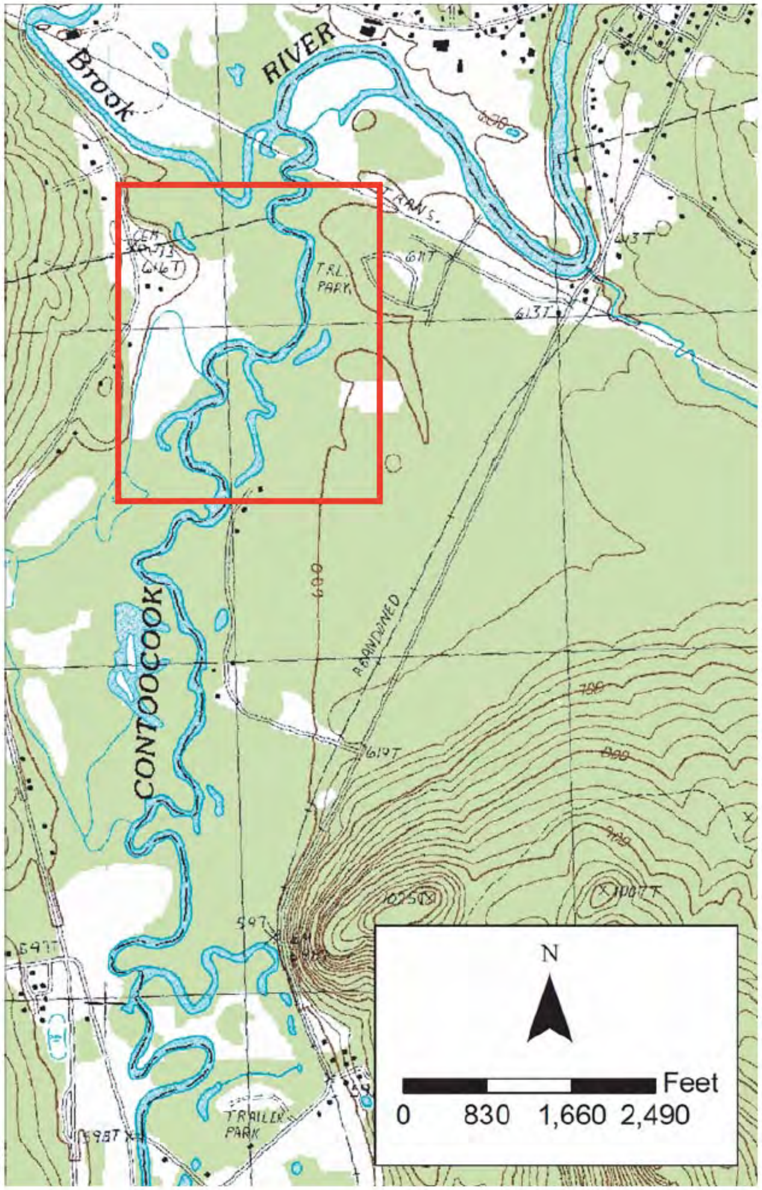
Drainage area: 175 sq mi
Sinuosity: 2.00
Channel width: 60 ft
Meander wavelength: 400 ft

Radius of curvature: 110 ft
Meander amplitude: 175 ft
Length of oxbows / valley mile: 7,329 ft
Corridor width: 1,000 ft



Note: Red box highlights area of detail shown in aerial photograph

Contoocook River (Deering, NH)



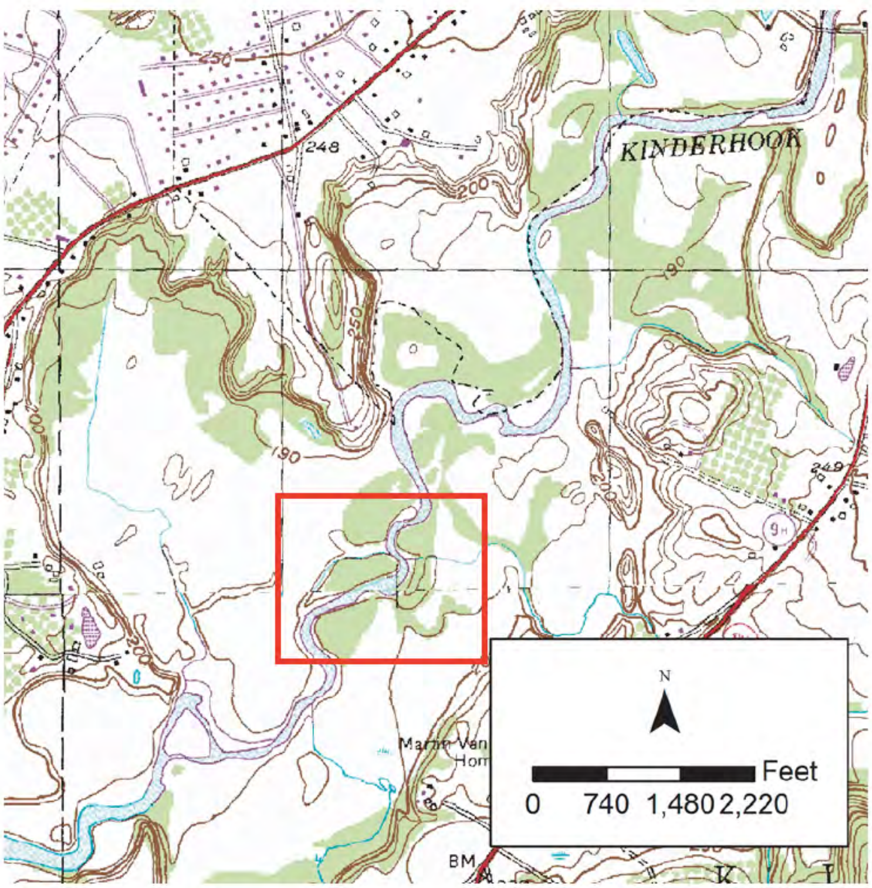
Note: Red box highlights area of detail shown in aerial photograph

Drainage area: 221 sq mi
Sinuosity: 1.74
Channel width: 80 ft
Meander wavelength: 650 ft
Radius of curvature: 160 ft
Meander amplitude: 375 ft
Length of oxbows / valley mile: 5,659 ft
Corridor width: 1,600 ft

Kinderhook Creek (Kinderhook, NY)

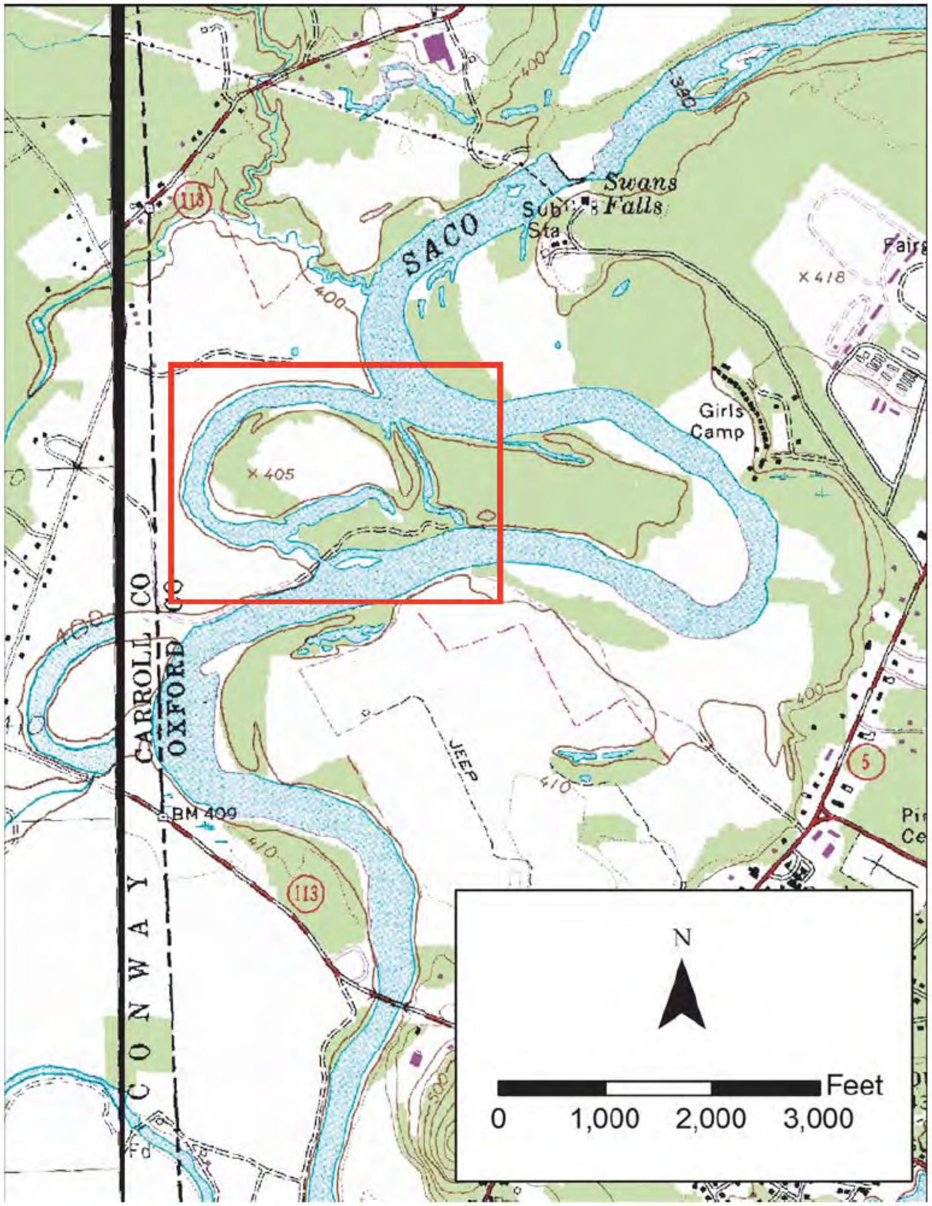
Drainage area: 316 sq mi
Sinuosity: 1.45
Channel width: 140 ft
Meander wavelength: 1000 ft

Radius of curvature: 290 ft
Meander amplitude: 375 ft
Length of oxbows / valley mile: 6,102 ft
Corridor width: 2,100 ft



Note: Red box highlights area of detail shown in aerial photograph

Saco River (Fryeburg, ME)

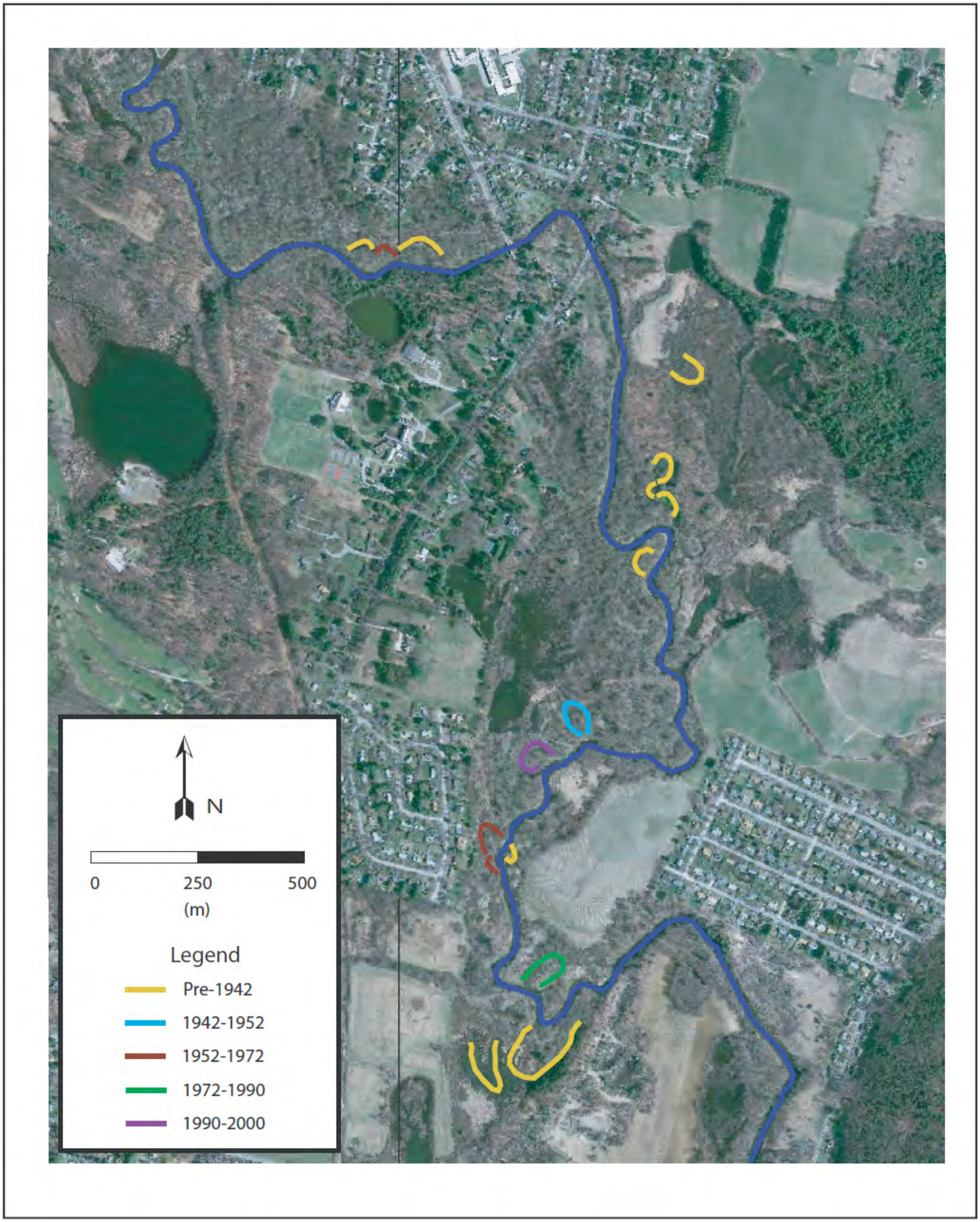


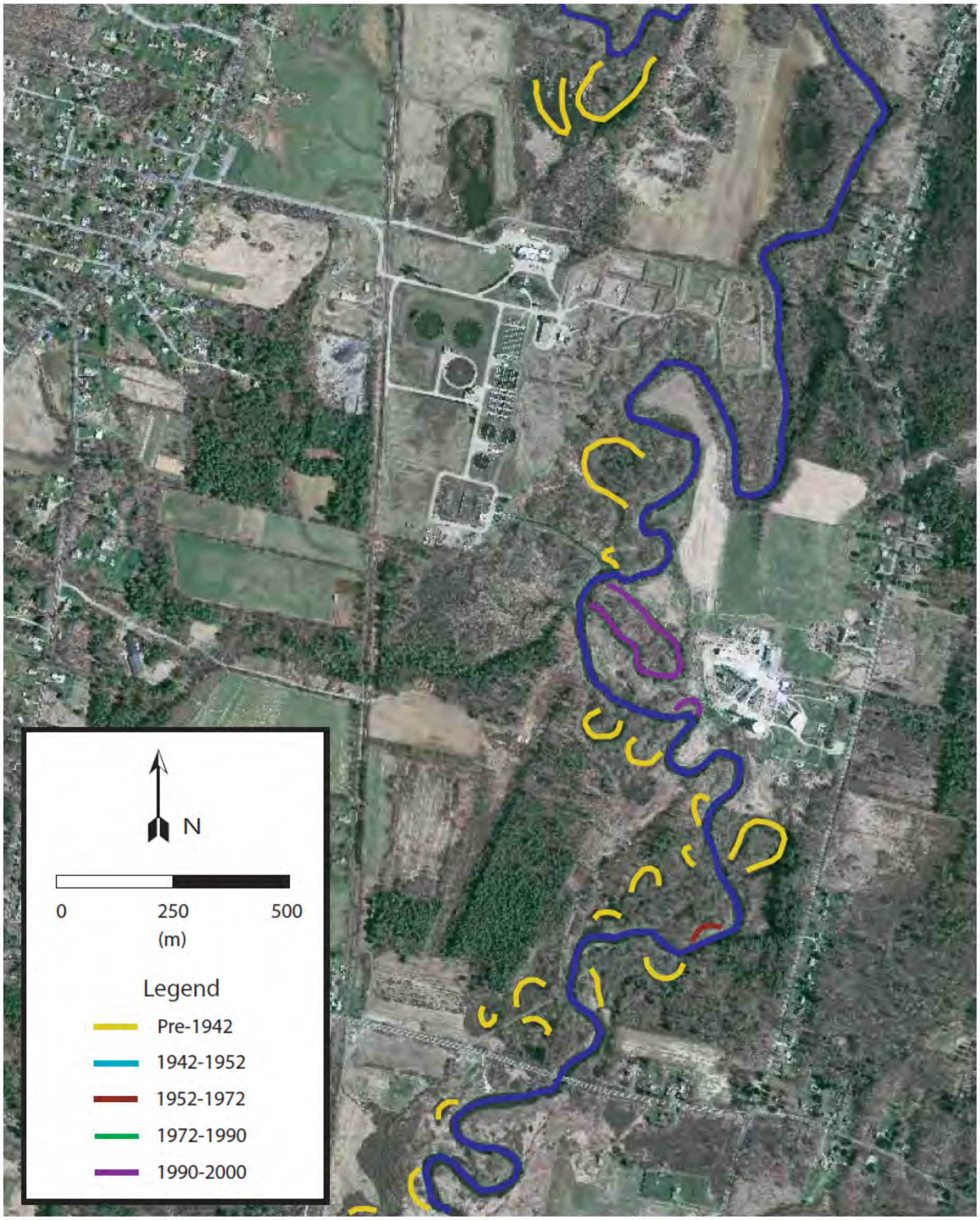
Note: Red box highlights area of detail shown in aerial photograph

Drainage area: 444 sq mi
Sinuosity: 2.25
Channel width: 300 ft
Meander wavelength: 4,000 ft
Radius of curvature: 900 ft
Meander amplitude: 2,750 ft
Length of oxbows / valley mile: 8,865 ft
Corridor width: 6,500 ft

APPENDIX B

Location of All Oxbows Between the East and West Branch Confluence and Woods Pond


N
0
250
500
(m)
Legend
Pre-1942
1942-1952
1952-1972
1972-1990
1990-2000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250
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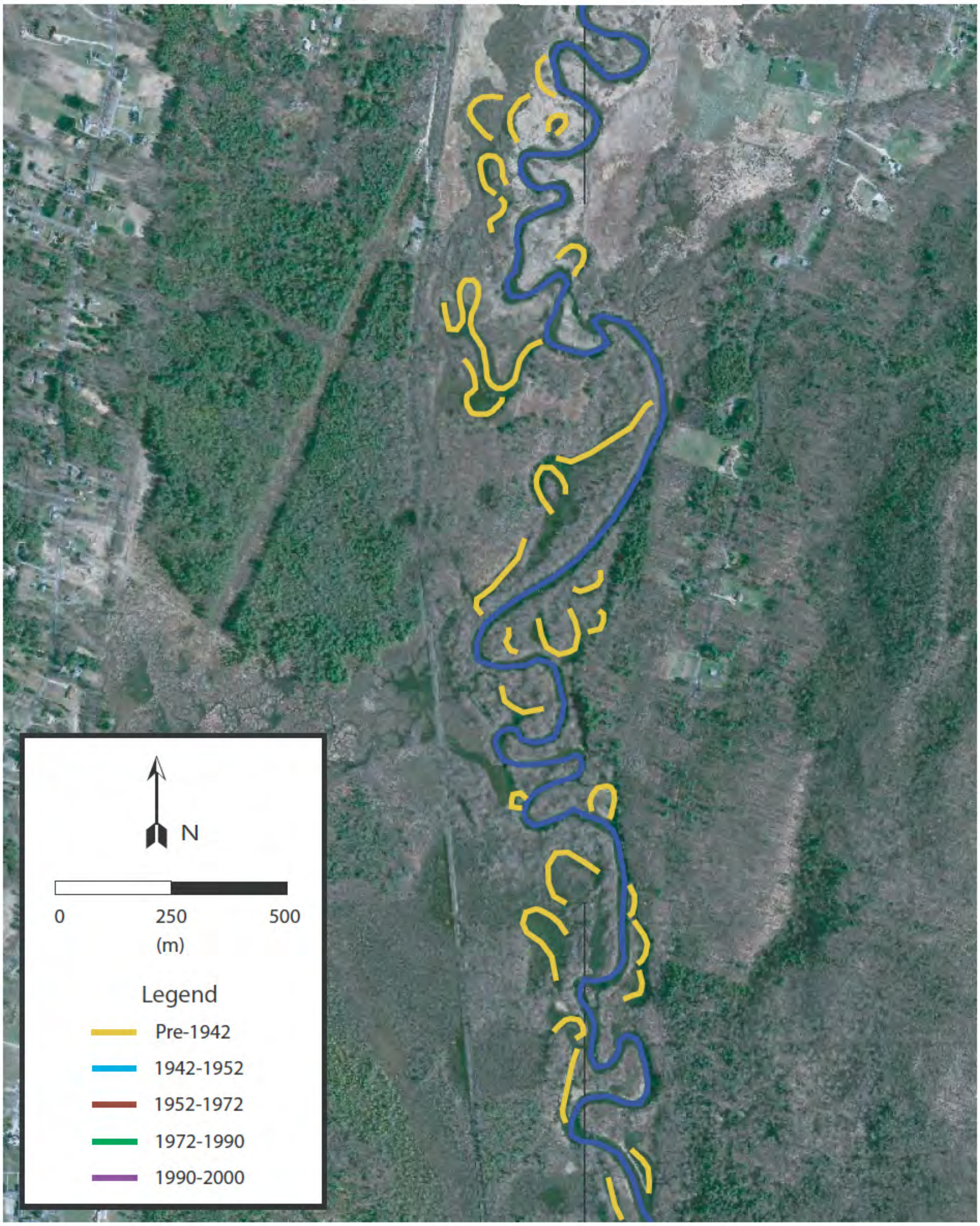
Pre-1942
1942-1952
1952-1972
1972-1990
1990-2000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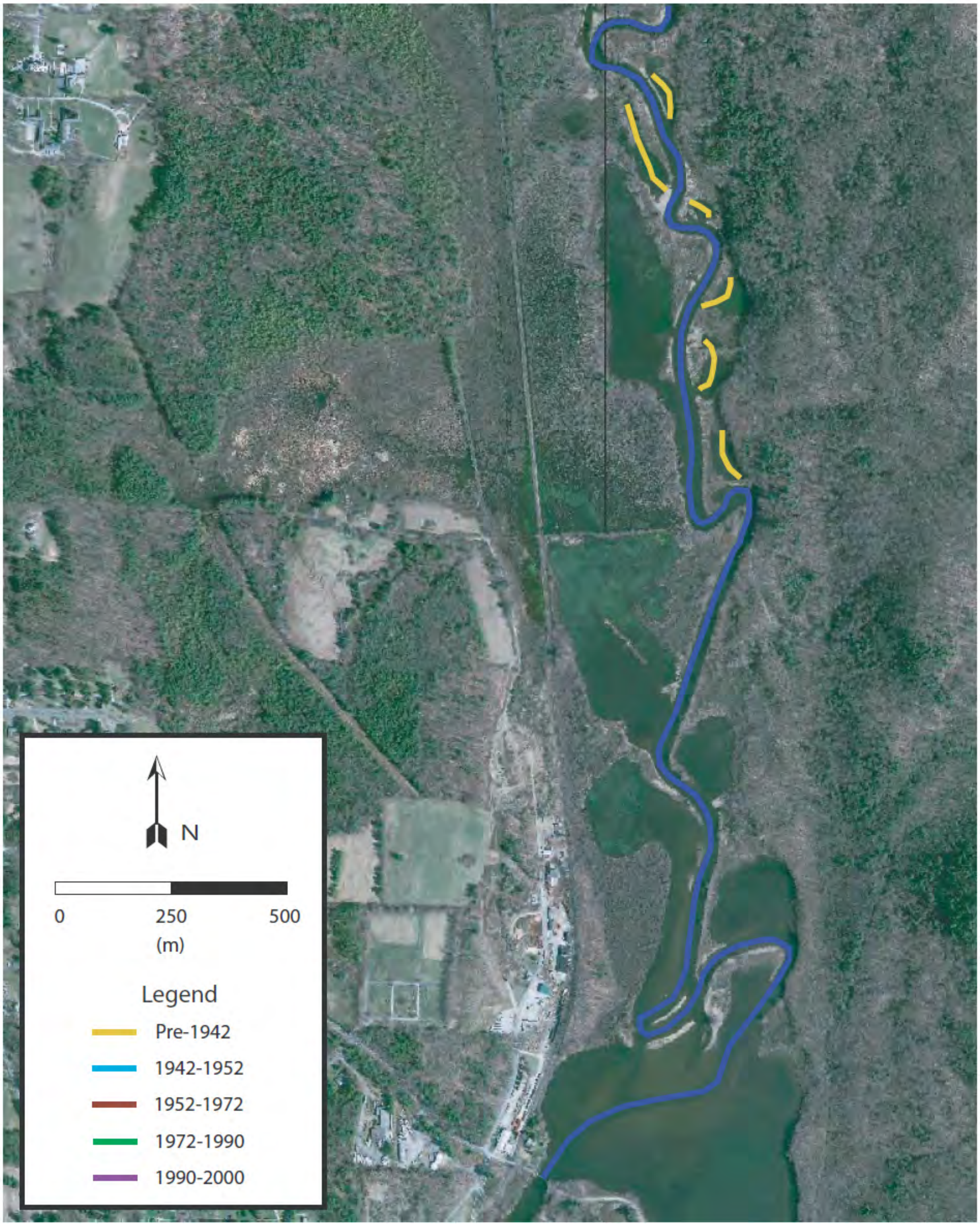
Pre-1942
1942-1952
1952-1972
1972-1990
1990-2000


N
0
250
500
(m)
Legend
Pre-1942
1942-1952
1952-1972
1972-1990
1990-2000

ATTACHMENT 3
ACTIVATED CARBON SUMMARY

The Isosceles Group

TECHNICAL MEMORANDUM

DATE: **July 27, 2012**

TO: **Scott Campbell, Weston Solutions, Inc.**

FROM: **Dick McGrath**

SUBJECT: **Review of recent studies of activated carbon amendment of contaminated sediment, with reference to bioavailability, ecotoxicology, and engineering considerations for activated carbon application**

Introduction

One important aspect of the well-established equilibrium-partitioning behavior of non-polar organic contaminants in sediment is the relationship between the organic carbon content of the sediment and bioavailability of the contaminant. Bioavailability, in turn, is a major factor controlling the toxicity of the sediment or, conversely, the maximum concentration of the contaminant that can be tolerated by exposed biota without adverse impact. In general, increasing the sediment organic carbon content decreases contaminant bioavailability, which has the practical application for management of contaminated sediment sites of allowing higher concentrations of contaminants to remain *in situ* without adverse biological effects. Such an approach may have significant advantages at sites where active remediation of contaminated sediment via more traditional removal techniques such as dredging would result in undesirable harm to the habitat.

Project managers and investigators have become increasingly interested over the last several years in amending natural sediments with activated carbon (AC) to increase the total organic carbon content, and also with technologies to apply AC directly to sediments or to incorporate AC into sediment caps that can be used either in conjunction with, or as a substitute for, sediment removal. A growing body of research on AC amendment of contaminated sediments, both laboratory studies and *in situ*, has been conducted to demonstrate the applicability of this approach. The majority of these studies address three important questions regarding the applicability of AC amendment to contaminated sediment sites:

1. Reduction in bioavailability – Although reduction in contaminant bioavailability has been amply demonstrated in concept through research studying equilibrium-partitioning behavior, will similar effects be seen in real-world situations with the elevated levels of contaminants typical of hazardous waste sites?

2. Potential toxicity of AC – does the amendment of contaminated sediments with AC in itself present a risk to plants or animals inhabiting the sediment?

3. Engineering considerations – can AC be effectively incorporated into sediments and sediment cap designs and can AC or AC-amended caps be placed at contaminated sediment sites in a manner that meets the long-term project objectives?

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In February of 2012, U.S. EPA Region 10 (Seattle) sponsored a Technical Workshop entitled "Use of Activated Carbon Amendment as an In-situ Sediment Remedy at the Lower Duwamish Waterway Superfund Site." The Workshop brought EPA regulators and site managers together with many of the leading investigators in the field and, although focused on the Lower Duwamish Waterway, the Workshop presentations covered a wide range of other contaminated sediment sites around the world. Accordingly, the proceedings of the Workshop represent a review of the current state-of-the-art with respect to AC amendment at contaminated sediment sites and provide direct insight into the three questions referenced above. This memorandum is intended to address each of the questions by summarizing material presented at the Workshop as well as other studies from the scientific literature.

Reduction in Bioavailability

As a result of extensive research conducted over many years, and the now widespread acceptance of equilibrium-partitioning theory to explain the behavior and toxicity of many organic contaminants in aquatic systems, there is little question that the organic carbon fraction of sediment is a major determinant of bioavailability and that, for the range of organic fractions commonly seen in the environment, bioavailability is strongly inversely correlated with the total organic content of the sediment. Several of the presentations at the Workshop addressed, either directly or indirectly, the question of whether the well-understood concepts of equilibrium partitioning behavior are applicable to natural sediment and/or sediment caps that have been artificially amended with AC.

There was a strong consensus from the presentations at the Workshop that AC amendment is effective in reducing bioavailability of contaminants in sediment and that the reduced bioavailability remains in effect for several years. Ghosh (2012a) reviewed a number of studies that clearly demonstrated large reductions in bioavailability of organic contaminants with AC amendment in the range of 5% by weight, and also that AC amendment reduced both contaminant concentrations in pore water and contaminant flux to overlying water. Greenberg (2012a), reviewing an AC amendment pilot study conducted at the Grasse River, concluded that AC amendment in the range of 4 to 5% by weight reduced bioavailability of PCBs by over 95%. Cho et al. (2012a) also reported a decrease in PCB bioavailability with AC amendment from a pilot study conducted at the Hunters Point site in San Francisco Bay, indicating that the effectiveness of the AC persisted for at least 5 years. Reible (2012), in summarizing results from a number of sites, concluded that AC amendment of sediment provides substantial reduction in contaminant bioavailability and mobility, even as the AC becomes fouled over time. He also found that incorporating AC into a sediment cap is particularly effective in reducing contaminant exposure and flux.

In related studies, Cornelisson et al. (2006) found that reduction in bioavailability from AC amendment might be species-specific. In a study that measures biota-sediment bioaccumulation factors (BSAFs) for PAHs with and without AC amendment, they reported reductions in the range of a factor of six to seven for a marine polychaete worm, but relatively little change for a marine gastropod. Fagervold et al. (2010) found that bioavailability of dioxins and furans from floodplain soils was naturally low in floodplain soil with high natural organic content, but could be reduced still further (up to 91% less) with AC amendment. For naturally low organic content soils, reductions of over 99% were possible with as little as 2% AC amendment by weight. Janssen et al. (2010) showed that bioaccumulation of PCBs by a marine worm was decreased by 95% in laboratory experiments, with no adverse effects on the organisms.

McLeod et al. (2004) demonstrated the type of carbon to be important in determining overall effectiveness, finding that activated carbon was considerably more effective than other types of carbon in reducing bioavailability of benzo[*a*]pyrene and PCB-52 to a marine clam. The effectiveness of AC amendment in reducing bioavailability was confirmed in a second study with the same species of marine clam (McLeod et al., 2007), and in a similar study using freshwater clams in the Grasse River (McLeod et al., 2008).

Numerous additional studies (e.g., Millward et al, 2005; Sun and Ghosh, 2007, 2008; Sun et al, 2008; Tomaszewski et al, 2008) report substantially the same findings for studies conducted both in the laboratory and *in situ*, using various organisms, in estuarine and freshwater environments, and with different organic contaminants. Similar results have also been reported from studies conducted using passive sampling devices (PSDs) as surrogates for living organisms.

<u>Potential Toxicity of Activated Carbon</u>

Although virtually all sediments contain varying amounts of organic carbon, and in some cases include carboniferous materials similar to AC, amendment of sediment with up to 5% AC represents the introduction of a comparatively large amount of a foreign substance into the natural sediment. Accordingly, for AC amendment to be a viable alternative technology for management of contaminated sediment sites, it must be demonstrated that addition of activated carbon in the quantities necessary to achieve a reduction in bioavailability of the contaminant does not itself have a detrimental effect on resident organisms. The relative lack of adverse impact resulting from AC amendment may be inferred from the numerous bioavailability studies using living organisms, which make no mention of any significantly increased mortality observed in the course of the study. Indeed, it would not have been possible to complete such studies if the adverse effects of AC amendment were substantial. In addition, there are a smaller number of studies that have been conducted specifically to address the question of potential toxicity.

Ghosh (2012b) summarized *in situ* work conducted at the Grasse River site to investigate potential harmful effects of AC amendment on benthic animals and plants. He reported that benthic macroinvertebrate community parameters (e.g., numbers, diversity, biomass) were similar between locations that had received AC amendment and upstream reference locations. It was noted, however, that decreased plant (*Elodea canadensis*) growth was correlated with increasing amounts of AC amendment, with the highest treatment by weight (7.5%) decreasing plant growth by 25%. Subsequent experiments demonstrated that this decrease in growth appeared due to simple dilution of natural sediment and the effect decreased over time as the AC aged following application.

Greenberg (2012b), summarizing work conducted by Kupryianchyk et al. (2011), reported that AC amendment had limited effects on an amphipod and isopod at low concentrations but that AC amendment could lead to increased mortality in amphipods, perhaps due to sequestration of necessary nutrients. The study was carried out with sediments that were sufficiently contaminated to cause 100% mortality in both species without treatment, however, so it was concluded that AC amendment resulted in substantial benefits that outweighed any deleterious effects. He also examined the Grasse River data and reached conclusions consistent with those of Ghosh (2012b).

In a study of the effects of AC amendment on the benthic community in San Francisco Bay, Cho et al. (2012) concluded that the amendment had no significant effect on the benthic community. The study also examined the secondary effect of the AC on deposit feeders, determining that any effects were minor. Menzie (2012) reviewed a range of studies, concluding that any effects of AC amendment on a range of species were minor. He also examined the potential effect of AC on fish, concluding that AC would not be toxic and exposure for fish would be low.

In a study focused primarily on powdered, as opposed to granulated, AC, Jonker et al. (2009) found that powdered AC was directly toxic to several organisms investigated and recommended that such powdered material be washed out of AC prior to application. They also found that marine crustaceans avoided AC-amended sediment and that AC in sediment apparently disrupts the feeding behavior of oligochaete worms. These effects appeared to be most directly associated with powdered AC, and the authors acknowledged that application of granular AC may not lead to similar issues.

Taken together, these studies tend to indicate that although there is some potential for ecotoxicological effects resulting from AC amendment of contaminated sediment, such risks can be managed by controlling the type of AC and the details of its application. The differing results reported for different target species, AC type, and application method underscore a need for well-designed pilot studies before widespread use of AC amendment at a particular site.

Engineering Considerations for AC Application

AC amendment has been conducted successfully using a variety of engineering techniques. These range from simple broadcast application in the field, to mixing with other material which is then carefully placed on the sediment surface, to incorporation as a layer in engineered caps. Several of the presentations at the EPA Workshop described the methods that have been used to date and reviewed their effectiveness.

Carscadden (2012) reviewed the use of AC in the Slip 4 Early Action Site, part of the Lower Duwamish Estuary. Granulated AC was applied as part of a chemical isolation layer 12" in thickness over the previously dredged area. Blending of the AC was conducted onshore using standard equipment. The material was then applied and spread using a typical bucket dredge. Eek et al. (2012) presented the results of a thin-layer capping application in Norway at locations of 30 m and 100 m depth. For this work, materials were mixed in a hopper dredge and applied by pumping to the bottom. This study found the AC layer to be effective but also underscored the importance of adapting methods to local conditions.

McDonough et al. (2007), in a study conducted in the Anacostia River, demonstrated that it is possible to incorporate a thin layer of AC into reactive core mat (RCM) as part of a sediment cap which includes an overlying habitat layer. The RCM/AC layer was effective in sequestering underlying contaminants and was not disturbed by the subsequent development of a benthic community in the habitat layer.

Melton (2012) reviewed a number of technologies that can be used to apply AC to meet project objectives at various types of sites, noting that the particular form of AC and also the method used to apply AC-amended sediment caps can, and should, be tailored to the site to ensure long-term physical stability. Engineering techniques are available that protect the integrity and function of AC amendment in both low and high scour areas. A variety of site-specific conditions such as natural waterway dynamics, vessel traffic, infrastructure, and human activities must be considered in selecting the best application method but that there are a wide range of available methods that can successfully account for these factors.

Overall, the presenters emphasized the need to select the form of AC as well as the application method to site-specific conditions. Pilot studies, such as those conducted in the Grasse River, are particularly necessary to ensure that the proposed approach will be effective.

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ATTACHMENT 4
MASSACHUSETTS DIVISION OF FISHERIES AND WILDLIFE CORE HABITAT AREA MAPS AND LETTER DATED JULY 31, 2012

July 31, 2012

Robert G. Cianciarulo, Chief
Massachusetts Superfund Section
Office of Site Remediation and Restoration
EPA New England (OSRR-07-01)
5 Post Office Square
Boston, MA 02109-3912

Re: Housatonic River, Core Habitat Areas in the Primary Study Area

Dear Mr. Cianciarulo:

As you are aware, the states of Massachusetts and Connecticut have been working cooperatively for the last several months to discuss potential approaches to clean up the Rest of River portion of the GE Housatonic site. These discussions have focused, in part, on the need to address the risks from polychlorinated biphenyls (PCBs) to humans, fish, and wildlife while avoiding, mitigating or minimizing the impacts of the cleanup on the unique ecological character of the Housatonic River. Minimizing impacts to habitat and, in particular, species listed pursuant to the Massachusetts Endangered Species Act, M.G.L. c. 131A ("MESA"), and 321 CMR 10.00 (the "MESA Regulations") presents unique challenges as almost the entire Primary Study Area (PSA) is mapped as Priority Habitat for state-listed species (for a description of Priority Habitat and its regulatory function please see: http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/priority_habitat/priority_habitat_home.htm. Therefore, in order to help identify the most important areas for habitat protection, as well as habitats and species that might be particularly sensitive to impacts from PCB remediation activities, the Massachusetts Division of Fisheries and Wildlife ("DFW") developed maps of "Core Habitat Areas." The purpose of this letter is to provide an overview of the approach we used to identify the Core Areas.

As part of our Priority Habitat mapping process, taxonomic experts from DFW's Natural Heritage & Endangered Species Program ("NHESP") routinely delineate habitat for each state-listed species, based on actual field-documented records, or "occurrences." There are four types of Housatonic Core Areas. Core Areas 1, 2, and 3 represent subsets of the delineated state-listed species habitat found in the PSA. Core Area 4 represents a subset of the documented and potential vernal pool habitat in the PSA. Please refer to the enclosed maps dated May 21, 2012 which depict the locations of these Core Areas, entitled "Core Habitat Areas, Housatonic River Primary Study Area (PSA)", "Core Habitat Areas (Core Area 2), Housatonic River Primary Study Area (PSA)", and "Part of the Housatonic River Showing Primary Study Area, High Species Richness, and Vernal Pools".

Core Area 1 includes the highest quality habitat for species that are most likely to be adversely impacted by PCB remediation activities (Table 1). As can be seen in Table 1, most of these species are plants that are not mobile, and are very sensitive to the expected effects of soil remediation activities. Core Area 1 also includes habitat for one state-listed moth species that inhabits mature floodplain forest, one habitat area for the Jefferson's Salamander, and Triangle Floater mussel beds. Some of the plant species found in Core Area 1 are located in floodplain forest, which is not readily restorable and would take decades to return to its current state, if ever. Finally, Core 1 includes areas that are excellent examples of two rare natural communities—High Terrace Floodplain Forest and Black Ash Bur Oak Hemlock Swamp.

Core Area 2 includes the highest quality habitat for more mobile species that may be less vulnerable to remediation impacts, species where the habitat is likely to be somewhat more easily restored, and listed species that may be of a somewhat lower conservation concern, given their state-wide distribution (e.g. American Bittern; see Table 2). For example, the Mustard White is a Threatened butterfly species of significant conservation concern that uses a mix of natural areas along the river and old field habitat. It may be possible to remediate its habitat in phases, restoring and replacing host plants as the work is completed.

Core Area 3 includes those areas with dense concentrations of state-listed species. Specifically, Core Area 3 includes areas where Division biologists have delineated overlapping habitat for eight (8) or more state-listed species.

Core Area 4 includes all certified vernal pools in the PSA as well as additional potential vernal pool habitat areas which, based on information provided by GE and EPA, are likely to meet the Massachusetts criteria for vernal pool certification based on the presence of "obligate" vernal pool breeding amphibians see:
http://www.mass.gov/dfwele/dfw/nhesp/vernal_pools/vernal_pool_cert.htm.

These Core Areas played an important role during recent discussions between the EPA and the states of Massachusetts and Connecticut regarding potential remediation approaches to Rest of River. Consistent with the requirements of MESA and the MESA Regulations, the Core Areas are helping to 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, EPA and the Commonwealth believe that a framework has been established to achieve MESA permitting 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, avoidance of impacts when practical, careful consideration of PCB remediation methods and the sequence and timing of remediation activities, as well as after-the-fact habitat mitigation are all approaches that 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 is likely to be unavoidable. In those cases, consistent with MESA's status as a location-specific applicable or relevant and appropriate requirement ("ARAR"), the Commonwealth will work with GE and the EPA 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).

If you have any questions about this letter, please don't hesitate to contact me.

Sincerely,

Jon Regosin, Ph.D.
Chief of Conservation Science
Natural Heritage & Endangered Species Program

Encl.: Table 1. Species and Natural Communities Included in Core Area 1 Delineation
Table 2. Species and Natural Communities Included in Core Area 2 Delineation

cc: Mark Tisa, MA Division of Fisheries & Wildlife
Richard Lehan, MA Department of Fish & Game
Mike Gorski, MA Dept. of Environmental Protection
Eva Tor, MA Dept. of Environmental Protection
Traci Iott, CT Dept. of Energy & Environmental Protection

TABLE 1. Species and Natural Communities Included in Core Area 1 Delineation

Common Name	Scientific Name
Triangle Floater	*Alasmidonta undulata*
Crooked-Stem Aster	*Symphyotrichum prenanthoides*
Wapato	*Sagittaria cuneata*
Bristly Buttercup	*Ranunculus pensylvanicus*
Bur Oak	*Quercus macrocarpa*
Ostrich Fern Borer	*Papaipema sp. 2 nr. pterisii*
High-terrace floodplain forest	
Red Maple - Black Ash - Hemlock - Bur Oak Swamp	
Hairy Wild Rye	*Elymus villosus*
Intermediate Spike Sedge	*Eleocharis intermedia*
Narrow Leaved Spring Beauty	*Claytonia virginica*
Tuckerman's Sedge	*Carex tuckermanii*
Gray's Sedge	*Carex grayi*
Jefferson Salamander	*Ambystoma jeffersonianum*

Taxonomic Group	MESA Status
Mussel	No Longer Listed
Plant	Special Concern
Plant	Threatened
Plant	Special Concern
Plant	Special Concern
Butterflies & Moths	Special Concern
Natural Community	
Natural Community	
Plant	Endangered
Plant	Threatened
Plant	Endangered
Plant	Endangered
Plant	Threatened
Amphibian	Special Concern

TABLE 2. Species and Natural Communities Included in Core Area 2 Delineation

Common Name	Scientific Name	Taxonomic Group
American Bittern	*Botaurus lentiginosus*	Bird
Mustard White	*Pieris oleracea*	Butterfiles & Moths
Wood Turtle	*Glyptemys insculpta*	Turtle
Common Moorhen	*Gallinula chloropus*	Bird

MESA Status
Endangered
Threatened
Special Concern
Special Concern

Core Habitat Areas
Housatonic River Primary Study Area (PSA)

1 0.5 0 1 Miles

Core Habitat Areas (Core Area 2)
Housatonic River Primary Study Area (PSA)

1 0.5 0 1 Miles

Part of the Housatonic River
Showing Primary Study Area, High Species Richness, and Vernal Pools

1 0.5 0 1 Miles

ATTACHMENT 5
CAP CROSS SECTION REFINEMENT – LAYER SIZING, REST OF RIVER – REACH 5A

Memo

Stantec

To:	Scott Campbell Weston Solutions, Inc. 10 Lyman Street, Suite 2 Pittsfield, MA 01201	From:	Nicholas D'Agostino, PE & Daniel Nein, CWB Stantec Consulting 5 LAN Drive Westford, MA 01886
File:	195600459	Date:	February 24, 2012

Reference: Cap Cross Section Refinement – Layer Sizing
Rest of River – Reach 5A
Housatonic River PCB Remediation, Pittsfield, MA

As requested, Stantec Consulting (Stantec) has completed preliminary calculations to size the habitat, armor, filter, and isolation layers for the referenced project. It should be noted that the calculations and recommendations presented herein are preliminary in nature and are not intended to be used for a final design without further verification. In determining the sizing for the various layers of the cap, it was assumed that the underlying soil after sediment removal along the river bottom would be granular (sand) for both riffles and pools.

The Rest of River, from the confluence at the East and West Branches of the Housatonic River to Woods Pond Dam, is primarily a low-gradient stream and part of an overall riverine system recognized as having a long history of landscape alteration, settlement patterns, and structural control of the river (e.g., dams, channelization, bank armoring) (Massachusetts Natural Heritage and Endangered Species Program 2010). The sediment bed consists of coarse to fine sands with approximately ten percent silts and clays in Reaches 5A and 5B and fine sands and silts in Reach 5C (Woodlot Alternatives, Inc. 2002), which is consistent with the general trend observed through extensive bed sediment core sampling that the average percentage of sediment becomes finer from upstream to downstream (Weston Solutions, 2004).

The sizing of the armor layer of the cap was based upon a 2-year storm event with a peak annual flow of 1,725 cubic feet per second (cfs) for cross section XS105. A Mannings 'n' value of 0.03 and channel slope of 0.001 was used in estimating flow and velocity. The flood level in the channel would rise to elevation (El) 958.9, which corresponds to a velocity of 4.67 feet per second. The river bottom for cross Section XS105 was estimated to be at El 949± at its deepest point, resulting in a water depth of 9.9 feet.

Several velocity-based methods were utilized to determine the D_{50} size of the riprap and included the US Army Corps of Engineers (USACE, 1994), US Bureau of Reclamation (USBR, 1967), US Geological Survey (USGS, 1966), and Isbash, (1936) methods. The D_{50} size for each of these methods was calculated to be 1.71 inches, 3.5 inches, 5.16 inches, and 1.82 inches, respectively. The attached figure provides an example of D_{50} size versus velocity for a variety of methods, which indicates the USGS method as being too conservative when compared to the other methods. A D_{50}

size of 3.5 inches is recommended for this channel. Angular rock is recommended for the riprap armor layer with the following gradation and corresponding weight:

D_{100}	5.25 inches	14 pounds
D_{50}	3.5 inches	4 pounds
D_{10}	1.8 inches	0.6 pounds

The thickness of the riprap armor layer was determined by multiplying the D_{100} stone size by 2.5 times, resulting in a layer thickness of 13 inches. The D_{85} was estimated to be 4.5 inches and D_{15} to be 2 inches

The habitat layer was sized based on critical dimensionless shear stress calculations using a value of 0.035, and is intended to replicate existing surficial bed habitat conditions and where possible improve surficial bed habitat conditions for aquatic species present. Applying a factor of safety of 2.0 and using an empirical data set for gravel bed streams (Rosgen, 2006) a D_{84} value of 3 inches was determined. The following gradation of the habitat layer is recommended at an overall thickness of 6 inches.

D_{100}	3.5 inches
D_{84}	3.0 inches
D_{50}	1.0 inches
D_{16}	0.25 inches

Aquatic species such as dragonflies (i.e. aquatic larvae), mussels, and wood turtle, all found in the Rest of River, are capable of inhabiting a range of riverine sand and gravel bed compositions, which was a consideration during cap design. The triangle floater (*Alasmidonta undulata*) occupies a wide range of substrate and flow conditions, but like most mussel species prefers habitat of low-gradient river reaches with sand and gravel substrates (Nedeau et al 2000). The wood turtle (*Glyptemys insculpta*), also a state-listed species of Special Concern, prefers slower moving streams and rivers with sandy bottoms and vegetated banks (Ernst and Lovich 2009). Similarly, the larvae of dragonflies inhabit a bed sediment gradient of sandy substrates found in flowing waterways (Nikula et al 2003). Aquatic habitat suitability was also a consideration during earlier phases of remediation design. A post-remediation aquatic community assessment of the 1½-mile reach conducted in 2007 found macroinvertebrate taxa richness, relative abundance, and biomass increased when compared to 2000 data and; fish sampling identified a diverse and abundant post-remediation fish population consistent with the expected fish community composition, with noticeably greater fish presence in the vicinity of stone structures provided as part of habitat restoration in the river channel (Weston Solutions, Inc. 2007).

Once the habitat layer is placed at the site, sands and other small-sized sediments from upstream should fill the interstitial void space relatively soon thereafter, which is anticipated to offer similar existing habitat conditions for aquatic species present. Smaller sands can also be added during construction, and it is recommended that sand comprise approximately 30 percent of the layer, with gravel as specified above comprising 70 percent of the layer.

Reference: Cap Cross Section Refinement – Layer Sizing
Rest of River – Reach 5A
Housatonic River PCB Remediation, Pittsfield, MA

The filter layer beneath the armor layer should consist of a gravel (coarse) layer underlain by an isolation sand (finer) layer. These layers were sized based upon the following equation (Brown, 1989):

$$\frac{D_{15}\text{ (coarse layer)}}{D_{85}\text{ (finer layer)}} < 5 < \frac{D_{15}\text{ (coarse layer)}}{D_{15}\text{ (finer layer)}} < 40$$

Utilizing this relationship, it was determined that a gravel filter layer beneath the armor layer corresponding to an AASHTO No. 57 stone would need to be 6 inches thick. The recommended gradation for this gravel filter layer is as follows:

Sieve Size	Percent Passing by Weight
1-½ inch	100
1 inch	95 to 100
½ inch	25 to 60
No. 4	0 to 10
No. 8	0 to 5

An average value for D_{85} and D_{15} for this gravel filter layer was estimated to be 0.75 inch and 0.25 inch, respectively.

For the riprap to gravel filter interface, the size of the gravel was determined from the following equation:

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (gravel filter layer)}} = 2.63 < 5 < \frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (gravel filter layer)}} = 8.3 < 40 \quad \text{OK}$$

Therefore the gravel portion of the filter will provide an adequate transition between the riprap and underlying isolation layer.

This six inch thick gravel layer would then be underlain by a six inch thick sand isolation layer corresponding to a Massachusetts Department of Transportation (MassDOT) specification M1.03.0 Type c. The purpose of the isolation layer is to minimize the advective and diffusive flux of PCB migration from the underlying sediments up through the cap. This sand layer should be blended with organic material at the source to achieve a total organic content of 0.5 percent by weight. The recommended gradation for the sand/isolation layer is as follows:

Sieve Size	Percent Passing by Weight
2 inch	100
½inch	50 to 85
No. 4	40 to 75
No. 50	8 to 28
No. 200	0 to 10

An average value for D_{85} and D_{15} for this sand isolation layer was estimated to be 1.00 inch and 0.009 inch, respectively. The gravel filter layer to sand layer interface was estimated as follows:

$$\frac{D_{15}\text{ (gravel filter layer)}}{D_{85}\text{ (sand layer)}} = 0.24 < 5 < \frac{D_{15}\text{ (gravel filter layer)}}{D_{15}\text{ (sand layer)}} = 27.3 < 40 \quad \text{OK}$$

The gradation of the gravel filter layer will provide adequate protection for the underlying sand isolation layer.

The river bed sediment gradations were obtained for Reach 5B from Table 4-6 from the RFI Report (General Electric, 2003) which provided an arithmetic mean for the percentages of gravel (1.4%), sand (76%), silt (18%), and clay (4.1%). For the purposes of this analysis, it was assumed that the gradation of the sediment at the proposed bed excavation limit would be similar to the river bed sediment gradation noted above. From this information D_{85} and D_{15} values were estimated to be 0.02 inch and 0.001 inch, respectively. The sand filter to sediment interface was estimated as follows:

$$\frac{D_{15}\text{ (sand layer)}}{D_{85}\text{ (river bed sediment)}} = 0.45 < 5 < \frac{D_{15}\text{ (sand layer)}}{D_{15}\text{ (river bed sediment)}} = 9 < 40 \quad \text{OK}$$

The gradation of the sand isolation filter will provide adequate protection of the underlying sediments.

A 3-inch thick mixing layer should be placed over the bottom of the excavation and should consist of gravel to prevent infiltration of the underlying soil/sediment into the isolation layer during construction.

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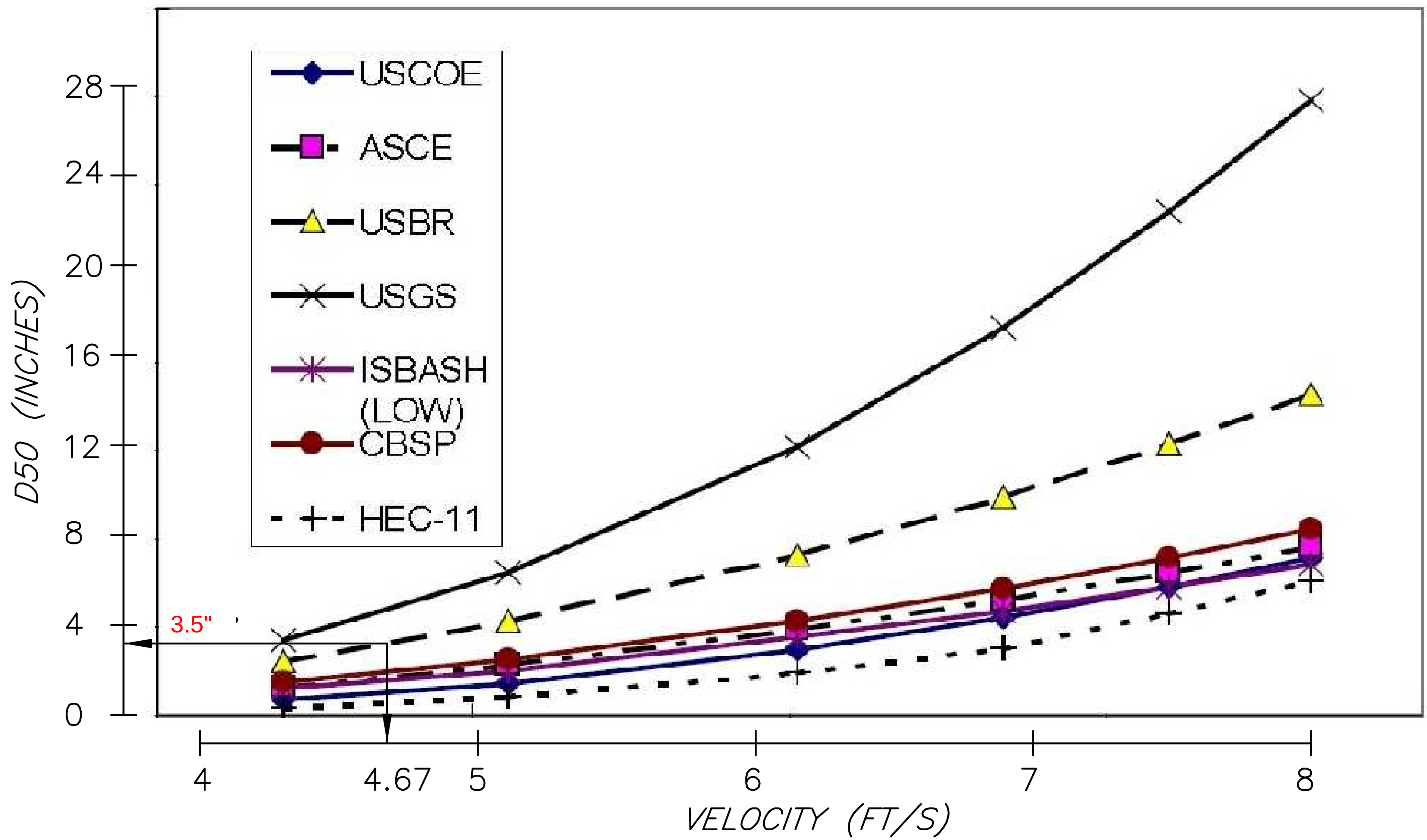

ATTACHMENT 6
DERIVATION OF REMOVAL VOLUMES AND REMOVAL ACREAGES FOR SED 9/FP 4 MOD

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The Trusted Integrator for Sustainable Solutions

MEMORANDUM

TO: Dean Tagliaferro, U.S. Environmental Protection Agency

FROM: Scott Campbell, Weston Solutions, Inc.

DATE: 15 May 2014

RE: GE-Pittsfield/Housatonic River Project; Task Order 2
W.O. No. 20502.169.095.0270
Derivation of Removal Volumes and Removal Acreages for SED 9/FP 4 MOD
DCN: HR-051514-AAYQ

The purpose of this memorandum is to summarize the derivations used to estimate removal volumes and areas associated with SED 9/FP 4 MOD. In general, removal volumes were estimated based on the SED 9 and FP 4 volumes and information provided by GE in its October 2010 Revised Corrective Measures Study (RCMS), and revised as appropriate to account for the modifications to SED 9 and FP 4. Modifications to SED 9 and FP 4 were included in the EPA Region 1 June 2011 Report and Proposal to the EPA National Remedy Review Board (the 2011 NRRB Package); the May 2012 "Potential Remediation Approaches to the GE-Pittsfield/Housatonic River Site 'Rest of River' PCB Contamination," that EPA developed in consultation with the States of Massachusetts and Connecticut (hereinafter referred to as the "Status Report"); and the EPA Region 1 August 2012 Response to the EPA National Remedy Review Board (the "August 2012 NRRB Response"). Further clarifications have been made to SED 9/FP 4 MOD since August 2012 and include the use of averaging, coupled with not-to-exceed surficial concentrations of 50 mg/kg PCBs, in the backwaters and Reaches 7 and 8.

In its RCMS, GE used geographic information system (GIS) techniques to estimate removal volumes and acreages of capping, backfill, and thin-layer capping. GE computed surface areas based on the GIS representation of the shoreline within each reach or portion of a reach (GE, 2010). Except where noted, EPA used similar techniques to estimate removal volumes and removal acreages for SED 9/FP 4 MOD.

Certain volume estimates in this document are based upon assumptions made regarding the thickness of engineered caps in the Housatonic River (also referred to as caps). Cap thickness affects the dredge/excavation depth required (and thus, the volume of contaminated sediment required to be transported and disposed of off-site). Specific Engineered Cap Performance Standards and design principles will be included in EPA's Draft Resource Conservation and

Recovery Act (RCRA) Permit. EPA's proposed Engineered Cap Performance Standards do not specify particular thicknesses. Thus, the estimates herein are for purposes of providing information regarding volume, cost, and other construction parameters. These estimates should not be construed as EPA proposals, EPA decisions, or enforceable requirements as to the design of any cap.

Table 1 summarizes the removal volumes estimated for SED 9/FP 4 MOD.

Table 1 – Summary of Removal Volumes and Acres for SED 9/FP 4 MOD

Reach	River Bed Cut (ft)	Volumes (cubic yards)*					Removal Area (Acres)
		Riverbed	Riverbank	Pond/ Backwater	Floodplain	Total	
5A	2.5	168,000	25,000			193,000	42
5B	1 foot in limited areas	500	500			1,000	<<1
5C	2	186,000				186,000	57
Backwaters				95,000		95,000	59
Woods Pond				285,000		285,000	60
7	1 to 1.5			84,000		84,000	38
8	1 to 1.5			71,000		71,000	41
FP	1 or 3				75,000	75,000	45
	Totals	**354,500**	**25,500**	**535,000**	**75,000**	**990,000**	**343**

* Consistent with the methods used in GE's RCMS and in the EPA Region 1 2011 and 2012 reports to the National Remedy Review Board, removal volumes and areas are rounded in this memorandum.

The following sections provide details regarding the derivation of the volumes presented in Table 1.

Reach 5A Sediments

In the RCMS, GE estimated that a total of 134,000 cubic yards (yd^3) of sediment would be removed with capping over 42 acres for SED 9 in Reach 5A. This estimate involved sediment removal of 2 feet (ft) over the entire reach. In its June 2011 Report to EPA's National Remedy Review Board (NRRB) and in the Status Report, EPA estimated a removal volume of 168,000 yd^3 based on 2.5 ft of sediment removal and capping for the entire 42-acre reach (WESTON, 2011; EPA, 2012a). The sediment removal volume for Reach 5A was calculated by using the ratio of excavation depth for SED 9 MOD compared to the excavation depth for SED 9 times the volume for SED 9. This is shown in Equation 1:

Equation 1: *Removal Volume (yd^3) = (2.5 ft/2.0 ft) x 134,000 yd^3 = 168,000 yd^3*

Reach 5A Banks

In the RCMS, GE estimated for SED 9 that approximately 25,000 yd^3 would be removed from Reach 5A banks (approximately 10 linear miles). This volume would be removed from both banks along the entire 5-mile reach. The Status Report approach for SED 9/FP 4 MOD involved determining volumes during remedial design where there are riverbanks with PCBs containing 5 mg/kg or greater of total PCBs and a Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) rating classified as moderate-high or greater using the methodology outlined pursuant to the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2006). For example, applying the data from a May 2009 site-specific riverbank field survey conducted using the BANCS model (Stantec, 2009) and the existing PCB data described below to the remedial design determination approach outlined above, approximately one-third (or 3.5 miles) of the Reach 5A riverbanks would be disturbed, with a removal volume of approximately 25,000 yd^3.

The table in Attachment 1 depicts the 14 BEHI ratings from Very Low Low to Extreme for each riverbank segment in Reach 5A. PCB concentration data were then binned into concentration ranges of less than 5, 5 to 10, 10 to 25, 25 to 50, and greater than 50 mg/kg.[1] Based on this evaluation, approximately 15,400 linear ft of riverbanks contain soils with tPCB concentrations exceeding 5 mg/kg and have a rating classified as Moderate-High or greater.

The linear feet of removal was increased to 17,600 ft for the purpose of estimating that one-third of the riverbanks would be removed. The excavation depth into the bank was set to 6 ft for the purpose of estimating removal volumes and accounting for differing bank restoration techniques.

---

[1] Mapping of riverbank PCB concentrations is based on Thiessen polygon-based GIS coverage used in the CMS floodplain assessments converted to a 3-meter grid. The analysis includes riverbank and adjacent floodplain soil data.

In addition, bank heights are variable throughout Reaches 5A and 5B (see Appendix G of GE's RCMS). For the purpose of this estimate, an average bank height of 6.3 ft was assumed. The riverbank removal volume for Reach 5A was calculated using Equation 2:

Equation 2: $Removal\ Volume\ (yd^3) = LF \times BH \times D \times CF$

Where:

LF is the linear ft of bank removal;

BH is the estimated bank height (ft);

D is the depth of the removal cut (ft); and

CF is the conversion factor equal to 0.037 to convert cubic ft to cubic yards.

Thus the SED 9/FP 4 MOD Reach 5A riverbank removal volume is as follows:

$$17{,}600\ ft \times 6.3\ ft \times 6\ ft \times 0.0370\ yd^3/ft^3 = 25{,}000\ yd^3$$

<u>Reach 5B Sediment</u>

In the RCMS, GE estimated that a total of 88,000 yd^3 of sediment would be removed with capping over 27 acres in Reach 5B under SED 9. This estimate involved sediment removal of 2 ft over the entire reach. EPA's Status Report approach, developed in consultation with the States of Massachusetts and Connecticut, limited removal to only areas containing greater than 50 mg/kg tPCB in the top foot of sediment. This approach involves an estimated 500 yd^3 of sediment removal.

For the purpose of providing a Reach 5B removal volume estimate, a width of 85 ft is assumed, which is based on an analysis that determined the average width of the Reach 5B channel is approximately 85 ft. This analysis is depicted in Figure 1 of Attachment 2. To arrive at an excavation length, it was assumed that sediment excavation would be from a point 25 ft upstream and 25 ft downstream of the removal location. The number of locations exceeding 50 mg/kg was determined based on plotting PCB surface sediment data and overlaying the Reach 5B model grid. This analysis showed that there are three model grid cells in Reach 5B that contain surface samples exceeding 50 mg/kg.

Equation 3: *Removal Volume* $(yd^3) = N_{Loc} \times L \times W \times D$

Where:

N_{Loc} is the number of locations in Reach 5B with sediments greater than 50 mg/kg tPCB. Each removal location was assigned the same removal footprint;

L is the length of the removal cut (ft);

W is the width of the removal cut (ft);

D is the depth of the removal cut (ft); and

CF is the conversion factor equal to 0.037 to convert cubic ft to cubic yards.

Thus the SED 9/FP 4 MOD Reach 5B sediment removal volume is as follows:

$$3 \times 50 \text{ ft} \times 85 \text{ ft} \times 1 \text{ ft} \times 0.0370 \text{ yd}^3/\text{ft}^3 = 500 \text{ yd}^3$$

Reach 5B Banks

In the RCMS, GE estimated that SED 9 would involve approximately 10,000 yd^3 of soil removal from Reach 5B riverbanks (approximately 4 linear miles). The Status Report approach involved the removal of riverbank soils in areas with greater than 50 mg/kg tPCB in the top foot of bank soil.

The SED 9/FP 4 MOD Reach 5B riverbank removal volume was estimated using an approach similar to the Reach 5A riverbank approach. In this approach, spatially interpolated PCB data for riverbanks and floodplain soils were used to derive the removal volume estimate. Similar to Reach 5A riverbanks, PCB concentration data were then binned into concentration ranges of less than 5, 5 to 10, 10 to 25, 25 to 50, and greater than 50 mg/kg. See Table 1 in Attachment 3. Based on this evaluation, there is approximately 1,350 linear ft of riverbanks with tPCB concentrations exceeding 50 mg/kg. Because removal of Reach 5B banks is not based on erodability, BEHI/NBS ratings are not applicable. For the purpose of this estimate, an average bank height of 5 ft was assumed. The riverbank removal volume for Reach 5B was calculated using Equation 4:

Equation 4: *Removal Volume* $(yd^3) = LF \times BH \times D \times CF$

Thus the removal volume for Reach 5B banks is as follows:

$$1{,}350 \text{ ft} \times 5 \text{ ft} \times 2 \text{ ft} \times 0.0370 \text{ yd}^3/\text{ft}^3 = 500 \text{ yd}^3$$

Reach 5C Sediments

In the RCMS for SED 9, GE estimated a total of 156,000 cubic yards (yd^3) of sediment would be removed with capping over approximately 57 acres in Reach 5C. This estimate involved sediment removal of 2 ft from 20 acres in the upper section of Reach 5C and 1.5 ft of removal from 37 acres in the lower section of Reach 5C. In its June 2011 Report to EPA's National Remedy Review Board and in the Status Report, EPA assumed 2 ft of sediment removal and capping for the entire 57-acre area for a total of 186,000 yd^3 (WESTON, 2011; EPA, 2012a). The sediment removal volume for Reach 5C was calculated as follows:

- Retain GE's estimate of 66,000 yd^3 for the 20 acres in the upper section of Reach 5C.
- For the lower section of Reach 5C, use the ratio of excavation depth for SED 9 MOD compared to the depth for SED 9 times the volume for SED 9. This is shown in Equation 5:

Equation 5: *Removal Volume* $(yd^3) = (2.0\ ft/1.5\ ft) \times 90{,}000\ yd^3 = 120{,}000\ yd^3$

Thus the total removal volume for the upper and lower sections of Reach 5C is as follows:

$$66{,}000\ yd^3 + 120{,}000\ yd^3 = 186{,}000\ yd^3$$

Backwaters

In GE's RCMS, removal of backwater sediment for SED 9 occurs in areas with tPCBs greater than 1 mg/kg and a water depth less than 4 ft.[2] For backwater areas with tPCBs greater than 1 mg/kg and water depth greater than 4 ft, sediments are capped without removal. GE estimated a total of 109,000 yd^3 of sediment would be removed with capping over approximately 68 acres of the 86 total backwater acres. This estimate entailed sediment removal of 1 ft from 14 acres in areas defined as small backwaters and 1 ft of removal from 54 acres in areas defined as large backwaters. An additional 3 acres would be capped without removal, and the remaining 15 acres would be subject to monitored natural recovery.

In the Status Report, EPA's SED 9/FP 4 MOD approach called for the removal of 1 ft of certain backwater sediment followed by capping in areas with tPCB greater than 1 mg/kg, except in areas designated as priority endangered species habitat ("Core Area 1"). There would be no areas with capping without excavation. EPA subsequently clarified that for backwaters outside of Core Area 1, excavation is required to achieve an average sediment concentration of 1 mg/kg or less in surface and subsurface sediments after capping. In addition, discrete areas within Core

[2] 1 mg/kg delineation based on 0 to 1-ft Thiessen polygons.

Area 1 with tPCBs in sediments greater than 50 mg/kg would be removed and capped (EPA, 2012a). The Status Report estimated 95,000 yd^3 would be removed from 61.5 acres, while avoiding removal in approximately 8.5 acres in Core Area 1. A further refinement of this estimate is described below.

Attachment 4 includes two tables that summarize SED 9 removal areas and Core Area 1 overlap acreage. The difference in the estimates is accounted for by recent EPA updates to the SED 9 GIS polygon layer used to define the backwater areas. In the RCMS, GE defined the backwater areas using a GIS polygon approach. EPA updated the approach to define the backwaters spatially by using the project GIS hydrographic layer, which conforms to the habitat boundaries used to generate Thiessen layers. Figure 1 in Attachment 4 depicts these updated backwater boundaries overlain with Core Area 1. Table 1 in Attachment 4 presents the original estimates, and Table 2 in Attachment 4 summarizes these revised SED 9 removal acres, MNR acres, and Core Area 1 acres that overlay the backwaters. Preliminary volume calculations were conducted using information in both tables as shown below.

Method 1. Table 1 in Attachment 4 provides a summary of removal acres, MNR acres, and Core Area 1 acres that overlay the backwaters based on GE's mapping of backwaters and an overlay of Core Area 1.

Equation 6: $Removal\ Volume\ (yd^3) = (SED_{BR} - SED_{CA1} + SED_{CA150}) \times CF$

Where:

> SED_{BR} is the SED 9/FP 4 MOD backwater remediation (derived from SED 9) in acres;
>
> SED_{CA1} is the acres in Core Area 1 that overlap with SED 9/FP 4 MOD backwater remediation areas;
>
> SED_{CA150} is the estimated acres in Core Area 1 with tPCBs greater than 50 mg/kg; and
>
> CF is the conversion factor equal to 1,613 cubic yards in a one ft cut per acre.

Thus the backwater sediment removal volume is as follows:

$$99{,}000\ yd^3 = (70\ \text{acres} - 9\ \text{acres} + 0.5\ \text{acres}) \times 1\ \text{ft} \times 1{,}613\ yd^3/(\text{acre-ft})$$

Method 2. Table 2 in Attachment 4 provides a summary of removal acres, MNR acres, and Core Area 1 acres that overlay the backwaters based on EPA's mapping of backwaters and an overlay of Core Area 1.

Equation 7: *Removal Volume* $(yd^3) = (SED_{BR} - SED_{CA1} + SED_{CA150}) \times CF$

Where:

SED_{BR} is the SED 9/FP 4 MOD backwater remediation (derived from SED 9) in acres;

SED_{CA1} is the acres in Core Area 1 that overlap with SED 9/FP 4 MOD backwater remediation areas;

SED_{CA150} is the estimated acres in Core Area 1 with tPCBs greater than 50 mg/kg; and

CF is the conversion factor equal to 1,613 cubic yards in a one ft cut per acre.

Thus the backwater sediment removal volume is as follows:

$$103{,}000\ yd^3 = (74\ acres – 10.5\ acres + 0.5\ acres) \times 1\ ft\ x\ 1{,}613\ yd^3/(acre\text{-}ft)$$

The removal volume estimated by these two methods ranges from 99,000 yd^3 (61.5 acres) to 103,000 yd^3 (64 acres). However, these estimates do not factor in the change from excavating in all areas greater than 1 mg/kg to excavating and capping to achieve an average sediment concentration of 1 mg/kg. There are insufficient data to calculate the reduction in area and volume resulting from this changed approach; however, a reasonable estimate is that it could reduce volumes by 4,000 to 8,000 yd^3 (a reduction of 5 to 10%). Therefore, the estimate of 95,000 yd^3 cited in the Status Report is a reasonable estimate. The area associated with 95,000 yd^3 is actually 59 acres, as opposed to the 61.5 acres cited in the Status Report.

Reach 6 - Woods Pond

In the RCMS, GE estimated that for SED 9 a total of 244,000 yd^3 of sediment would be removed with capping over approximately 60 acres in Woods Pond. This estimate involved sediment removal of 3.5 ft from 37 acres in the "shallow" portion of Woods Pond and 1 ft from 23 acres in the "deep hole" portion of the pond. GE's SED 9 shallow and deep delineation for Woods Pond is depicted in Figure 6-24a of GE's RCMS, presented in Attachment 5.

In June 2011, EPA's preferred alternative to the NRRB was consistent with GE's SED 9 in terms of removing 1 ft of sediment from deep areas and 3.5 ft from shallow areas of Woods Pond for a removal volume of 244,000 yd^3. The May 2012 Status Report and August 2012 Regional Response specified a minimum of 1 ft of sediment removal with capping, which results in a minimum post-capping water depth of 6 ft, except in near-shore areas. In near-shore areas, a moderately sloped bed is to be constructed, sloping from the shoreline to a water depth of 6 ft. EPA estimated that 285,000 yd^3 would be removed from Woods Pond using the Status Report and Regional Response approach (WESTON, 2011; EPA, 2012a; EPA, 2012b).

The estimate of 285,000 yd^3 of sediment removal is based on a two-step approach combining Woods Pond Environmental Fluid Dynamics Code (EFDC) model grid cells and Woods Pond grid cells specified as human health risk sediment exposure areas. As described in EPA's 2004 Model Calibration Report, Woods Pond grid cells in the EFDC model were assigned an initial condition bottom elevation. The derivation of model bathymetry in Woods Pond is presented in Appendix B.2 of EPA's Model Calibration Report. These bottom elevations are depicted in Figure B.2-9 in EPA's Model Calibration Report, presented in Attachment 5 (WESTON, 2004).

Bed elevation changes are computed during the validation and projection simulations due to deposition and erosion in individual grid cells. Bed elevations computed for the time corresponding to the start of sediment excavation in Woods Pond in a previously completed simulation were used to determine the depth of sediment removal required to achieve a post-capping water depth of 6 ft throughout the majority of the pond [based on the Woods Pond Dam crest elevation of 948.27 ft (289.02 meters)]. The removal volume in each grid cell necessary to achieve the post-capping water elevation was calculated from the product of the grid cell surface area and depth of removal, and then summed.

A different approach was used to approximate a moderately sloped bed in the near-shore area identified as sediment exposure area 3 (SA 3). Sediment removed from each SA 3 cell within the footprint of Woods Pond was targeted for an average 3-ft removal rather than what was necessary to achieve a post-capping water elevation depth of 6 ft. The 3-foot average is estimated to account for sloping from the edge of Woods Pond to a water depth of 6 ft. The sediment removal volume in these grid cells was calculated as the product of the surface area and a 3-ft removal depth. The total Woods Pond removal volume of 285,000 yd^3 was calculated by adding each SA 3 grid cell removal volume to the removal volume calculated for grid cells associated with the post-capping water elevation of 6 ft. The SA 3 grid cells are depicted in Figure 3-15a of GE's RMCS, presented in Attachment 5. These calculations do not account for the sedimentation accumulation in Woods Pond during the intervening period between dredging and capping. This additional sediment accumulation may need to be considered during design activities.

The last figure in Attachment 5 presents a series of maps that depict the pre-remediation water depths used to calculate the required depth of sediment removal to achieve a 6-ft water depth, depths after capping is complete (approximately 8.5 years later, because of the delayed capping), and the change in water depth between these two conditions. It is noted that these water depths are calculated based on a water surface elevation at the dam crest elevation. Water depths would be approximately 0.8 ft deeper at average flow conditions.

Reach 7 and 8 Impoundments

The SED 9 approach and its modifications for impounded areas behind the four Reach 7 dams and the Reach 8 dam have generally remained consistent throughout the 2010 RCMS, EPA's

2011 NRRB Package, EPA's Status Report, and the August 2012 NRRB Response. These four dams in Reach 7 are Columbia Mill Dam, Eagle Mill Dam, Willow Mill Dam, and Glendale Dam (Subreaches 7B, 7C, 7E, and 7G, respectively), and Rising Pond in Reach 8. Although the current SED 9 MOD plan allows for averaging, removal of sediment associated with dam removal, and removal to 1 mg/kg of PCBs without capping, the volume estimates below are based on excavation and capping of the entire impoundments as described in SED 9 of GE's 2010 RCMS. This estimate is likely a reasonable worst-case approach, because it requires excavation throughout the entire impoundments in Reach 7 and 8, without accounting for averaging. However, excavating sediment in conjunction with dam removal or to achieve an average of 1 mg/kg PCBs without capping may require excavation to depths greater than those shown in Table 2 below. However, excavation under these options also may not be required throughout the entire impoundments in Reach 7 and Reach 8.

The removal volume for these impoundments was estimated by using a combination of 1.5 ft of removal in areas of high sheer stress and 1 ft of removal in areas of low shear stress followed by capping. Delineation of these areas was determined by an evaluation conducted by GE (see Appendix F of the RCMS). Figure F-3 in the RCMS, as presented in Attachment 6, shows the distribution of shear stresses in Reaches 7 and 8. Table 2 shows the removal acres by high and low shear stress areas, removal depth, and removal volume for each impoundment.

Table 2 – Reach 7 and 8 Impoundment Removal Acres, Depth, and Volumes

Impoundment	Removal Acres	Removal Depth (ft)	Removal Volume (yd^3)[1]
Columbia Mill (HS)[2]	7	1.5	22,000
Columbia Mill (LS)[3]	3	1	
Eagle Mill (HS)	8	1.5	19,000
Willow Mill (HS)	8	1.5	19,000
Glendale Dam (HS)	6	1.5	24,000
Glendale Dam (LS)	6	1	
Rising Pond (HS)	5	1.5	71,000
Rising Pond (LS)	36	1	

Notes

[1] Calculated using the following equation: *Removal Volume (yd^3) = acres x depth (ft) x 1,613 yd^3/(ft-acre).*

[2]HS = high shear stress area.

[3]LS = low shear stress area.

Floodplain

In the RCMS, GE's FP 4 approach for floodplain soils involved removal and backfill to achieve the Reasonable Maximum Exposure (RME) Interim Media Protection Goals (IMPGs) based on a 10^{-5} cancer risk or a non-cancer Hazard Index (HI) of 1, whichever is lower (more protective) for both direct contact of floodplain soils and consumption of agricultural products from floodplain soils. For certain "frequently used subareas," the top 3 ft of soil would be removed and backfilled to achieve the above-mentioned IMPGs. In addition, FP 4 targeted soil removal and backfill to achieve the upper-bound IMPGs for ecological receptors. GE's FP 4 approach involved the removal of 121,000 yd^3 of soil from 72 acres, which included soil removal in approximately 15 acres of vernal pools (GE, 2010).

In the Status Report, and reiterated in the August 2012 NRRB Response, EPA's floodplain remediation approach is modeled after the FP 4 alternative in GE's RCMS. EPA's approach, developed in consultation with the States, is to excavate 1 ft of floodplain soils to generally meet the 10^{-5} cancer risk or the HI = 1, and to target 3 ft of removal and backfill in the frequently used subareas with no specific areas of additional excavation to meet ecological IMPGs. This FP 4 MOD approach would avoid the highest priority habitat (Core Area 1), except as needed to meet the IMPG of 10^{-4} and an HI = 1, and would minimize removal in Core Areas 2 and 3 on a case-by-case basis. FP 4 MOD calls for the remediation of vernal pools in a phased adaptive management approach (EPA, 2012a). Based upon an evaluation of the areas that may exceed the 10^{-5} cancer risk or the HI = 1 and the potential overlap of those areas with Core Areas 1, 2, or 3, EPA estimates the FP 4 MOD approach will result in the removal of approximately 75,000 yd^3 of material in approximately 45 acres of the floodplain. For additional information regarding this approach and field work protocols, see the Status Report Appendix (EPA, 2012a).

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ATTACHMENT 1

- Table 1: Reach 5A River Banks Binned by BEHI rating and PCB Concentration Data

Summary of Reach 5A River Banks BEHI Ratings Binned by PCB Concetration Ranges

Reach 5A

Total Length (Ft.) of BEHI Accessment - Reach 5A

47,862.60

BEHI Rating	5 - 10	10 - 25	25 - 50	> 50	Total Length BEHI Rating	Percent of Total Length	Cumulative % of All Banks	Percent of Erodible Banks (24,879 Ft.)	Cumulative % of Erodible Banks
Extreme	49.11	29.47	19.64	58.93	157	0.33%	**0.33%**	0.63%	**0.63%**
Very High Extreme	49.11	157.15	137.51	--	344	0.72%	**1.05%**	1.38%	**2.01%**
Very High High	--	176.80	68.75	117.86	363	0.76%	**1.81%**	1.46%	**3.47%**
Very High	157.15	992.02	333.95	324.13	1,807	3.78%	**5.58%**	7.26%	**10.74%**
High Very High	9.82	225.91	245.55	--	481	1.01%	**6.59%**	1.93%	**12.67%**
High Mod	166.97	923.27	717.01	294.66	2,102	4.39%	**10.98%**	8.45%	**21.12%**
High	589.32	2435.86	1178.64	834.87	5,039	10.53%	**21.51%**	20.25%	**41.37%**
Mod High	795.58	2367.10	1001.84	962.56	5,127	10.71%	**32.22%**	20.61%	**61.98%**
Mod	952.73	4773.49	2170.66	1561.70	9,459	19.76%	**51.98%**	38.02%	**100.00%**
Mod Low	667.90	1188.46	1041.13	933.09	3,831	8.00%	**59.98%**		
Low	1090.24	4027.02	1306.33	1070.60	7,494	15.66%	**75.64%**		
Low Mod	284.84	2062.62	1149.17	667.90	4,165	8.70%	**84.34%**		
Very Low	39.29	883.98	874.16	255.37	2,053	4.29%	**88.63%**		
Very Low Low	49.11	98.22	147.33	--	295	0.62%	**89.25%**		
					42,716	**51.98%**			
Total Length Conc. Bin	4901	20341	10392	7082	**42,716**				
Percent of Total Length	10.24%	42.50%	21.71%	14.80%	**89.25%**				
Cumulative % of All Banks	**89.25%**	**79.01%**	**36.51%**	**14.80%**					

ATTACHMENT 2

- Figure 1: Average Width of Reach 5B Channel

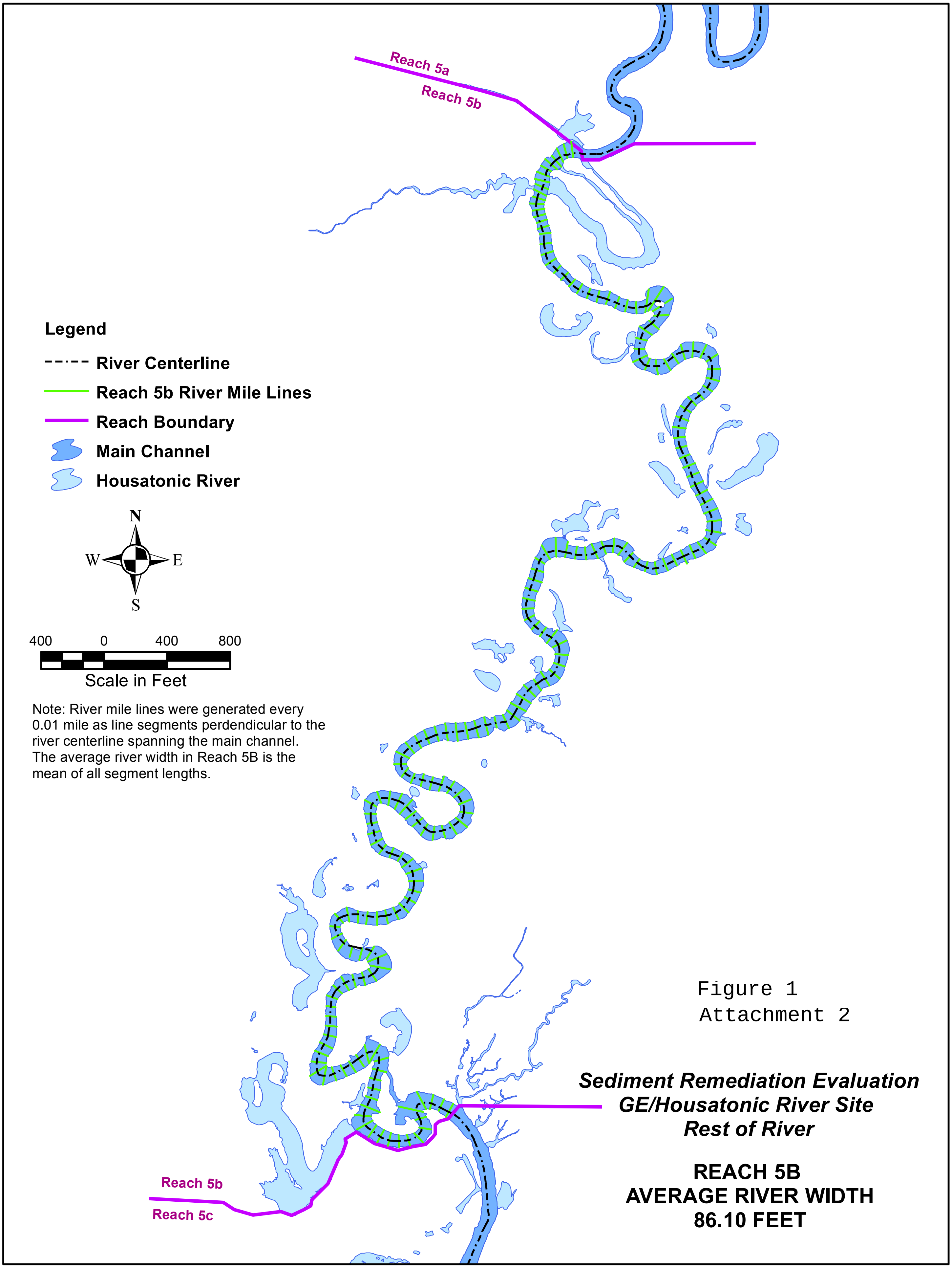


Figure 1
Attachment 2

Sediment Remediation Evaluation
GE/Housatonic River Site
Rest of River

REACH 5B
AVERAGE RIVER WIDTH
86.10 FEET

ATTACHMENT 3

- Table 1: Reach 5B River Banks Binned by PCB Concentration Data

Summary of Reach 5B River Banks Binned by Concentration Range

	PCB Concentration (mg/kg)					
Reach 5B	**< 5**	**5 - 10**	**10 - 25**	**25 - 50**	**> 50**	**Total Length (ft)**
Length Conc. Bin	6,099	5,638	7,317	6,188	1,346	26,588
Percent of Total Length	22.94%	21.20%	27.52%	23.27%	5.06%	100.00%

ATTACHMENT 4

- Table 1: Summary of Removal Acres, MNR acres, and Core Area 1 Acres that Overlay the Backwaters
- Figure 1: Updated Backwater Boundaries Overlain with Core Area 1
- Table 2: Revised Summary of Removal Acres, MNR acres, and Core Area 1 Acres that Overlay the Backwaters

Table 1: Summary of Removal Acres, MNR Acres, and Core Area 1 Acres that Overlay the Backwaters

Core1 Areas shown are overlap in areas designated in SED 9 MOD for remediation				
REACH	**SED 9 MOD Backwater Remediation (acres)**	**SED 9 MOD Backwater MNR (acres)**	**Total backwater Acres**	**Acres in Core Group 1**
Reach 5A	6.13	0.00	6.13	3.70
Reach 5B	6.67	1.91	8.58	1.19
Reach 5C	23.00	6.03	29.03	2.12
Reach 5D	23.34	7.06	30.40	1.96
Reach 6A	6.36	0.00	6.36	0.00
Reach 7A	4.55	0.00	4.55	0.00
Total	**70.05**	**15.00**	**85.05**	**8.96**

Backwater ID	Acres in Core1
BWL_02	0.73
BWL_03	0.13
BWL_04	2.03
BWL_05	0.28
BWL_07	0.12
BWL_09	1.93
BWS_02	1.81
BWS_03	0.93
BWS_04	0.34
BWS_06	0.56
BWS_12	0.07
BWS_13	0.37
BWS_15	0.82
BWS_16	0.19
BWS_17	0.16
TOTAL	**10.47**

Floodplain Remediation Evaluation
GE/Housatonic River Site
Rest of River

FIGURE 1
NHESP CORE AREA 1 WITH rCMS BACKWATER AREAS

Table 2: Revised Summary of Removal Acres, MNR Acres, and Core Area 1 Acres that Overlay the Backwaters

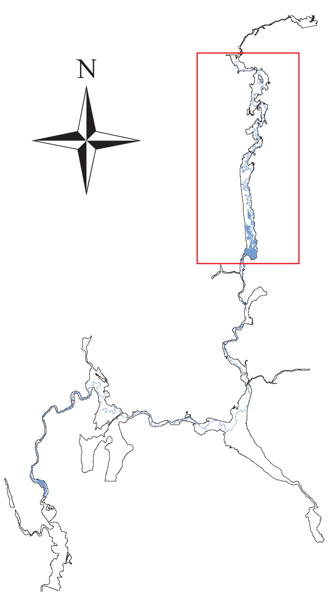
Core1 Areas shown are overlap in areas designated in SED 9 MOD for remediation				
REACH	**SED 9 MOD Backwater Remediation (acres)**	**SED9 MOD Backwater MNR (acres)**	**Total backwater Acres**	**Acres in Core Group 1**
Reach 5A	5.50	0.00	5.50	3.08
Reach 5B	6.81	1.81	8.62	1.28
Reach 5C	11.03	4.07	15.10	3.78
Reach 5D	39.93	7.07	47.00	2.34
Reach 6A	6.37	0.00	6.37	0.00
Reach 7A	4.57	0.00	4.57	0.00
Total	**74.21**	**12.95**	**87.16**	**10.47**

BWL_05 is in traditional Reach 5D (~ 12.26 acres). Previously allocated to Reach 5C.

ATTACHMENT 5

- Figure 6-24a of GE’s RCMS: GE’s SED 9 shallow and deep delineation for Woods Pond
- Figure B.2-9 in EPA’s Model Calibration Report: Model Grid in Woods Pond with Bottom Elevation Used for Each Cell
- Figure 3-15a of GE’s RMCS: Model grid cells selected to represent the sediment human health direct contact exposure areas in Reaches 5 & 6
- Figure Depicting the Pre-Remediation Water Depths Used to Calculate Required Depth of Sediment to Achieve 6-Foot Water Depth

LOCATOR



SCALE

0 0.25 0.5 Miles

LEGEND

Basemap Information

- Housatonic River
- 1 mg/kg PCB Isopleth
- Housatonic Railroad
- Major Road
- Dam

Remediation Information

Sediment Remediation Type

- Removal of Top 1 ft
- Removal of Top 1.5 ft
- Removal of Top 2 ft
- Removal of Top 3.5 ft
- Engineered Capping
- Access Road/ Staging Area

SED 9 includes bank removal/stabilization for Reaches 5A and 5B.

Figure 6-24a.

Sediment Alternative 9 (SED 9) in Reaches 5 and 6.

ARCADIS

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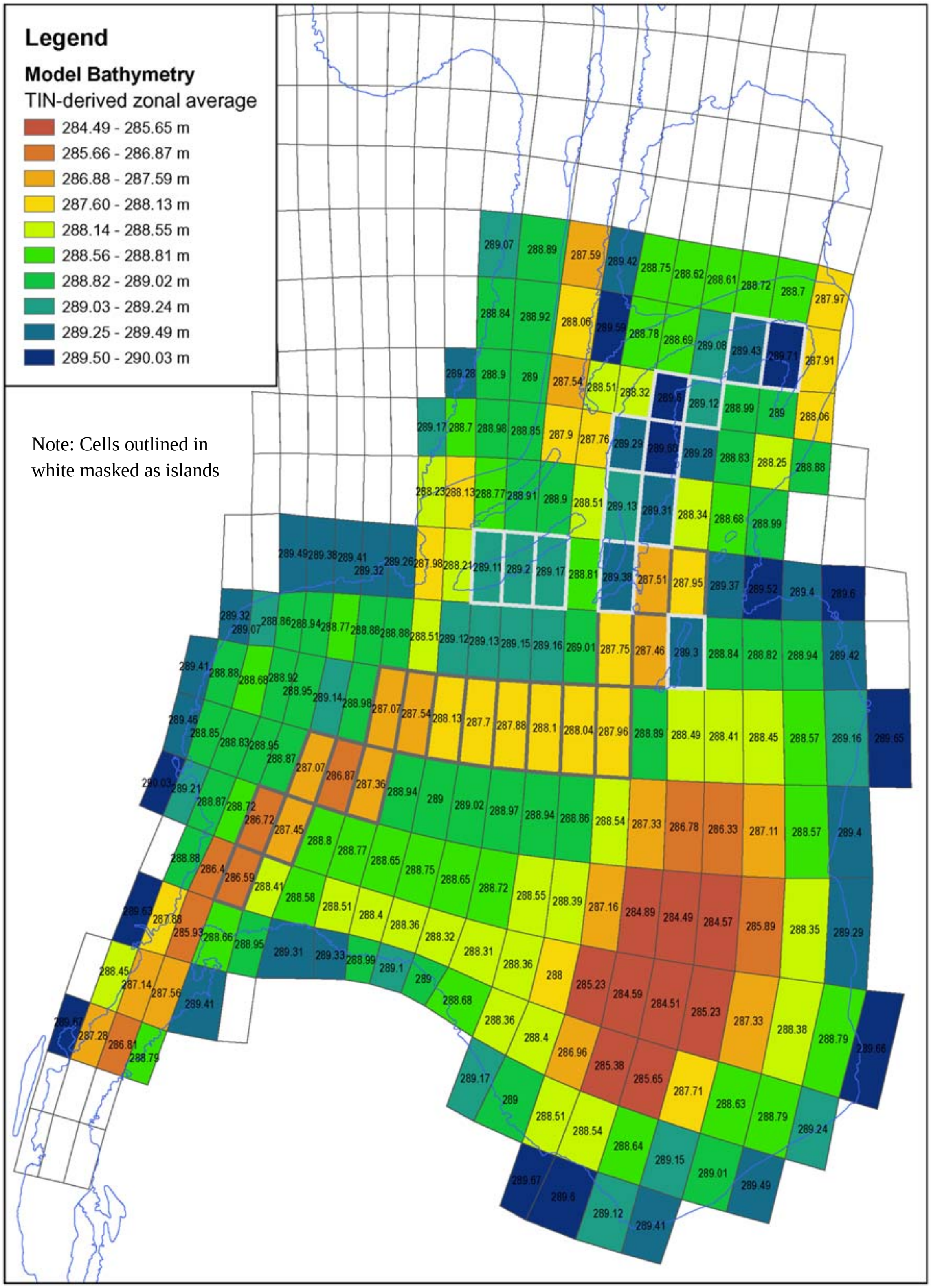

Figure B.2-9 Model Grid in Woods Pond with Bottom Elevation Used for Each Cell

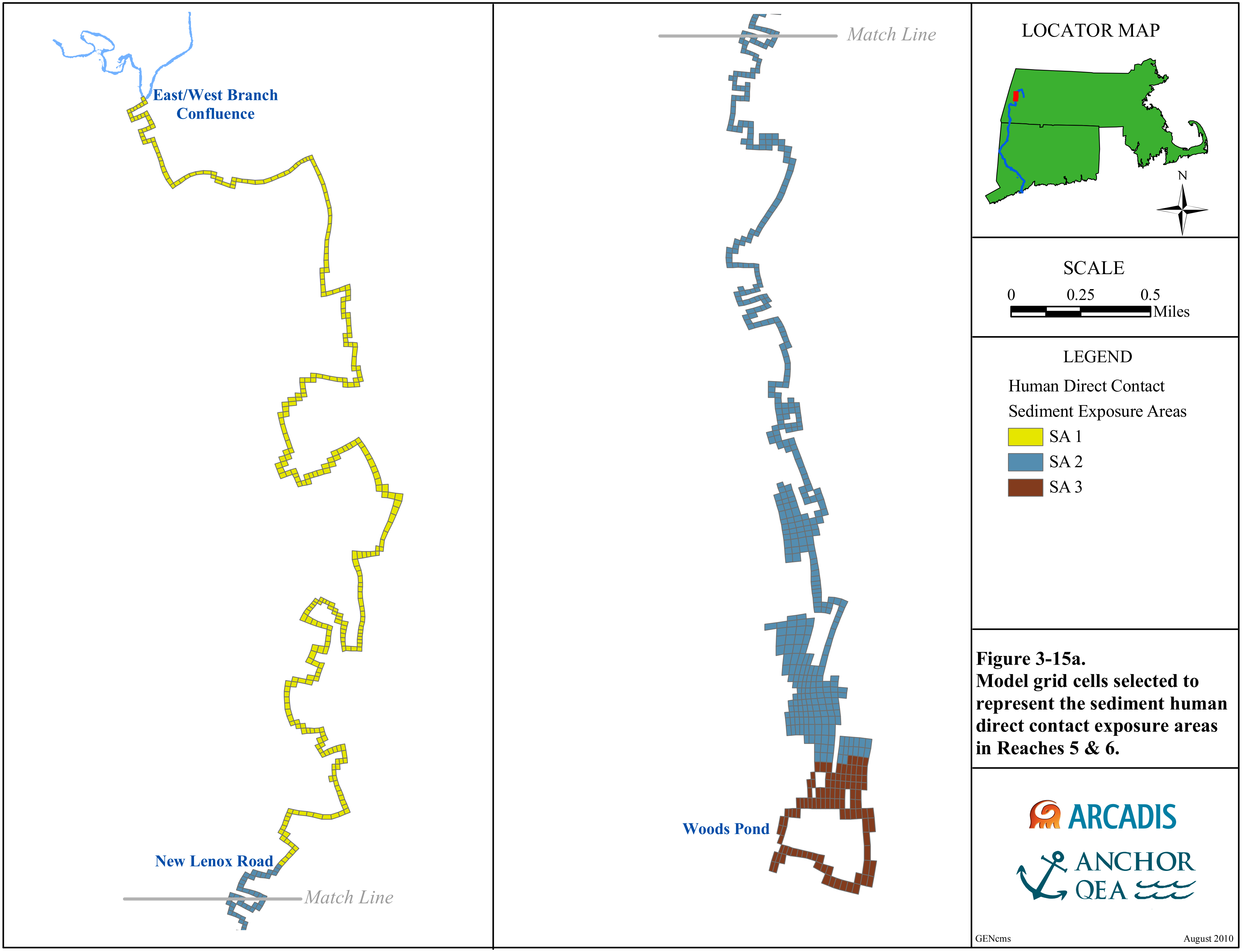

Figure 3-15a.
Model grid cells selected to represent the sediment human direct contact exposure areas in Reaches 5 & 6.

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GENcms

August 2010

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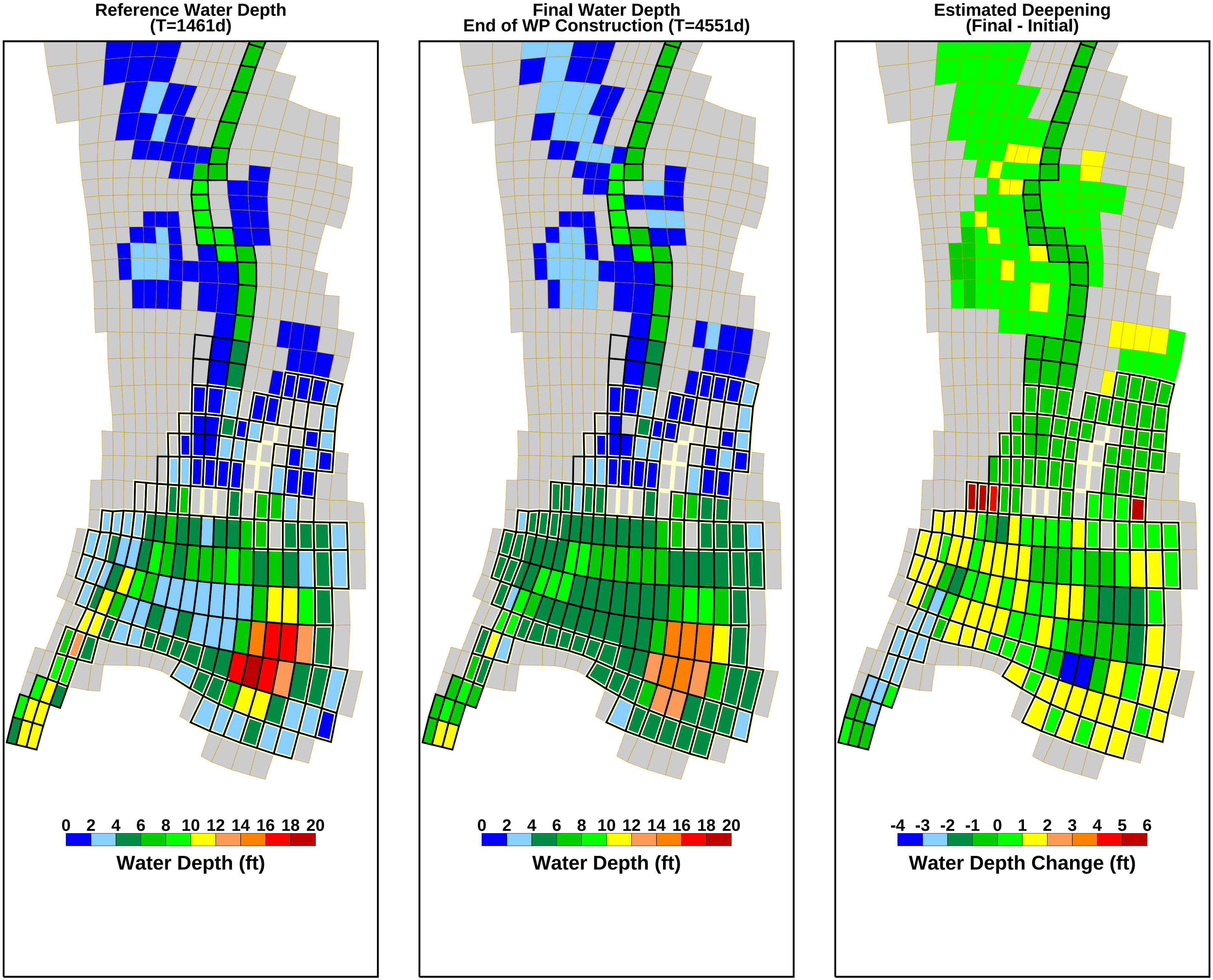


Reach 6 SA3 Grid Cells (yellow highlighting)

ATTACHMENT 6

- Figure F-3 in GE’s RCMS: Distribution of shear stresses in Reaches 7 and 8.

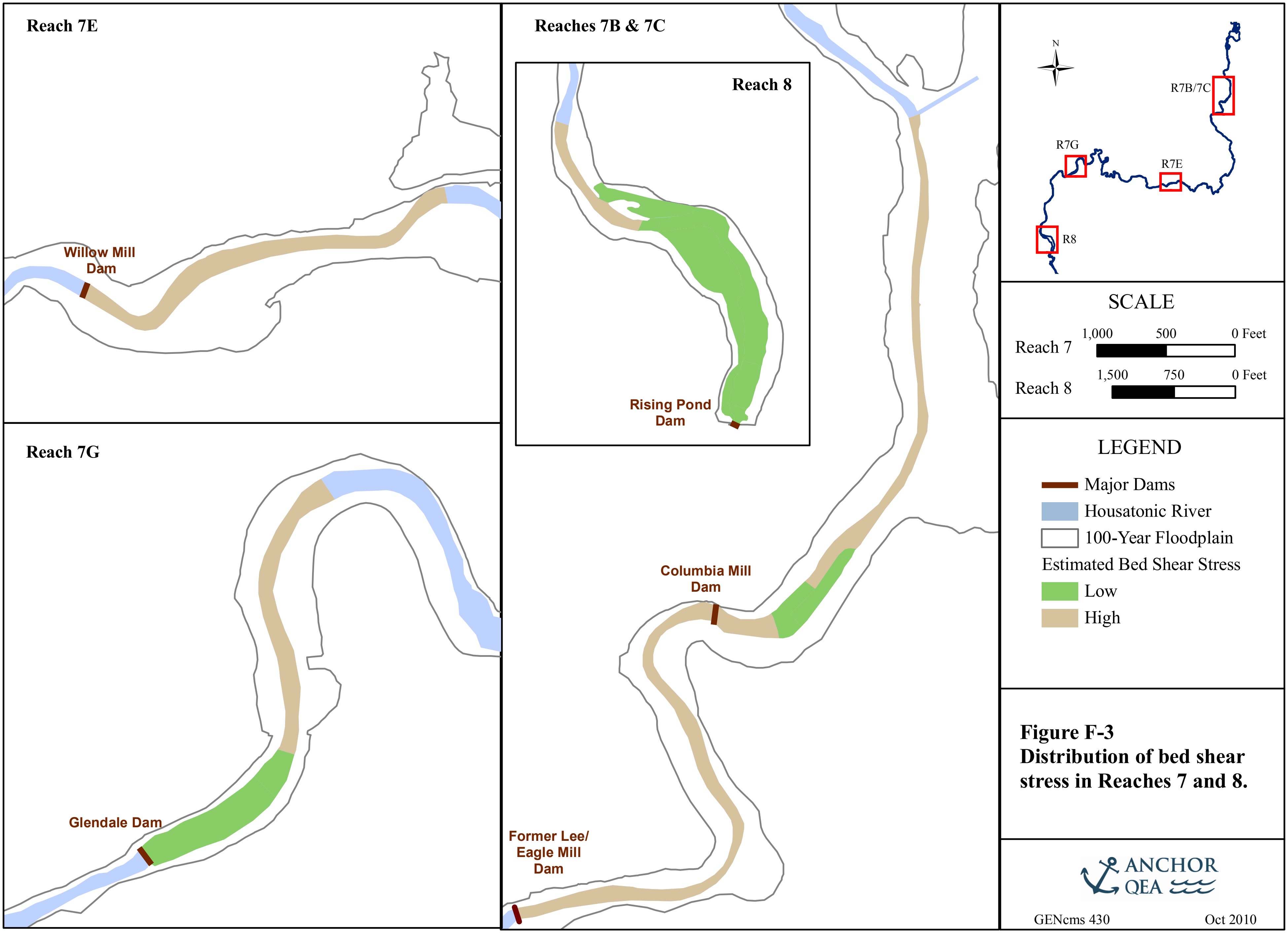


Figure F-3
Distribution of bed shear stress in Reaches 7 and 8.

ATTACHMENT 7
COMPARISON METRICS

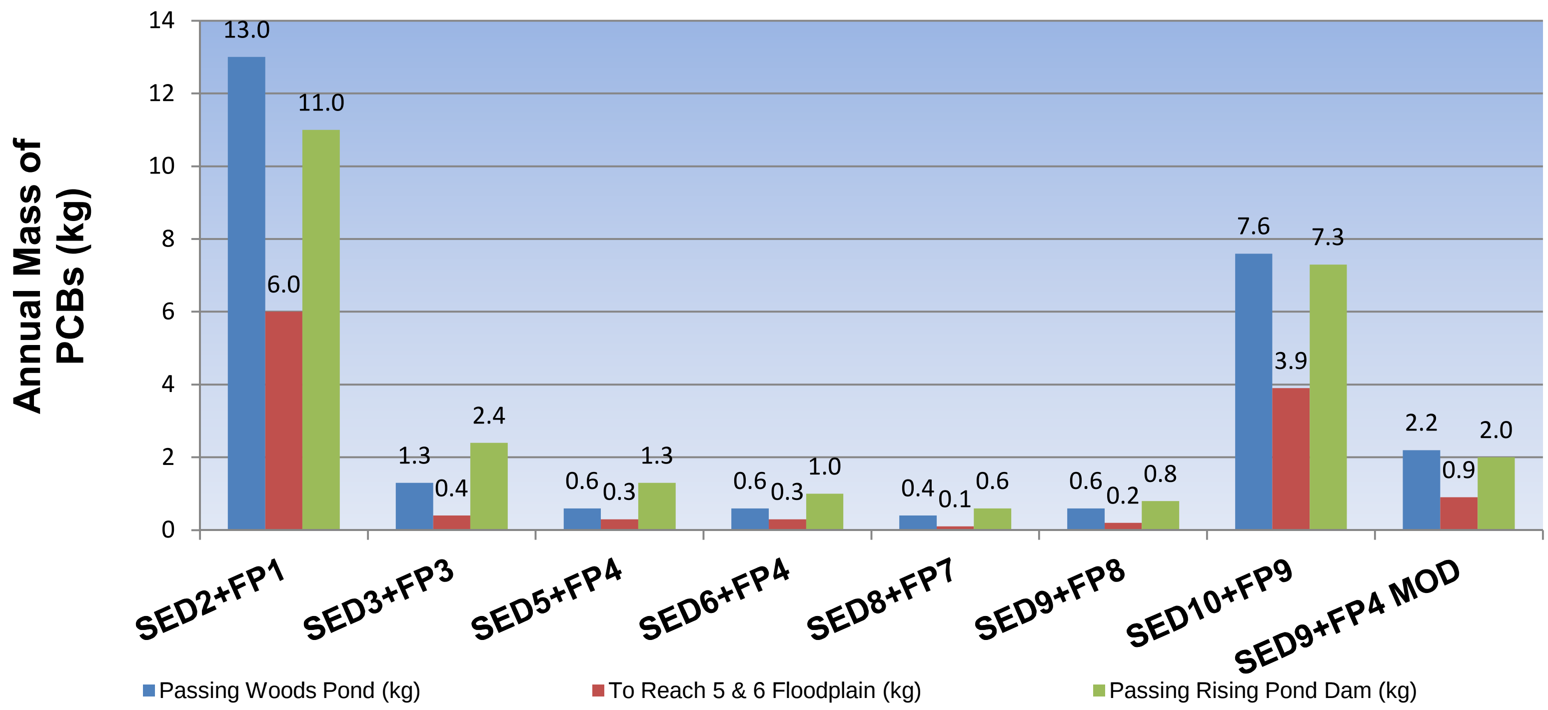
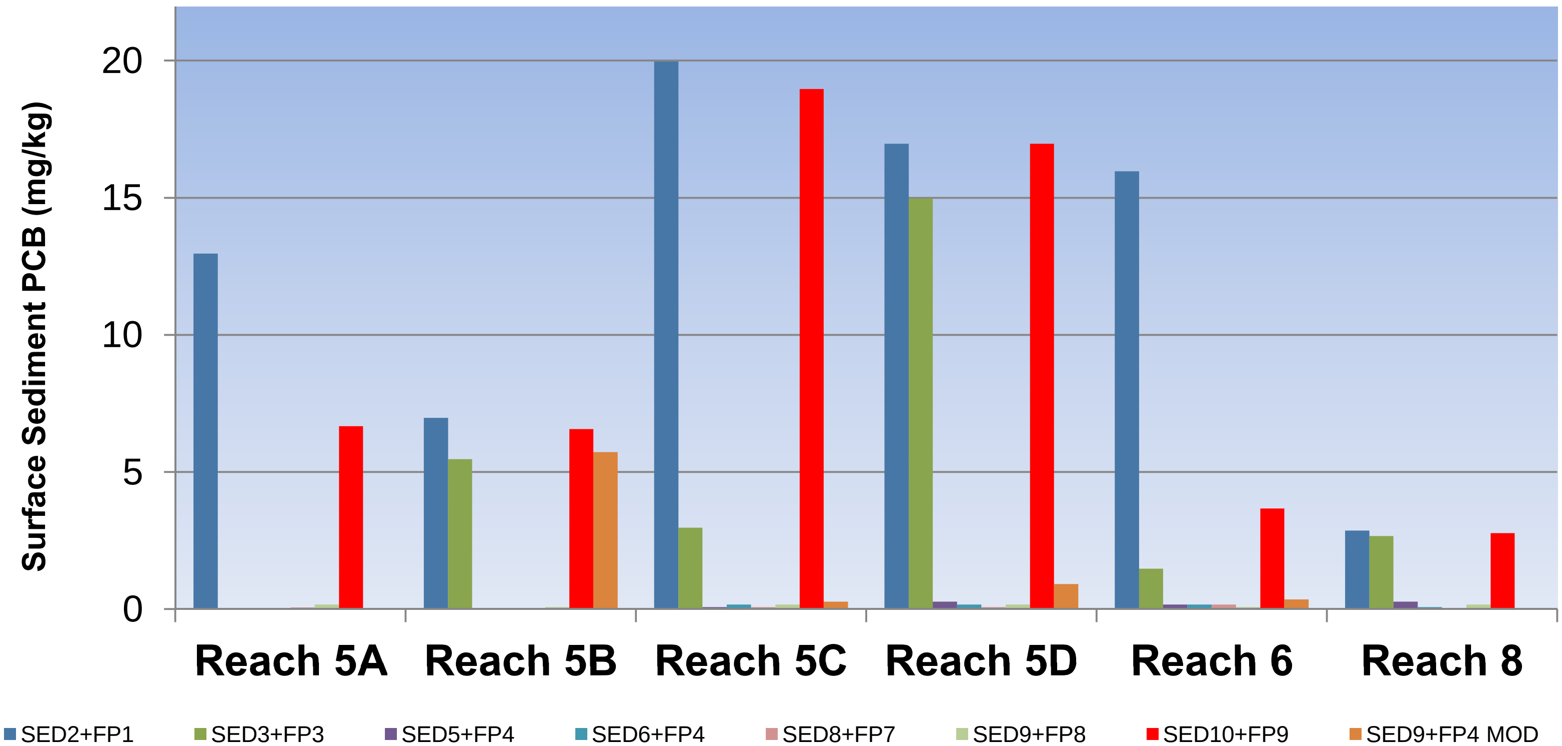
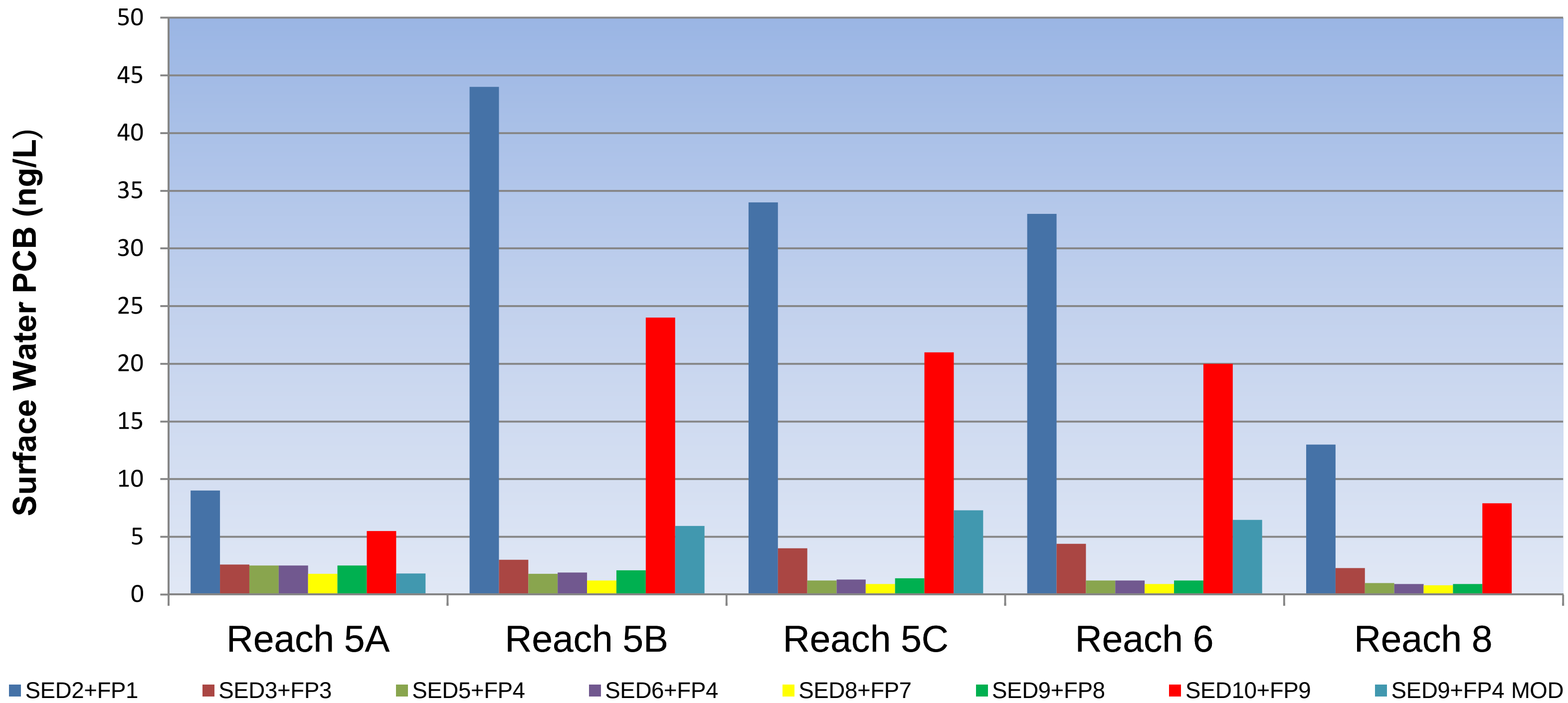


Figure 1 - Average Annual Mass of PCBs Passing Woods Pond and Rising Pond and Transported to Reach 5 & 6 During the Model Period for Combination Alternatives (averaged over last 5 years of simulation)



Reach 7 and CT Reaches are not presented on this figure. Concentrations for these reaches are presented as ranges in the CMS

Figure 2 - Model Predicted Average Surface Sediment (0-6") PCB Concentration at End of Projection Period for Combination Alternatives



Reach 7 and CT Reaches are not presented on this figure. Concentrations for these reaches are presented as ranges in the CMS.

Figure 3 - Model Predicted Average Surface Water PCB Concentration at End of Projection Period for Combination Alternatives

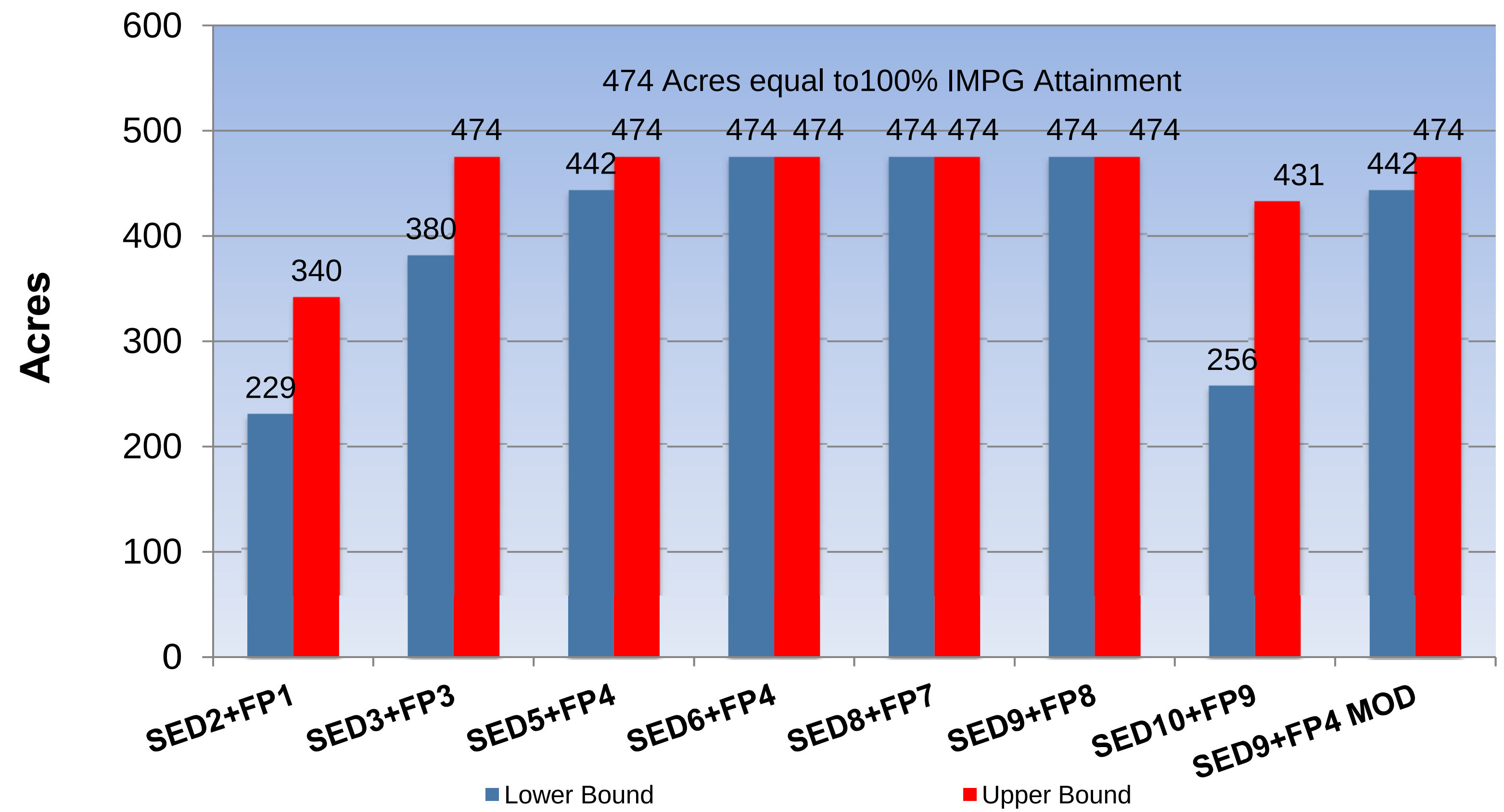


Figure 4 - Benthic Invertebrates IMPG Attainment in Acres for Combination Alternatives

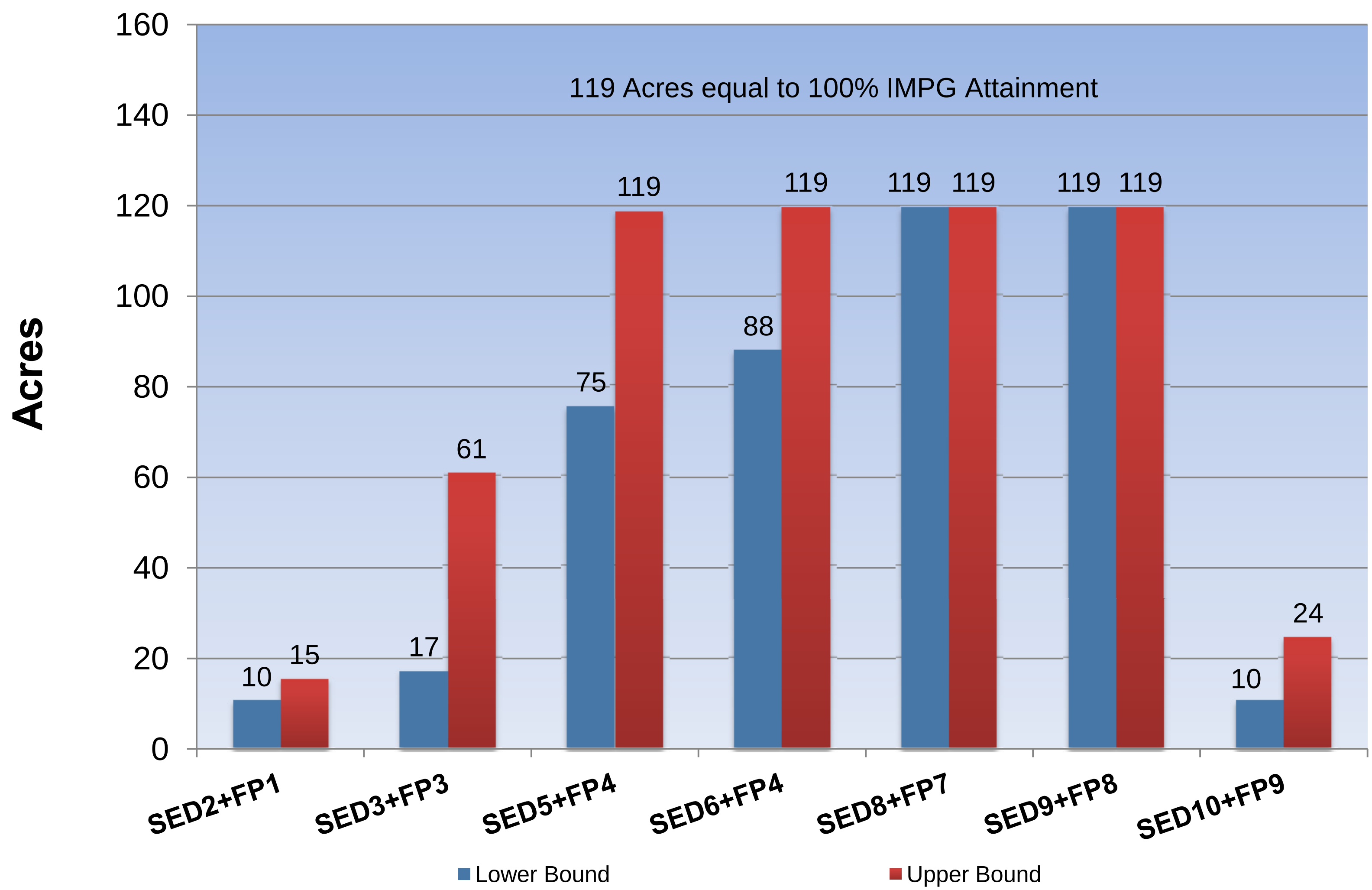
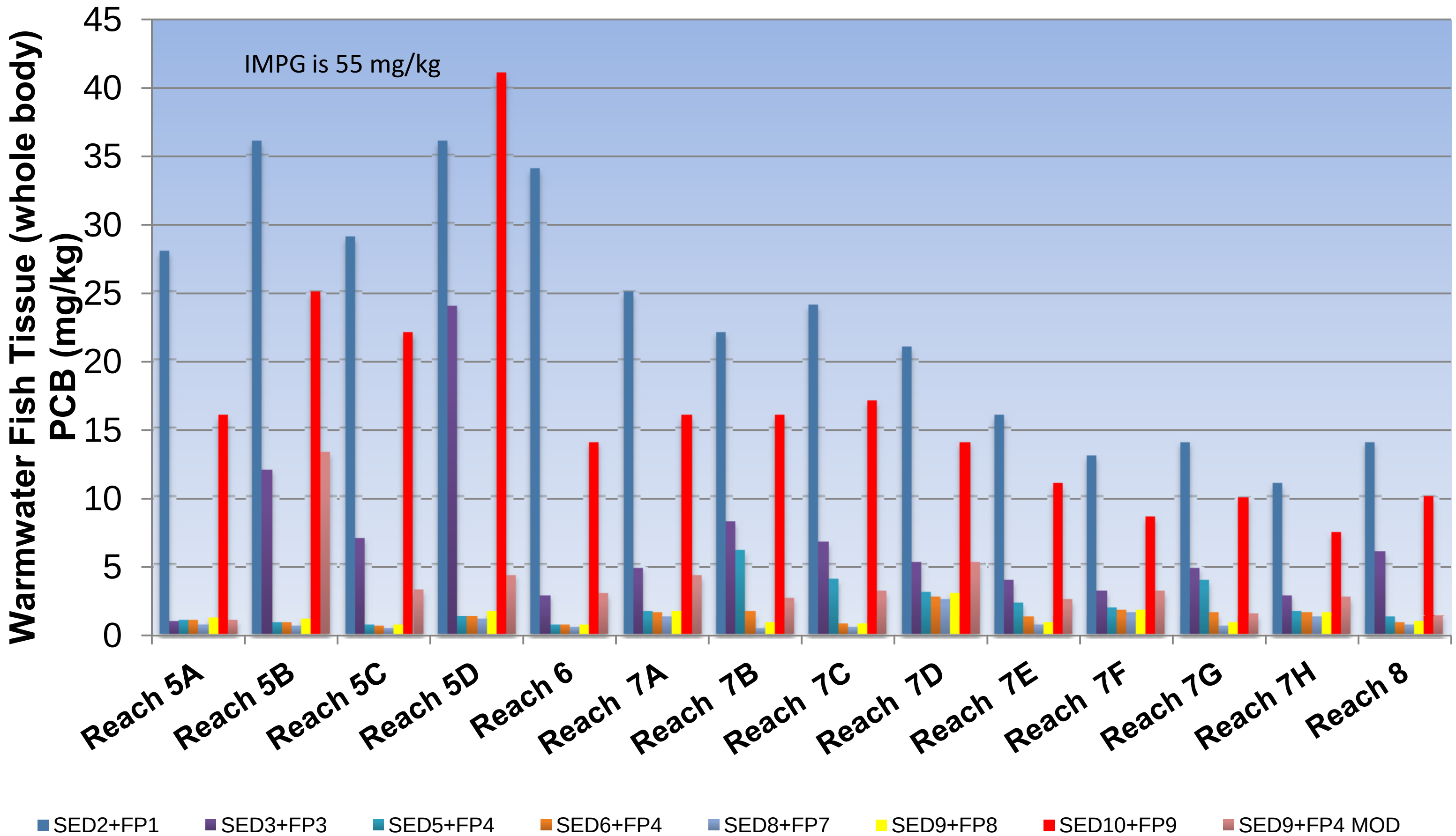


Figure 5 - Amphibian IMPG Attainment in Acres for Combination Alternatives



Tissue concentrations reported in GE's RCMS were noted to be "autumn average" but appear to be annual averages. To facilitate comparisons, values shown for SED 9/FP 4 MOD are annual averages

Figure 6 - Projected Warmwater Fish Tissue (whole body) PCB Concentration at the End of Model Projection Period for Combination Alternatives

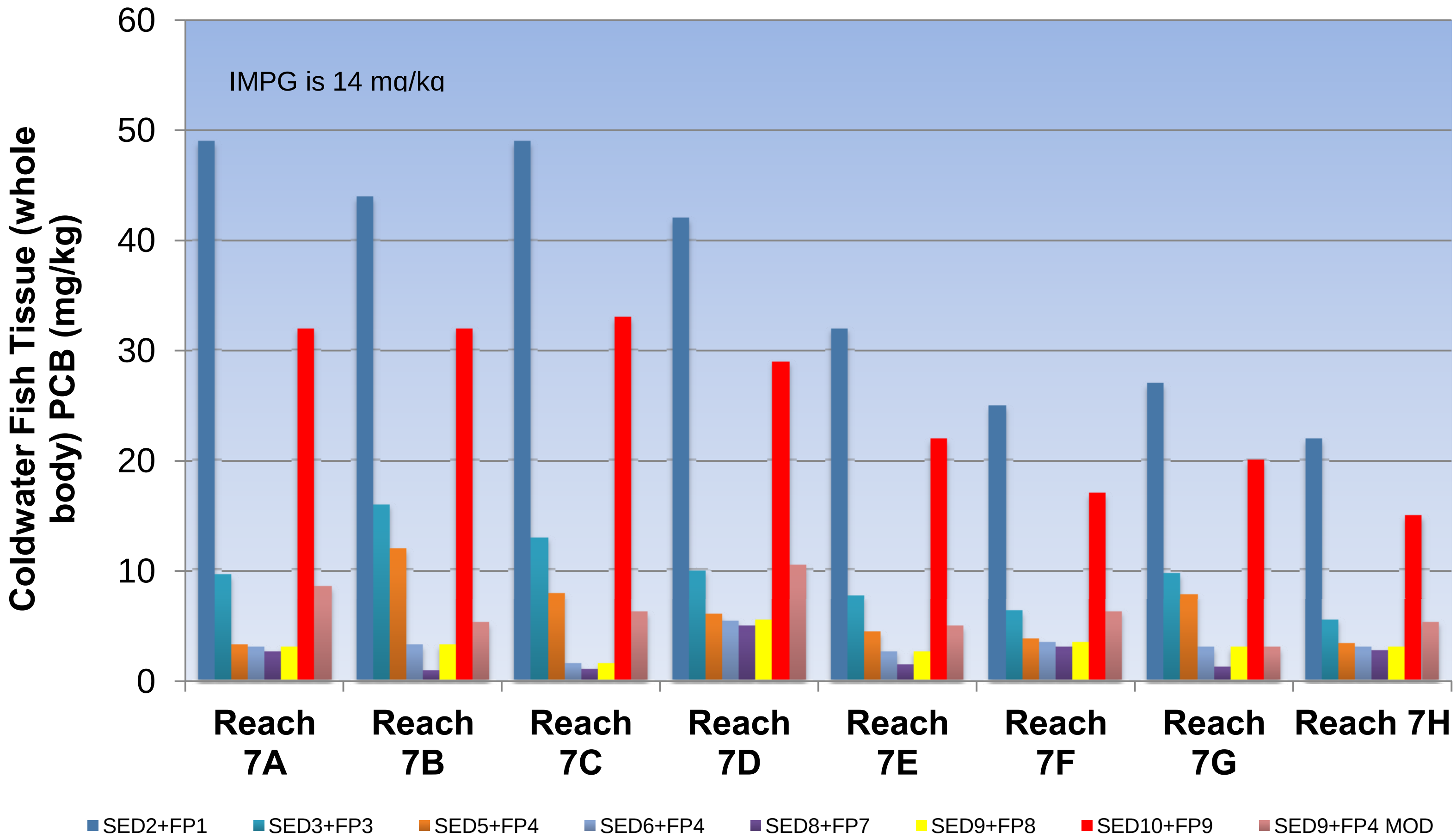


Figure 7 - Projected Coldwater Fish Tissue (whole body) PCB Concentration at the End of Model Projection Period for Combination Alternatives

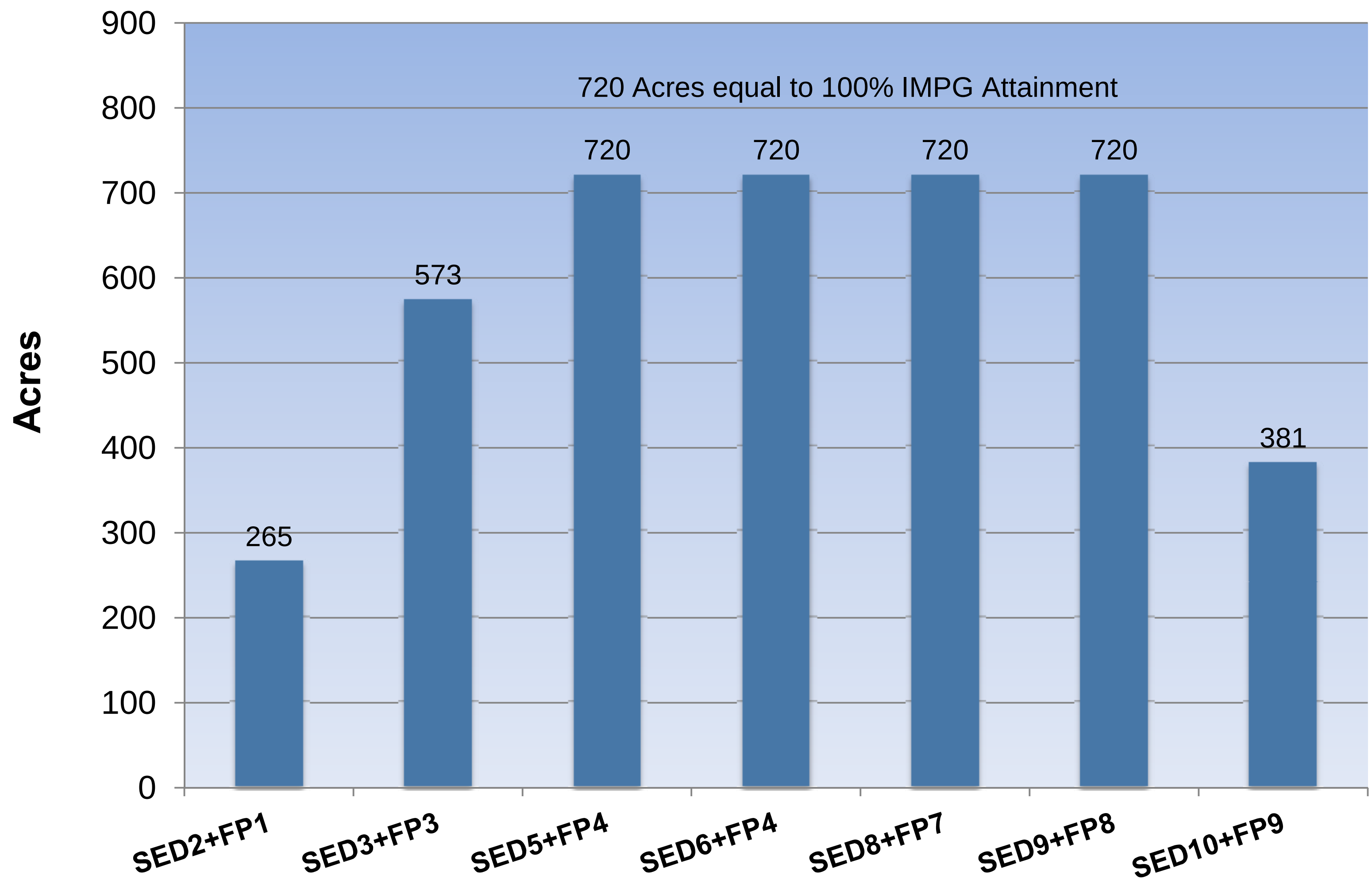


Figure 8 - Insectivorous Birds (Wood Duck) IMPG Attainment in Acres for Combination Alternatives

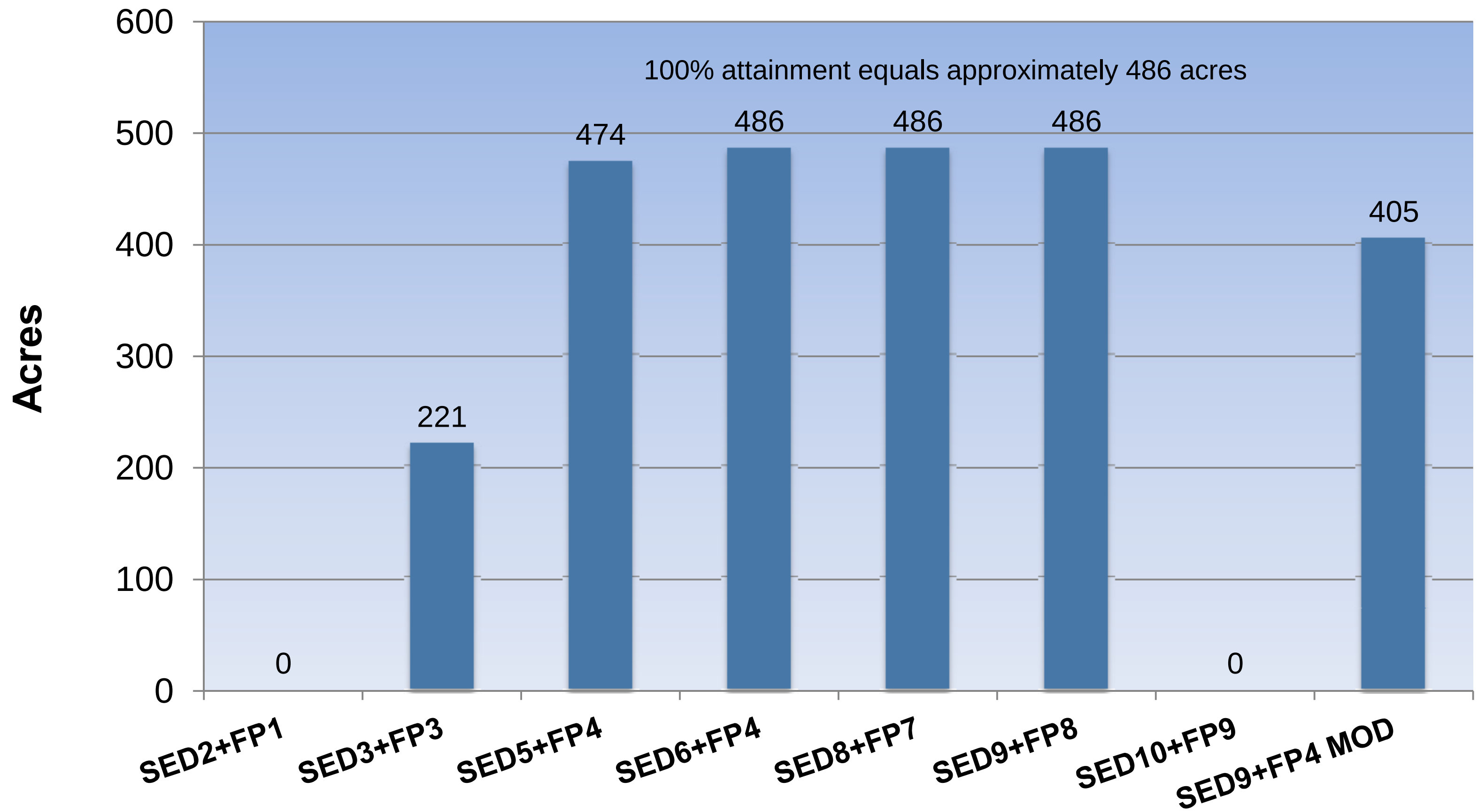


Figure 9 - Piscivorous Bird IMPG Attainment for Combination Alternatives

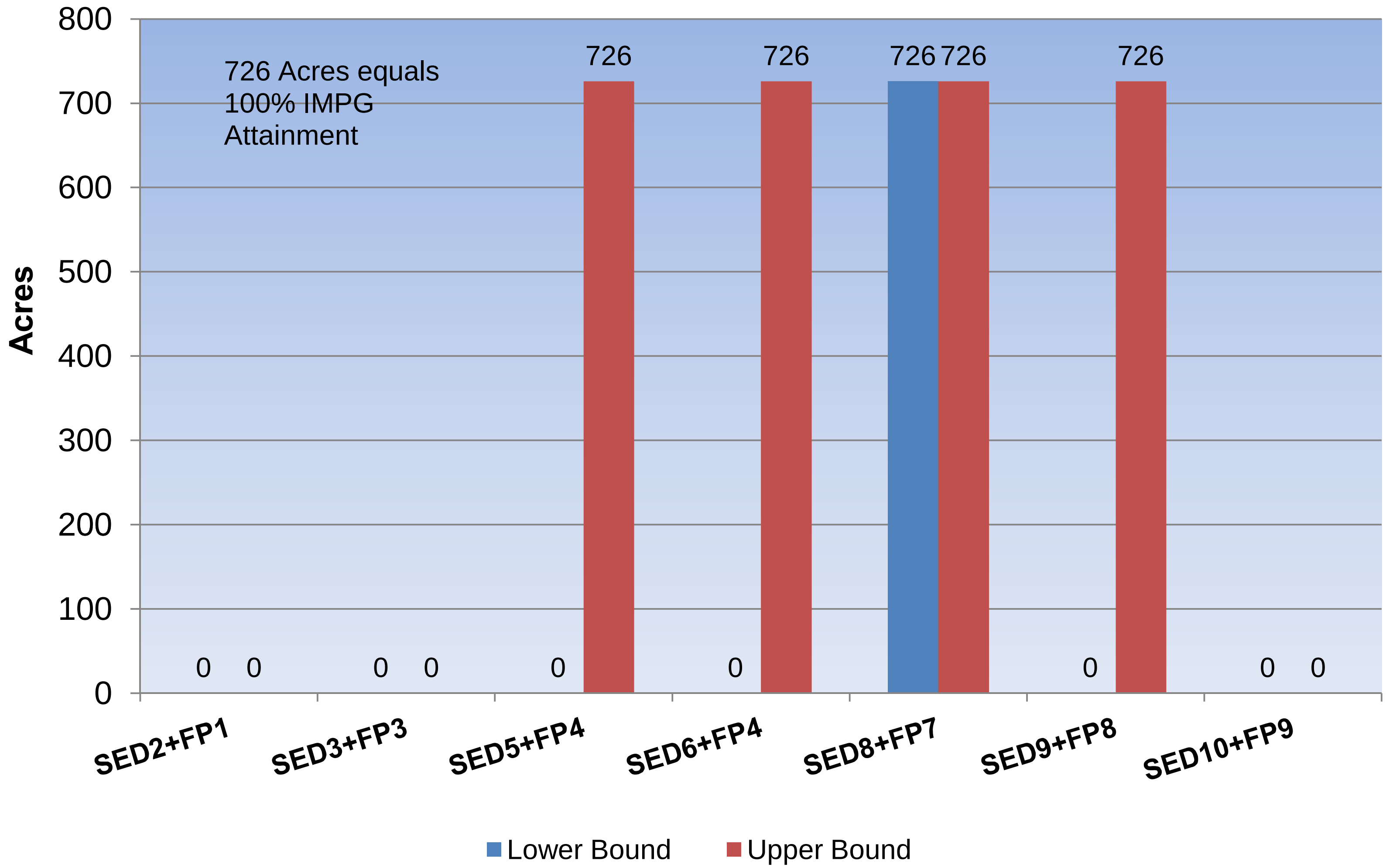


Figure 10 - Piscivorous Mammals (Mink) IMPG Attainment in Acres for Combination Alternatives

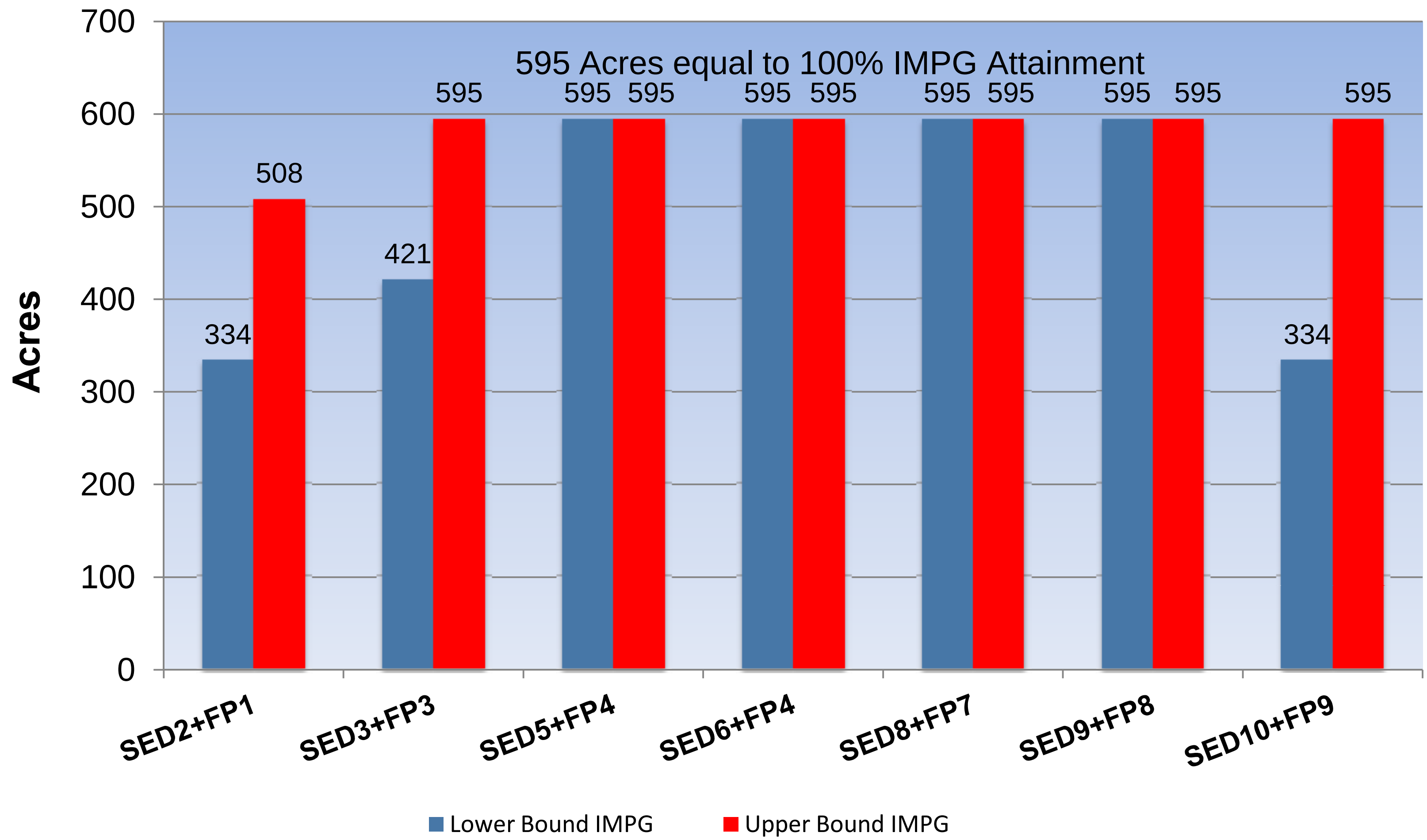
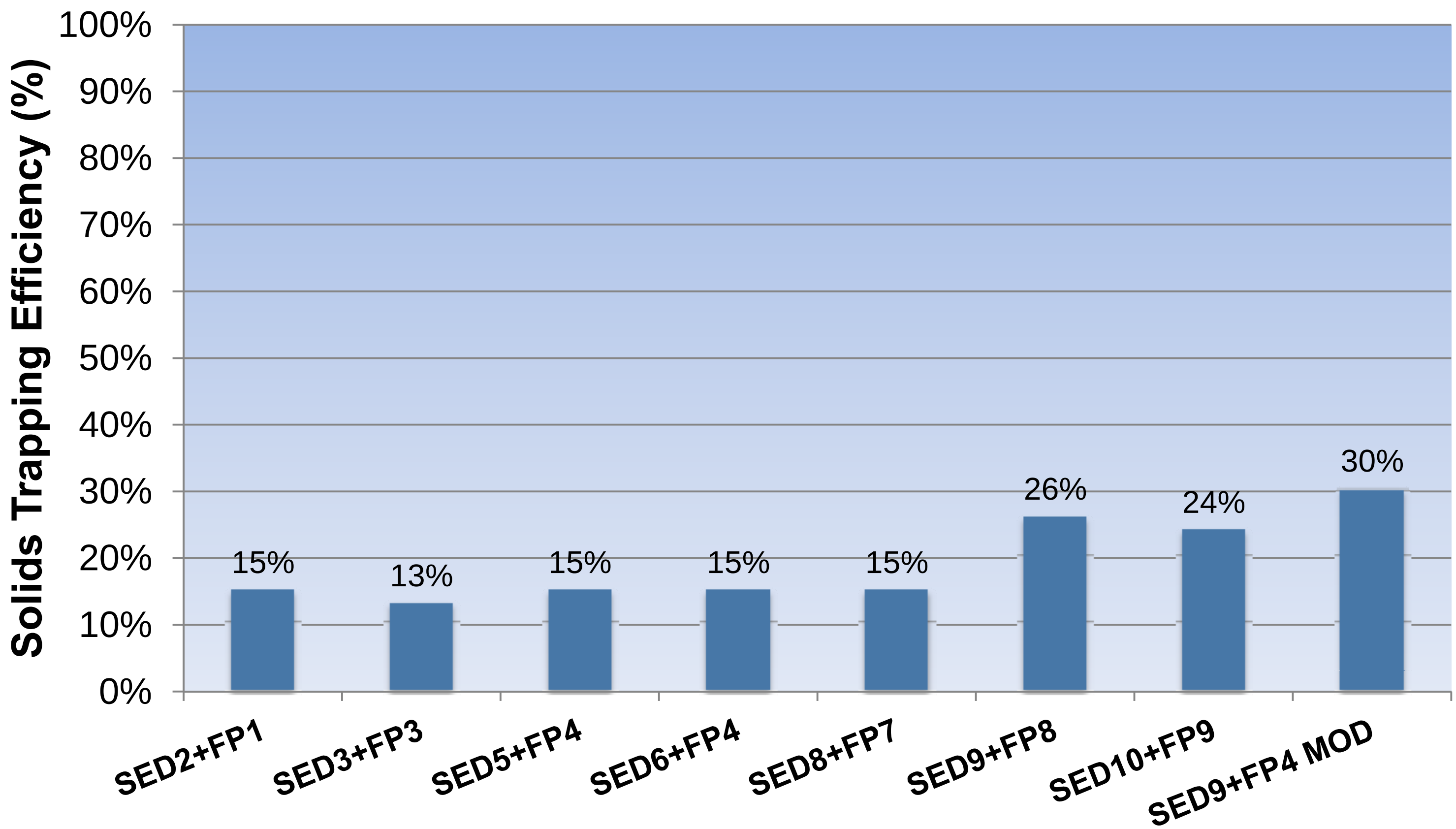


Figure 11 - Omnivorous and Carnivorous Mammals IMPG Attainment in Acres for Combination Alternatives



Trapping efficiencies for PCBs were not provided in the Corrective Measures Study Report. The PCB trapping efficiency numbers will be lower than the solids shown above.

Figure 12 - Solids Trapping Efficiency of Woods Pond for Combination Alternatives Relative to MNR (15% solids trapping efficiency)

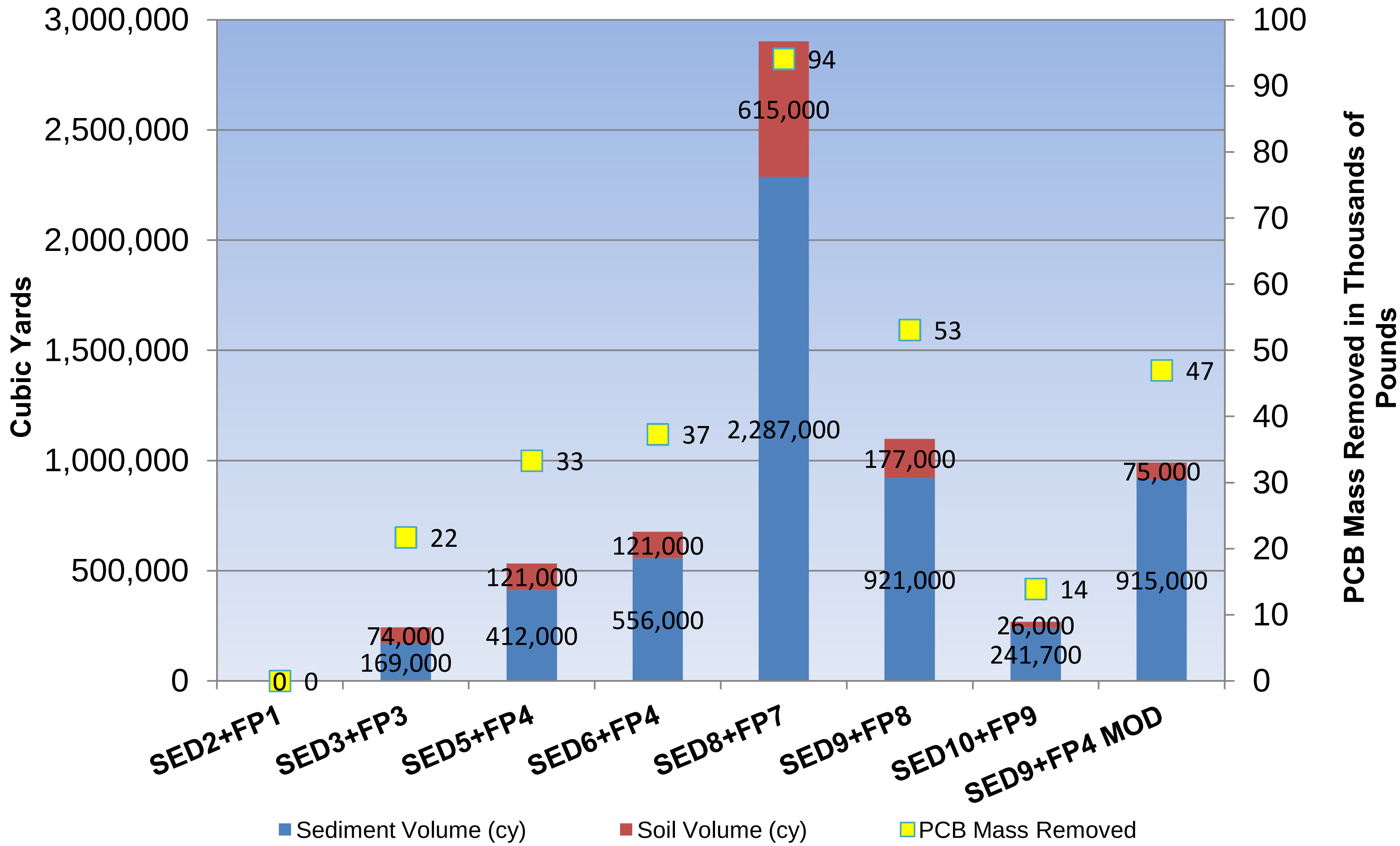
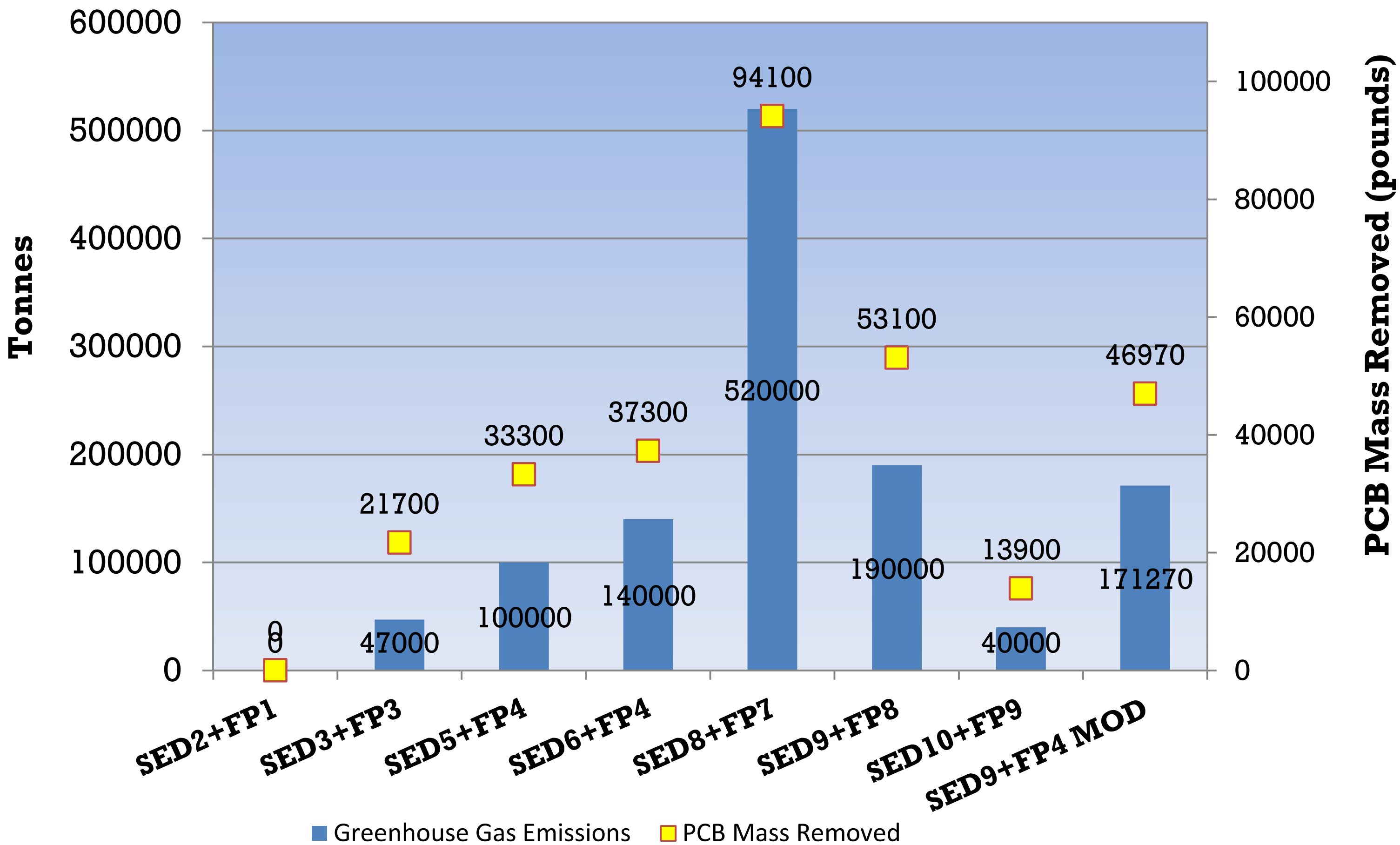
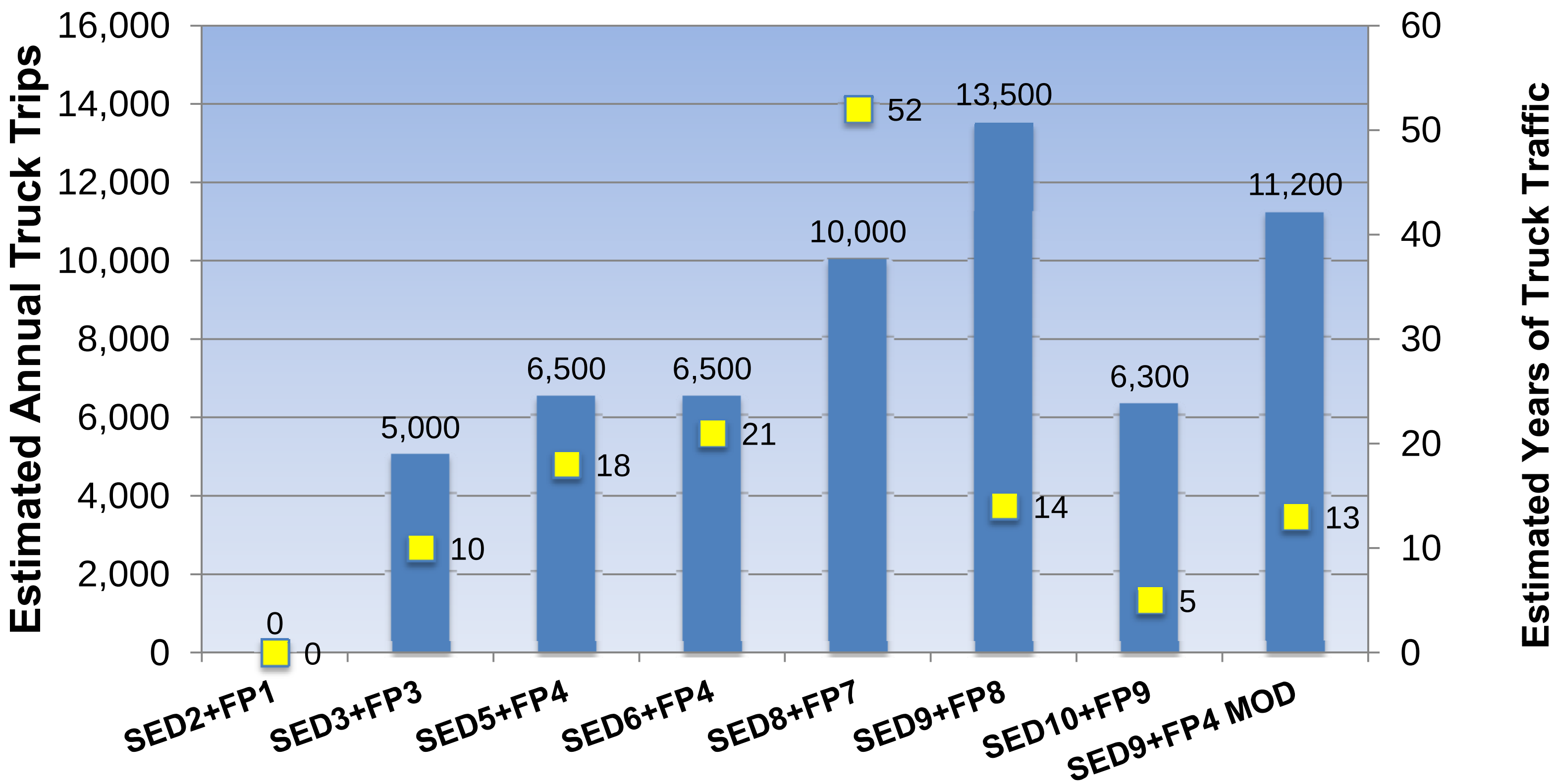


Figure 13 - Sediment and Soil Removal Volumes and PCB Mass Removed for Combination Alternatives



Estimate for SED9+FP4 MOD is based on ratios of similar alternatives.

Figure 14 - Greenhouse Gas Emissions with PCB Mass Removed for Combination Alternatives



SED9+FP4 MOD based on excavation volumes, backfill volumes, truck capacities and information presented in the Revised CMS.

Figure 15 - Estimated Annual Truck Trips and Total Years of Truck Traffic for Removal of Excavated Material and Delivery of Capping/Backfill Material for Combination Alternatives

ATTACHMENT 8
COST ASSUMPTIONS MEMORANDUM FOR SED 9/FP 4 MOD

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The Trusted Integrator for Sustainable Solutions

M E M O R A N D U M

TO: Dean Tagliaferro, U.S. Environmental Protection Agency

FROM: Tony Delano, Weston Solutions, Inc.

DATE: 15 May 2014

RE: GE-Pittsfield/Housatonic River Site – Rest of River
W.O. No. 20502.169.095.0264
SED 9/FP 4 MOD/TD 1 RR Cost Assumptions Memorandum
DCN: HR-051514-AAYP

INTRODUCTION

The purpose of this memo is to provide a cost estimate for EPA's preferred remedy, referred to as SED/FP 4 MOD and TD 1 RR. This in an update of WESTON's cost assumptions memorandum dated 7/25/12, which was included as Attachment B-10 to EPA's August 3, 2012 Regional Response to the National Remedy Review Board Comments on the Site Information Package for the GE-Pittsfield/Housatonic River Rest of River Project.

In general, costs provided by GE supporting its October 2010 Revised CMS (RCMS) were used as a baseline for all construction costs for the SED 9/FP 4 MOD portion of the alternative. Modifications to those costs, in quantities, materials, or methods, were then made to provide the best possible basis for comparison to the alternatives presented in the RCMS. In addition, adjustments have been made to adjust the October 2010 costs to present day costs (March/April 2014).[1]

Volume estimates were taken from WESTON's May 15, 2014 memorandum titled *Derivation of Removal Volumes and Removal Acreages for SED 9/FP 4 MOD*.

Table 1 summarizes the quantities assumed in the cost estimate by reach for SED 9/FP 4 MOD.

---

[1] Due to rounding, all costs may not sum correctly in this memorandum. Rounding occurs in multiple places within this document and within the backup spreadsheets. All final sums are representative of the final calculated values from the Excel cost spreadsheet model.

Table 1 – Summary of Volumes for SED 9/FP 4 MOD

Reach	River Bed Cut (feet)	Volumes (cubic yards)					Area (Acres)
		Riverbed	Riverbank	Pond/ Backwater	Floodplain	Total	
5A	2.5	168,000	25,000			193,000	42
5B	1 foot in limited areas	500	500			1,000	<<1
5C	2	186,000				186,000	57
Backwaters				95,000		95,000	59
Woods Pond				285,000		285,000	60
7	1 to 1.5			84,000		84,000	39
8	1 to 1.5			71,000		71,000	41
FP	1 or 3				75,000	75,000	45
	Totals	**354,500**	**25,500**	**535,000**	**75,000**	**990,000**	**343**

SECTION 1.0 - DEVELOPMENT OF PREFERRED REMEDY COSTING BASED UPON 2010 REVISED CMS, EXCLUDING TREATMENT/DISPOSITION COMPONENTS

This section provides the basis for the development of the assumptions for pricing based upon 2010 dollars for the preferred remedy, excluding treatment/disposition (T/D) components.

SED 9/FP 4 MOD Component

Item numbers (e.g., “1.0”) refer to item numbers in the GE detailed cost information, which is the basis for all costs presented in the CMS. In some cases, a different item number was used for the SED item and corresponding FP item for the same category of cost (e.g., dewatering). To consolidate the explanation of assumptions, these items have been combined in this section. Consistent with GE’s approach, indirect additional capital costs for project/construction management (5%), engineering and administration (5%), and contingency (5%) are calculated based upon the total of all capital costs (except operations and maintenance and long-term monitoring) and then added to the capital costs. This method was used to ensure consistency between the CMS alternatives and the preferred remedy when accounting for these soft costs.

These percentages, when viewed collectively at the 35% level, are reasonable. The percentages are within ranges typically used for projects of this nature (i.e., based on experience with similar projects at the feasibility study level or early design development) and are within the ranges cited in EPA guidance for feasibility study costing (see *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA 540-R-00-002, July 2000*).* This guidance document recommends a range for contingency of 5 to 55%, depending on the technology, but notes the range is typically 10 to 25%. For the design, management, and administrative components, EPA suggests a total of 17% (5% for Project Management, 5% for Remedial Design, and 6% for construction management), but again these are recommended ranges. Although these categories and percentages do not match GE's categories exactly, the total of 35% selected by GE compared with EPA's total recommended percentage of 42% is generally acceptable and within the overall indirect cost sample ranges provided by EPA.

One area of difference between EPA guidance and GE's method is the lack of indirect costs added to the long-term monitoring and operations and maintenance costs in GE's RCMS. For operations and maintenance (O&M) costs, EPA recommends the addition of 30% contingency, 5 to 10% for project management, and 10 to 20% for technical support. GE did not include any markup. For consistency, this memorandum uses GE's methodology; therefore, GE's estimate and the estimate in this memorandum likely underestimate total long-term monitoring and O&M costs.

SED 9/FP 4 MOD Item 1.0 Pre-Design Investigation

- For all reaches, this cost was estimated at 5% of all on-site construction-related costs for SED 9 MOD, and 10% of all on-site construction-related costs for FP 4 MOD, consistent with GE's method for estimating these costs.
- The costs for this line item are shown by reach in Table 2.

SED 9/FP 4 MOD Item 2.0 Mobilization/Demobilization

- For all reaches, this cost was estimated at 5% of all on-site construction-related costs.
- The costs for this line item are shown by reach in Table 3.

Table 2 – Pre-Design Investigation Cost

Reach	**SED 9 MOD Total**
5A	$1,850,000
5B	$120,000
5C	$3,114,000
5D	$887,000
6	$1,429,000
7	$886,000
8	$701,000
Subtotal SED 9 MOD	**$8,987,000**
FP 4	
Reach	**FP 4 MOD Total**
5A	$706,000
5B	$318,000
5C	$204,000
6	$19,000
7	$39,000
Subtotal FP 4 MOD	**$1,286,000**
Subtotal SED 9 Mod/FP 4 Mod	**$10,273,000**
Plus Project/Construction Management (5%)	$514,000
Plus Engineering and Administration (5%)	$514,000
Plus Contingency (25%)	$2,568,000
TOTAL	**$13,869,000**

Table 3 - Mobilization/Demobilization Cost

Reach	SED 9 MOD Total
5A	$1,850,000
5B	$120,000
5C	$3,114,000
5D	$887,000
6	$1,429,000
7	$886,000
8	$701,000
Subtotal SED 9 MOD	**$8,987,000**
FP 4	
Reach	**FP 4 MOD Total**
5A	$353,000
5B	$159,000
5C	$102,000
6	$10,000
7	$19,000
Subtotal FP 4 MOD	**$643,000**
Subtotal SED 9 Mod/FP 4 Mod	**$9,630,000**
Plus Project/Construction Management (5%)	$482,000
Plus Engineering and Administration (5%)	$482,000
Plus Contingency (25%)	$2,408,000
TOTAL	**$13,001,000**

SED 9/FP 4 MOD Item 3.0 Construction of Staging Areas/Access Roads

- All costs were estimated on a reach-specific basis using a unit cost of $/acre or lump-sum pricing (Reaches 5D and 6 only) based upon unit costs for GE's SED 9 and FP 8 alternatives as presented in the RCMS. These unit costs were multiplied by the estimated area of staging areas and access roads, developed to optimize staging area sizes and locations, to determine a total estimated cost.

- The costs for this line item are shown by reach in Table 4.

Table 4 – Assumptions and Costs for Item 3.0, Construction of Staging Areas/Access Roads

Reach	GE SED 9 (acres or lump sum)	GE SED 9 ($/acre or lump sum)	GE SED 9 Total	SED 9/FP 4 MOD Acres	SED 9/FP 4 MOD Total
5A	40.6	$156,158	$6,339,000	27.5	$4,290,000
5B	15.5	$194,323	$3,012,000	0.5	$100,000
5C	12.5	$231,520	$2,894,000	11	$2,520,000
5D	LS	$247,000[1]	$247,000	---	$247,000
6	LS	$496,000[1]	$496,000	---	$496,000
7	7.6	$223,816	$1,701,000	7	$1,500,000
8	3.2	$236,563	$757,000	5	$1,278,000
				Subtotal SED 9 MOD	**$10,431,000**
FP 4 MOD					
Reach	**GE FP 8 Basis (acres)**	**GE FP 8 ($/acre)**	**GE FP 8 Total**	**SED 9/FP 4 MOD Acres**	**SED 9/FP 4 MOD Total**
5A	17.6	$28,580	$503,000	6.23	$179,000
5B	9.62	$24,324	$234,000	2.45	$60,000
5C	7.59	$34,783	$264,000	1.26	$43,000
6	0.51	$13,725	$7,000	0.81	$11,000
7	0	$0	$0	0	$0
				Subtotal FP 4 MOD	**$293,000**
				Subtotal SED 9 Mod/FP 4 Mod	**$10,724,000**
				Plus Project/Construction Management (5%)	$536,000
				Plus Engineering and Administration (5%)	$536,000
				Plus Contingency (25%)	$2,681,000
				TOTAL	**$14,477,000**

<u>Notes:</u>

LS = Lump sum pricing.

Item 4.0 Sheeting – Not Used

SED 9 Item 5.0/FP 4 MOD Item 4.0 Dewatering

- Dewatering estimates by reach were based upon the number of days required to complete excavation or dredging and the unit costs determined from GE's SED 9 and FP 8 alternatives as presented in the RCMS.
- The costs for this line item are shown by reach in Table 5.

Table 5 – Assumptions and Costs for Dewatering

Reach	GE SED 9 (days)	GE SED 9 ($/day)	GE SED 9 Total	SED 9/FP 4 MOD Days	SED 9/FP 4 MOD Total
5A	536	$3,507*	$1,876,000	772	$2,710,000
5B	320	$25,534	$8,171,000	4	$100,000
5C	378	$23,294	$8,805,000	451	$10,500,000
5D	264	$4,852	$1,281,000	230	$1,110,000
6	385	$5,068	$1,951,000	450	$2,270,000
7	0	0	0	0	0
8	129	$6,341	$818,000	129	$820,000
Subtotal SED 9 MOD					**$17,510,000**
Reach	**GE FP 8 (days)**	**GE FP 8 ($/day)**	**GE FP 8 Total**	**SED 9/FP 4 MOD Days**	**SED 9/FP 4 MOD Total**
5A	342	$395	$135,000	171	$68,000
5B	150	$420	$63,000	70	$30,000
5C	176	$398	$70,000	47	$19,000
6	5	$400	$2,000	4	$1,000
7	36	$360	$13,000	10	$4,000
Subtotal FP 4 MOD					**$122,000**
Subtotal SED 9 Mod/FP 4 Mod					**$17,623,000**
Plus Project/Construction Management (5%)					$882,000
Plus Engineering and Administration (5%)					$882,000
Plus Contingency (25%)					$4,408,000
TOTAL					**$23,803,000**

*The calculated daily rate is based upon the RCMS rate for SED 9. The original cost memo date July 2012 had a rate double this amount. The rationale was that for SED 9 MOD, dewatering would not be needed 100% of the time during excavation, and would be needed only one half the time; however, on those days when dewatering was needed (for example, for areas that had to be isolated with jersey barriers), twice the dewatering equipment would be needed. Therefore, a daily rate twice that in the RCMS was used for a duration one half the number of days anticipated for the overall task. It was, therefore, concluded that using the GE SED 9 rate as is was acceptable for use in SED 9 MOD for the full duration of the task.

SED 9 Item 6.0/FP 4 MOD Item 5.0 Water Treatment

- Water treatment estimates were based upon the number of days required to complete excavation or dredging and the unit rate determined from GE's SED 9 alternative as presented in the RCMS.
- No water treatment costs were included for the FP 4 portion of the alternative based on the assumption in the RCMS for GE's FP 8 that there would be no water treatment costs.
- The costs for this line item are shown by reach in Table 6.

Table 6 – Assumptions and Costs for Water Treatment

Reach	GE SED 9 (Days)	GE SED 9 ($/day)	GE SED 9 Total	SED 9/FP 4 MOD Days	SED 9/FP 4 MOD Total
5A	536	$10,709	$2,875,000	386	$4,130,000
5B	320	$2003	$641,000	4	$10,000
5C	378	$32,373	$12,237,000	451	$14,597,000
5D	264	$2,674	$706,000	230	$615,000
6	385	$3,062	$1,179,000	450	$1,378,000
7	305	$2,669	$814,000	305	$814,000
8	129	$2,658	$345,000	129	$345,000
				Subtotal SED 9 MOD	**$21,889,000**
				Plus Project/Construction Management (5%)	$1,094,000
				Plus Engineering and Administration (5%)	$1,094,000
				Plus Contingency (25%)	$5,472,000
				TOTAL	**$29,550,000**

SED 9 Item 7.0 Debris Removal

- Debris removal estimates were based upon the number of acres requiring remediation and the unit rate determined from GE's SED 9 total costs for debris removal and the number of acres as presented in the RCMS.
- The costs for this line item are shown by reach in Table 7.
- There are no debris removal costs for the floodplain alternatives.

Table 7 – Assumptions and Costs for Debris Removal

Reach	GE SED 9 (Acres)	GE SED 9 ($/Acre)	GE SED 9 Total	SED 9/FP 4 MOD Acres	SED 9/FP 4 MOD Total
5A	42	$3,500	$147,000	42	$147,000
5B	27	$7,074	$191,000	1	$7,000
5C	57	$7,000	$399,000	57	$399,000
5D	68	$7,000	$476,000	59	$413,000
6	60	$7,000	$420,000	60	$420,000
7	38	$3,474	$132,000	38	$132,000
8	41	$7,073	$290,000	41	$290,000
				Subtotal SED 9 MOD	**$1,808,000**
				Plus Project/Construction Management (5%)	$90,000
				Plus Engineering and Administration (5%)	$90,000
				Plus Contingency (25%)	$452,000
				TOTAL	**$2,441,000**

SED 9 Item 8.0/FP 4 MOD Item 6.0 Excavation

- Excavation cost estimates were based upon the number of cubic yards of material requiring remediation and the unit rate determined from GE's SED 9 and FP 8 total costs for excavation and the number of cubic yards (CY) as presented in the RCMS.
- Because the volume of floodplain excavation has not been defined by reach for FP 4 MOD, the proportions of material to be excavated within each reach were estimated by using GE's FP 4 as an approximation. The percentage of the total volume in each reach for FP 4 was applied to the total volume of 75,000 CY for FP 4 MOD to develop reach-specific volume estimates.
- The costs for this line item are shown by reach in Table 8.

Table 8 – Assumptions and Costs for Excavation

Reach	GE SED 9 (CY)	GE SED 9 ($/CY)	GE SED 9 Total	SED 9 MOD CY	SED 9 MOD Total
5A	159,000	$34	$5,414,000	193,000	$6,600,000
5B	98,000	$120	$11,745,000	1,000	$120,000
5C	156,000	$83	$12,899,000	186,000	$15,370,000
5D	109,000	$65	$7,091,000	95,000	$6,180,000
6	244,000	$45	$10,939,000	285,000	$12,770,000
7	84,000	$73	$6,112,000	84,000	$6,110,000
8	71,000	$63	$4,499,000	71,000	$4,500,000
				Subtotal SED 9 MOD	**$51,650,000**
Reach	**GE FP 8 (CY)**	**GE FP 8 ($/CY)**	**GE FP 8 Total**	**FP 4 MOD CY**	**FP 4 MOD Total**
5A	85,500	$58	$4,973,000	42,500	$2,474,000
5B	37,500	$62	$2,318,000	17,400	$1,074,000
5C	43,800	$59	$2,576,000	11,600	$682,000
6	1,202	$72	$86,000	972	$70,000
7	9,039	$53	$475,000	2,519	$133,000
				Subtotal FP 4 MOD	**$4,433,000**
				Subtotal SED 9 Mod/FP 4 Mod	**$51,650,000**
				Plus Project/Construction Management (5%)	$2,804,000
				Plus Engineering and Administration (5%)	$2,804,000
				Plus Contingency (25%)	$14,021,000
				TOTAL	**$75,712,000**

SED 9 Item 9.0/FP 4 MOD Item 7.0 Backfill Material Placement

- Backfill material placement estimates were based upon the number of cubic yards of backfill material requiring placement and the unit rate determined from GE's SED 9 total costs for backfill and the number of cubic yards as presented in the RCMS.
- Where a habitat layer is specified as part of the backfill cross section, a premium of $1 was added to the $/CY estimated price to account for additional costs associated with meeting the specification of the grain sizes required for the habitat layer[2]. The habitat layer is included in Reaches 5A, 5B, 5C, 5D, and 6.
- For Reach 5B, a layer of activated carbon was assumed to be broadcast over the entire surface of the riverbed. It was assumed that the activated carbon cost is $1.50/lb and would be placed at a rate of 30,000 pounds per acre over the 27 acres of Reach 5B. This amount is equivalent to 1,200 CY of activated carbon at a density of 675 pounds per cubic yard. Because this item was not included in GE's estimates, a new method of installation for this material had to be developed. A vortex spreader would be used from a boat, with support on land for handling the activated carbon. Estimated productivity for this operation is 1 acre per week, with a total of 27 acres requiring coverage. The work crew is assumed to consist of seven workers with three on the boat, two hauling material, and two managing the stockpile of activated carbon. Application of the activated carbon in this manner would require approximately 27 weeks to complete. Using this assumed method, the total estimated cost is $1,769,000, resulting in a unit rate of $1,474 per cubic yard of activated carbon placed.
- The costs for this line item are shown by reach in Table 9.

[2] The grain size distribution has not yet been specified. The actual cost of the material will depend ultimately upon the specifications and the availability of this material as a supplied product or as a special order product.

Table 9 – Assumptions and Costs for Backfill Material Placement

Reach	GE SED 9 (CY)	GE SED 9 ($/CY)	GE SED 9 Total	SED 9/FP 4 MOD CY	SED 9 MOD ($/CY)	SED 9/FP 4 MOD Total
5A	134,000	$63.88	$8,563,000	193,000	$64.88	$12,520,000
5B	88,000	$94	$8,265,000	1,000	$95	$95,000[a]
5B (activated carbon only)[b]				1,200	$1,474	$1,769,000
5C	156,000	$89	$13,960,000	186,000	$90	$16,830,000
5D	114,000	$84	$9,537,000	95,000	$85	$8,100,000
6	96,800	$102	$9,832,000	96,800	$103	$9,930,000
7	83,800	$90	$7,581,000	83,800	$90	$7,580,000
8	71,700	$84	$5,956,000	71,700	$84	$5,950,000
					Subtotal SED 9 MOD	**$62,770,000**
Reach	**GE FP 8 (CY)**	**GE FP 8 ($/CY)**	**GE FP 8 Total**	**FP 4 MOD CY**	**FP 4 MOD Total**	
5A	85,500	$53	$4,506,000	42,500	$2,242,000	
5B	37,500	$55	$2,049,000	17,400	$949,000	
5C	43,800	$53	$2,339,000	11,600	$620,000	
6	1,202	$70	$84,000	972	$68,000	
7	9,039	$51	$462,000	2,519	$128,000	
				Subtotal FP 4 MOD	**$4,007,000**	
				Subtotal SED 9 Mod/FP 4 Mod	**$62,777,000**	
				Plus Project/Construction Management (5%)	$3,339,000	
				Plus Engineering and Administration (5%)	$3,339,000	
				Plus Contingency (25%)	$16,294,000	
				TOTAL	**$90,149,000**	

[a] Standard riverbed backfill material per preferred remedy, which includes a habitat layer.
[b] Assumes 27 acres of riverbed in Reach 5B would be treated with activated carbon at a rate of 30,000 lb/acre.

SED 9/FP 4 MOD Item 10.0 Bank Stabilization

Reach 5A

- Unit rates for bank stabilization presented in the RCMS were used to develop a generic cost per linear foot of riverbank for SED 9/FP 4 MOD. In terms of estimating cost, it was assumed that Reach 5A bank stabilization would consist of 32% bioengineering and 1% riprap, with the remaining 67% having no action taken. These assumptions yield a unit rate of $144.53 per linear foot for an assumed 33% of the riverbanks, or approximately 17,424 feet (ft) (3.3 miles). Based on these unit rates and assumptions, the total cost for riverbank stabilization is $2,520,000.

Reach 5B

- Bank stabilization was assumed to be required to restore the area of bank where 500 CY of material is proposed to be removed as part of SED 9/FP 4 MOD. To estimate a cost for this restoration, the unit rate for stabilization in Reach 5A was converted to a per square foot basis by assuming the average width of bank stabilization is 10 ft, yielding a unit rate of $13/square foot (sq ft). This was then applied to the area required to excavate 500 CY of material at an excavation depth of 2 ft, which is approximately 6,750 sq ft, resulting in a bank stabilization cost of $90,000.
- The costs for bank stabilization are shown by reach in Table 10.

Table 10 - Assumptions and Costs for Bank Stabilization

Reach	SED 9 MOD Total
5A	$2,520,000
5B	$90,000
Subtotal SED 9 MOD	**$2,610,000**
Plus Project/Construction Management (5%)	$131,000
Plus Engineering and Administration (5%)	$131,000
Plus Contingency (25%)	$653,000
TOTAL	**$3,524,000**

SED 9 Item 11.0/FP 4 MOD Item 8.0 Site Restoration

- Site restoration estimates were based on the number of acres requiring restoration and the unit rate as determined from GE's SED 9 total costs for site restoration and the number of acres restored as presented in the RCMS.
- Determination of the unit rate for site restoration assumes a certain proportion of the following types of habitats: forested wetland habitat, shrub and shallow emergent habitat, backwater and deep emergent marsh, vernal pool, grassy upland, forested upland. Each of these habitats has a different restoration cost per acre. The blended rate used in the RCMS is applicable to the mix of habitats determined by GE for FP 8. The actual mix of habitats is unknown because both the road and staging area network and the removal areas for the floodplains are currently unknown. Therefore, the costs shown in Table 11 are also based on the assumption that the proportions of the various habitat types for FP 4 MOD are the same as determined by GE for FP 8 in the RCMS.
- The cost by reach for site restoration is shown in Table 11.

Table 11 – Assumptions and Costs for Site Restoration

Reach	GE SED 9 (Acres)	GE SED 9 ($/Acre)	GE SED 9 Total	SED 9/FP 4 MOD Acres	SED 9/FP 4 MOD Total
5A	34.74	$32,326	$1,120,000	33.7	$1,090,000
5B	19.46	$31,449	$612,000	1	$30,000
5C	16.48	$35,133	$579,000	13.2	$463,000
5D	0	0	0	0	0
6	0	0	0	0	0
7	7.43	$29,610	$220,000	7	$208,000
8	5.44	$29,596	$161,000	5.4	$160,000
Subtotal SED 9 MOD					**$1,951,000**
Reach	**GE FP 8 (Acres)**	**GE FP 8 ($/Acre)**	**GE FP 8 Total**	**FP 4 MOD Acres**	**FP 4 MOD Total**
5A	52.0	$37,858	$1,969,000	32.6	$1,233,000
5B	22.9	$42,582	$973,000	16.1	$685,000
5C	26.6	$38,924	$1,035,000	11.3	$441,000
6	0.71	$40,845	$29,000	0.12	$5,000
7	5.6	$27,143	$152,000	2.8	$76,000
Subtotal FP 4 MOD					**$2,440,000**
Subtotal SED 9 Mod/FP 4 Mod					**$4,391,000**
Plus Project/Construction Management (5%)					$220,000
Plus Engineering and Administration (5%)					$220,000
Plus Contingency (25%)					$1,098,000
TOTAL					**$5,928,000**

SED 9 Item 12.0/FP 4 MOD Item 9.0 Transportation and Disposal for Staging Area and Access Road Materials (T/D costs for floodplain soil and sediment are discussed in Sections 2.0 and 4.0 below)

- Transportation and disposal costs as determined in this section are related to the disposal of staging area materials, which are assumed to be non-Toxic Substances Control Act (TSCA) materials, and are directly related to the size of the total area of staging areas and access roads. Unit rates are, therefore, based upon the GE's SED 9 total costs as presented in the RCMS for site restoration and the number of acres restored. (The actual size of staging and access roads will be optimized during remedial design consistent with EPA's objective of reducing remediation-related impacts.)
- No additional costs were included for FP 4 MOD, except for Reach 5B, because all roads and staging areas would be removed under the SED portion of this alternative, except Reach 5B, which involves very little sediment removal.
- The cost added for FP 4 in Reach 5B is $471,000, based upon a unit rate of $192,000 per acre for approximately 2.5 acres of roads and staging areas.
- The costs for transportation and disposal of staging area materials are shown by reach in Table 12.

Table 12 – Assumptions and Costs for Transportation and Disposal of Staging Area and Access Road Materials

Reach	GE SED 9 (Acres)	GE SED 9 ($/Acre)*	GE SED 9 Total	SED 9/FP 4 MOD Acres	SED 9/FP 4 MOD Total
5A	34.74	$304,499	$14,888,000	33.7	$10,260,000
5B	19.46	$192,240	$3,741,000	1	$190,000
5C	16.48	$414,684	$6,834,000	13.2	$5,470,000
5D	0	0	0	0	0
6	0	0	0	0	0
7	7.43	$298,789	$2,220,000	7	$2,100,000
8	5.44	$320,404	$1,743,000	5.4	$1,730,000
				Subtotal SED 9 MOD	**$19,750,000**
Reach	**GE FP 8 (Acres)**	**GE FP 8 ($/Acre)**	**GE FP 8 Total**	**FP 4 MOD Acres**	**FP 4 MOD Total**
5B	3.72	$192,000	$696,000	2.45	$471,000
				Subtotal FP 4 MOD	**$471,000**
				Plus Project/Construction Management (5%)	$1,011,000
				Plus Engineering and Administration (5%)	$1,011,000
				Plus Contingency (25%)	$5,055,000
				TOTAL	**$27,298,000**

* Although these costs are determined using a cost per acre unit price, the cost of transportation and disposal is a significant cost of this item. All material was assumed to be non-TSCA and was priced at the rate of $56 for transportation via trucking and $44 for disposal. The total price for T&D via rail would be $98 (based upon 2010/2011 pricing), or $2 less per ton, resulting in a slightly lower overall cost.

SED 9 Item 13.0/FP 4 MOD Item 10.0 Topographic Surveys

- GE originally based surveying costs upon the number of months to complete remediation of a reach or a lump-sum cost per survey. Unit rates were, therefore, based on the duration of SED 9 or the number of surveys required for SED 9, as specified in GE's RCMS. SED 9 MOD costs were based on the same units, whether duration or lump sum.
- The duration for Reach 5B was adjusted downward for SED 9/FP 4 MOD to reflect the limited excavation and backfill work proposed.
- For FP 4 MOD costs, surveying costs were based upon the duration of construction.
- The costs for topographic surveys are shown by reach in Table 13.

Table 13 – Assumptions and Costs for Topographic Surveys

Reach	GE SED 9 (duration or surveys)	GE SED 9 ($/month or each)	GE SED 9 Total	SED 9/FP 4 MOD (duration or surveys)	SED 9/FP 4 MOD Total
5A	34 months	$28,163/month	$958,000	42 months	$1,190,000
5B	2 each	$35,000 each	$70,000	2 each @ $5,000	$10,000
5C	2 each	$35,000 each	$70,000	2 each	$70,000
5D	2 each	$35,000 each	$70,000	2 each	$70,000
6	2 each	$35,000 each	$70,000	2 each	$70,000
7	2 each	$35,000 each	$70,000	2 each	$70,000
8	2 each	$35,000 each	$70,000	2 each	$70,000
				Subtotal SED 9 MOD	**$1,550,000**
Reach	**GE FP 8 (Months)**	**GE FP 8 ($/Month)**	**GE FP 8 Total**	**FP 4 MOD Months**	**FP 4 MOD Total**
5A	31	$28,065	$870,000	15	$433,000
5B	15	$27,067	$406,000	7	$188,000
5C	16	$28,438	$455,000	4	$120,000
6	0.41	$31,342	$13,000	0.34	$11,000
7	2.9	$28,651	$84,000	0.82	$23,000
				Subtotal FP 4 MOD	**$775,000**
				Subtotal SED 9 Mod/FP 4 Mod	**$2,325,000**
				Plus Project/Construction Management (5%)	$116,000
				Plus Engineering and Administration (5%)	$116,000
				Plus Contingency (25%)	$581,000
				TOTAL	**$3,139,000**

SED 9 Item 14.0/FP 4 MOD Item 11.0 Environmental Monitoring

- In the RCMS, environmental monitoring costs were based upon the number of months to complete remediation of a reach. The SED 9 MOD unit rates were, therefore, based upon the GE SED 9 duration as presented in the RCMS.
- For SED 9 MOD, the duration for Reach 5B was adjusted downward to reflect the limited excavation and backfill work proposed.
- The cost for environmental monitoring is shown by reach in Table 14.

Table 14 – Assumptions and Costs for Environmental Monitoring

Reach	GE SED 9 (months)	GE SED 9 ($/month)	GE SED 9 Total	SED 9/FP 4 MOD (months)	SED 9/FP 4 MOD Total
5A	34	$41,336	$1,405,000	42	$1,740,000
5B	24	$42,696	$1,025,000	1	$40,000
5C	28	$42,731	$1,196,000	36	$1,538,000
5D	28	$41,786	$1,170,000	24	$984,000
6	28	$41,518	$1,163,000	30	$1,264,000
7	31	$42,16 0	$1,307,000	31	$1,307,000
8	13	$46,154	$600,000	13	$600,000
				Subtotal SED 9 MOD	**$7,473,000**
Reach	**GE FP 8 (Months)**	**GE FP 8 ($/Month)**	**GE FP 8 Total**	**FP 4 MOD Months**	**FP 4 MOD Total**
5A	31	$27,806	$862,000	15	$429,000
5B	15	$27,267	$409,000	7	$189,000
5C	16	$28,000	$448,000	4	$119,000
6	0.41	$45,894	$19,000	0.34	$16,000
7	3	$27667	$83,000	0.8	$23,000
				Subtotal FP 4 MOD	**$776,000**
				Subtotal SED 9 Mod/FP 4 Mod	**$8,249,000**
				Plus Project/Construction Management (5%)	$412,000
				Plus Engineering and Administration (5%)	$412,000
				Plus Contingency (25%)	$2,062,000
				TOTAL	**$11,136,000**

SED 9 Item 15.0 Annual O&M/Monitored Natural Recovery/Long-Term Monitoring Program; Item 12.0 FP 4 MOD Annual O&M

- For SED 9, no changes were made to GE's assumptions and costs are, therefore, identical.
- For FP 4 MOD, GE's FP 8 costs as presented in the RCMS were prorated by the total estimated restoration area. As was the case in the RCMS, annual O&M was assumed to continue for 5 years following the completion of construction.
- No changes were made to the reach-wide Long-Term Monitoring Program, which includes fish, water column, and visual monitoring, sediment monitoring, and institutional controls and environmental restrictions and easements (EREs).
- The costs for this line item are shown by reach in Table 15.

Table 15 – Assumptions and Costs for Annual O&M and Long-Term Monitoring

Reach	GE SED 9 (years)	GE SED 9 ($/year)	GE SED 9 Total	SED 9 MOD (years)	SED 9 MOD ($/year)	SED 9 MOD Total
5A	5	$375,000	$1,875,000	5	$375,000	$1,875,000
5B	5	$30,000	$30,000	5	$30,000	$150,000
5C	5	$30,000	$30,000	5	$30,000	$150,000
5D	0	$0	$0	0	$0	$0
6	0	$0	$0	0	$0	$0
7	0	$0	$0	0	$0	$0
8	5	$15,000	$75,000	5	$15,000	$75,000
Subtotal SED 9 MOD						**$2,250,000**
Reach	**GE FP8 (Acres)**	**GE FP8 ($/Year)**	**GE FP8 Total**	**FP 4 MOD Acres**	**FP 4 MOD ($/Year)**	**FP 4 MOD Total**
5A	52	$177,000	$885,000	33	$111,000	$555,000
5B	23	$78,000	$390,000	16	$55,000	$275,000
5C	27	$92,000	$460,000	11	$39,000	$195,000
6	0.71	$15,000	$75,000	0.12	$3,000	$15,000
7	5.6	$20,000	$100,000	2.8	$10,000	$50,000
Subtotal FP 4 MOD						**$1,090,000**
Subtotal SED 9 Mod/FP 4 Mod						**$3,340,000**
Long Term Monitoring						$8,733,000
TOTAL						**$12,073,000**

Summary Cost Tables for the Preferred Remedy (Excluding T/D)

The following tables summarize the cost information provided in Tables 2 through 15. Table 16 provides a summary that includes a cost for all reaches for each cost category, for both the sediment and floodplain portions of the preferred remedy, the costs for project management, administration, engineering, and contingency (fixed percentages), long-term operations, maintenance, and monitoring, and totals.

Table 17 then provides a single cost number by reach for all cost categories, applies the fixed percentages, and includes the long-term monitoring and maintenance cost to arrive at a total alternative cost.

Table 16 – Summary of SED 9/FP 4 MOD by Cost Item

Cost Component	SED 9 MOD	FP 4 MOD	Subtotal	Management Engineering Contingency[a]	Subtotal	Annual O&M	Long Term Monitoring	TOTAL
Pre-Design Investigation[b]	$8,986,000	$1,296,000	$10,282,000	$3,599,000	$13,881,000	$ -	$ -	$13,881,000
Mobilization/Demobilization[c]	$ 8,986,000	$648,000	$9,634,000	$3,372,000	$13,006,000	$ -	$ -	$13,006,000
Construction of Staging Areas/Access Roads	$10,431,000	$392,000	$10,823,000	$3,788,000	$14,611,000	$ -	$ -	$14,611,000
Sheeting	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Dewatering	$17,510,000	$122,000	$17,632,000	$6,171,000	$23,803,000	$ -	$ -	$23,803,000
Water Treatment	$21,889,000	$ -	$21,889,000	$7,661,000	$29,550,000	$ -	$ -	$29,550,000
Debris Removal	$1,808,000	$ -	$1,808,000	$ 633,000	$2,441,000	$ -	$ -	$2,441,000
Excavation	$51,650,000	$4,433,000	$56,083,000	$19,629,000	$75,712,000	$ -	$ -	$75,712,000
Backfill Material Placement	$62,770,000	$4,007,000	$66,777,000	$23,372,000	$90,149,000	$ -	$ -	$90,149,000
Bank Stabilization	$2,610,000	$ -	$2,610,000	$914,000	$3,524,000	$ -	$ -	$3,524,000
Site Restoration	$1,951,000	$2,440,000	$4,391,000	$1,537,000	$5,928,000	$ -	$ -	$5,928,000
Transport and Disposal (Staging/Access)	$19,750,000	$471,000	$20,221,000	$7,077,000	$27,298,000	$ -	$ -	$27,298,000
Topographic Surveys	$1,550,000	$775,000	$2,325,000	$814,000	$3,139,000	$ -	$ -	$3,139,000
Environmental Monitoring	$7,473,000	$776,000	$8,249,000	$2,887,000	$11,136,000	$ -	$ -	$11,136,000
SUBTOTAL	$217,364,000	$15,360,000	$232,724,000	$81,454,000	$314,178,000	$ -	$ -	$314,178,000
Annual O&M[d]	$2,250,000	$1,090,000	$3,340,000	$ -	$3,340,000	$3,340,000	$ -	$3,340,000
LTM	$ -	$ -	$ -	$ -	$ -	$ -	$8,733,000	$8,733,000
Annual O&M and LTM SUBTOTAL	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$12,073,000
TOTAL	**$219,614,000**	**$16,450,000**	**$236,064,000**	**$81,454,000**	**$317,518,000**	**$3,340,000**	**$8,733,000**	**$326,000,000**

[a]This cost item includes 5% for Project/Construction Management, 5% for Administration and Engineering, and 25% for Contingency. These percentages are calculated based on the subtotal of capital costs and are not applied based on Annual O&M and LTM costs.
[b]Pre-Design costs are 5% of all construction costs for sediment alternatives, and 10% of all construction costs for floodplain alternatives, per RCMS procedures.
[c]Mobilization/demobilization costs are 5% of all construction costs for both sediment and floodplain alternatives.
[d]In the RCMS, Project and Construction Management (5%), Engineering and Administration (5%), and Contingency (25%), are added to all costs except for Annual Operations and Maintenance and Long-Term Monitoring. This method was replicated for the Preferred Alternative.

Summary of Overall Costs for SED 9/FP 4 MOD in 2010 Dollars (Excluding T/D)

Table 17 summarizes the cost by reach for SED 9/FP 4 MOD.

Table 17 – Summary of Cost by Reach for SED 9/ FP 4 MOD

Cost Item	Total Costs
Reach 5	$161,874,000
Reach 6 - Woods Pond	$31,667,000
Reach 7	$22,038,000
Reach 8 - Rising Pond	$17,145,000
Subtotal Capital Costs (excluding T/D)	**$232,724,000**
Plus Project/Construction Management (5%)	$11,636,000
Plus Engineering and Administration (5%)	$11,636,000
Plus Contingency (25%)	$58,181,000
Total Capital Costs	**$314,000,000**
Operations and Maintenance	$3,340,000
Long-Term Monitoring*	$8,733,000
Total Operation and Maintenance and LTM	**$12,000,000**
Total Cost of Alternative before T/D	**$326,000,000**
Present Worth	**$228,000,000**

*Includes the costs of institutional controls and EREs, as well as reach-wide environmental monitoring activities.

SECTION 2.0 - DEVELOPMENT OF PRICING FOR THE VARIOUS TREATMENT/DISPOSITION (T/D) COMPONENTS WITH THE PREFERRED REMEDY

The RCMS provides only the low estimate and high estimate for the SED/FP combination alternatives with each of the T/D options. With the exception of TD 1, which can be easily estimated for the SED 9/FP 4 MOD preferred remedy, estimates for the preferred remedy combined with each of the other TD options were developed using graphical and interpolative methods. Other methods are possible but relatively time consuming and costly to implement with a relatively small improvement in accuracy. For purposes of this comparison, the graphical/interpolative methods were used.

As discussed below in Section 4.0, EPA developed an estimate for transportation and disposal for TD 1 via rail transport in the 2010/2011 timeframe, as opposed to trucking, which was developed by GE for TD 1. This option is included as TD 1 RR.

Preferred Remedy with TD 1 via Trucking (2010 Pricing)

Table 18 provides backup information for the calculation of the preferred remedy volume combined with TD 1 via trucking for disposal using the 2010 RCMS pricing[3]. The transportation and off-site disposal rates via trucking in the RCMS are $220 per ton for TSCA material ($130 per ton for transport and $90 per ton for disposal) and $100 per ton for non-TSCA material ($56 per ton for trucking and $44 per ton for disposal).

Preferred Remedy with TD 1 RR (off-site disposal via rail, 2010/2011 Pricing)

Table 19 provides backup information for the calculation of the preferred remedy volume combined with TD 1 via rail transport for off-site disposal using pricing developed in the 2010/2011 timeframe by EPA. The rates for disposal via rail transport included $195 per ton for TSCA material ($110 per ton rail transport and $85 per ton for disposal) and $98 per ton for non-TSCA material ($43 per ton for rail transport and $55 per ton for disposal). Additionally, $300,000 in rail spur installation was assumed to be needed to provide the infrastructure on-site to load rail cars.

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[3] The pricing is the same in the 2008 CMS and 2010 revised CMS. GE did not make any changes to this aspect of pricing when preparing the revised CMS. In addition, disposal facilities were not identified in either CMS.

Table 18 – Costs for Preferred Remedy Combined with TD 1 via Trucking

Description	Units	Quantity	Unit Price	Total Cost
TRANSPORTATION AND DISPOSAL				
Transportation TSCA	Ton	557,324	$130.00	$72,452,000
Transportation Non-TSCA	Ton	1,046,476	$56.00	$58,603,000
Disposal TSCA	Ton	557,324	$90.00	$50,159,000
Disposal Non-TSCA	Ton	1,046,476	$44.00	$46,045,000
Waste Characterization Sampling	500 CY	2,138	$500.00	$1,069,000
			Subtotal	**$228,328,000**
Project/Construction Management (5%)				$11,416,000
Engineering and Administration (5%)				$11,416,000
Contingency (25%)				$57,082,000
TOTAL COST OF ALTERNATIVE (ROUNDED)				**$308,000,000**
Total Present-Worth				**$196,000,000**

Notes:

1. Quantity is based upon a total volume of 990,000 CY with an overall density factor of 1.62 tons per CY. This density accounts for the addition of Portland to cement in varying ratios, which is generally 15% in SED alternatives and 10% in floodplain alternatives.
2. The fraction of TSCA material has been assumed to be 34.75%. The fraction of non-TSCA material is assumed to be 65.25%.
3. The MA hazardous waste transport fee is not included in these estimates. The fee would potentially apply to TSCA material hauled by truck from the site. The fee is current $56.25/ton, including a vehicle identification fee. For SED 9/FP 4 MOD, the total fee is estimated to be $31,349,000.
4. Pricing reflects information provided in the October 2010 CMS price for TSCA and non-TSCA disposal via trucking.
5. Potential disposal facilities are not identified in the CMS.

Table 19 – Costs for Preferred Remedy Combined with TD 1 via Rail Transport

Description	Units	Quantity	Unit Price	Total Cost
TRANSPORTATION AND DISPOSAL				
Transportation TSCA	Ton	557,324	$110.09	$61,357,000
Transportation Non-TSCA	Ton	1,046,476	$43.00	$44,998,000
Disposal TSCA	Ton	557,324	$85.00	$47,373,000
Disposal Non-TSCA	Ton	1,046,476	$55.00	$57,556,000
Waste Characterization Sampling	500 CY	2,138	$500.00	$1,069,000
Rail Spurs	LS	1	$300,000	$300,000
			Subtotal	**$212,653,000**
Project/Construction Management (5%)				$10,633,000
Engineering and Administration (5%)				$10,633,000
Contingency (25%)				$53,163,000
TOTAL COST OF ALTERNATIVE (ROUNDED)				**$287,000,000**
Total Present-Worth				**$183,000,000**

Notes:

1. Quantity is based upon a total volume of 990,000 CY with an overall density factor of 1.62 tons per CY. This density accounts for the addition of Portland to cement in varying ratios, which is generally 15% in SED alternatives and 10% in floodplain alternatives.
2. The fraction of TSCA material has been assumed to be 34.75%. The fraction of non-TSCA material is assumed to be 65.25%.
3. The MA hazardous waste transport fee is not included in these estimates since it does not apply to material transported via rail.
4. Pricing reflects information obtained in early 2011 as part of EPA's development of the preferred remedy.
5. Potential disposal facilities include EQ in Michigan for TSCA waste and Republic Services in Niagara Falls, NY.

Preferred Remedy with TD 2 (On-Site Confined Disposal Facility) for Disposal Method

Table 20 summarizes the data points used to develop total and present worth costs for SED 9 MOD/FP 4 MOD coupled with TD 2, disposal in an on-site confined disposal facility (CDF). The costs were developed using a best fit graphical method.

Table 20 - Costs for Preferred Remedy Combined with TD 2

TD 2	Source	Cubic Yards	TD 2 Total Cost	TD 2 Total Present Worth
SED 6/FP 2	CMS	191,000	$100,300,000	$46,000,000
SED 9/FP 4 MOD	Interpolated	990,000	$317,200,000	$85,000,000
SED 8/FP 7	CMS	2,918,000	$510,000,000	$131,000,000

Preferred Remedy with TD 3 (Local Upland Disposal Facility) for Disposal Method

Table 21 summarizes the data points used to develop total and present worth costs for SED 9 MOD/FP 4 MOD coupled with TD 3, disposition in a local upland disposal facility(ies). The costs were developed using a best fit graphical method.

Table 21 - Costs for Preferred Remedy Combined with TD 3

TD 3	Source	Cubic Yards	TD 3 Total Cost	TD 3 Total Present Worth
SED 6/FP 2	CMS	191,000	$35,500,000	$17,000,000
SED 9/FP 4 MOD	Interpolated	990,000	$100,000,000	$33,000,000
SED 8/FP 7	CMS	2,918,000	$201,000,000	$49,000,000

Preferred Remedy with TD 4 (Chemical Extraction) for Disposal Method

Table 22 summarizes the data points used to develop total and present worth costs for SED 9 MOD/FP 4 MOD coupled with TD 4, chemical extraction of PCBs. The costs were developed using a best fit graphical method.

Table 22 - Costs for Preferred Remedy Combined with TD 4

TD 4	Source	Cubic Yards	TD 4 Total Cost	TD 4 Total Present Worth
SED 6/FP 2	CMS	191,000	$89,100,000	$70,000,000
SED 9/FP 4 MOD	Interpolated	990,000	$399,000,000	$170,000,000
SED 8/FP 7	CMS	2,918,000	$999,000,000	$286,000,000

<u>Preferred Remedy with TD 5 (Thermal Desorption, with Reuse) for Disposal Method</u>

Table 23 summarizes the data points used to develop total and present worth costs for SED 9 MOD/FP 4 MOD coupled with TD 5 (with reuse), thermal desorption of PCBs. The costs were developed using a best fit graphical method.

Table 23 - Costs for Preferred Remedy Combined with TD 5 (with Reuse)

TD 5 (with reuse of soils)	Source	Cubic Yards	TD 5 Total Cost	TD 5 Total Present Worth
SED 6/FP 2	CMS	191,000	$103,000,000	$81,000,000
SED 9/FP 4 MOD	Interpolated	990,000	$515,000,000	$280,000,000
SED 8/FP 7	CMS	2,918,000	$1,448,000,000	$569,000,000

<u>Preferred Remedy with TD 5 (Thermal Desorption, without Reuse) for Disposal Method</u>

Table 24 summarizes the data points used to develop total and present worth costs for SED 9 MOD/FP 4 MOD coupled with TD 5 (with reuse), thermal desorption of PCBs. The costs were developed using a best fit graphical method.

Table 24 - Costs for Preferred Remedy Combined with TD 5 (Without Reuse)

TD 5 (without reuse of soils)	Source	Cubic Yards	TD 5 Total Cost	TD 5 Total Present Worth
SED 6/FP 2	CMS	191,000	$106,000,000	$83,000,000
SED 9/FP 4 MOD	Interpolated	990,000	$540,000,000	$295,000,000
SED 8/FP 7	CMS	2,918,000	$1,525,000,000	$590,000,000

Table 25 summarizes the information above for the volume of material for the preferred remedy combined with each T/D option, along with minimum and maximum SED/FP combination alternatives to provide a range of TD costs for each alternative. The range of costs for TD 1 RR was generated using the unit rates and assumptions discussed above and using volumes of material estimated by GE in its CMS for the range of alternatives.

Table 25 - Cost Summary for Treatment/Disposition Alternatives – 2010 Pricing

Cost Category	TD 1	TD 1 RR	TD 2	TD 3	TD 4	TD 5 (with reuse)	TD 5 (without reuse)
Total Capital Costs	0	$300k	$6 – 20 M	$10 – 67 M	$17 – 20 M	$20 – 232 M	$20 – 232 M
Total Disposal, Operations, Monitoring, and Maintenance Costs	$55 – 832 M	$52 M – 787 M	$94 – 490 M	$26 – 134 M	$72 - 979 M	$83 – 1,216 M	$86 – 1,293 M
Total Cost for Alternative	$55 – 832 M	$52M – 787 M	$100 – 510 M	$36 – 201 M	$89 – 999 M	$103 – 1,450 M	$106 – 1,530 M
Total Present Worth	$40 – 220 M	$38M – 210 M	$46 – 131 M	$17 – 49 M	$70 – 286 M	$81 – 569 M	$83 – 590 M
Total TD Cost for SED 9/FP 4MOD	$308 M	$287 M	$317 M	$100 M	$399 M	$515 M	$540 M
Total TD Present Worth for SED 9/ FP 4 MOD	$196 M	$183 M	$85 M	$33 M	$170 M	$280 M	$295 M

Notes: All costs are in 2010 dollars. $ M = million dollars.

1. TSCA volume is estimated to be 34.75% of the total, with the remainder 65.25% assumed to be non-TSCA. A density of 1.62 tons per CY has been used for all sediments and soils, consistent with the CMS.
2. 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 CY to 2.9 million CY). 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.
3. Total capital costs are for engineering, labor, equipment, and materials associated with implementation.
4. 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.
5. 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.
6. 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.
7. 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.
8. Costs for TD 3 do not include the very likely extensive costs associated with the approval process required for an on-site landfill.
9. The MA hazardous waste transport fee is not included in TD 1. The fee would potentially apply to TSCA material hauled by truck from the site. The fee is currently $56.25/ton, including a vehicle identification fee. For SED 9/FP 4 MOD, the total fee is estimated to be $31,349,000. With the exception of TD 1 RR and TD 3, some portion of the excavated sediments in each of the other alternatives could potentially be subject to the Massachusetts Hazardous Waste Transporter Fee.

Total Costs of SED 9/FP 4 Mod Combined with TD 1 RR (2010 Pricing)

Table 26 presents the total capital costs of SED 9/FP 4 based upon the 2010 RCMS combined with TD 1 RR costs developed in 2010/2011 to provide comprehensive costs for EPA's preferred remedy reflective of the 2010 time frame.

Table 26 – SED 9/FP 4 MOD with TD 1 RR – 2010 Pricing

Item	Total Costs	Present Worth Costs
Total Capital Costs SED 9/FP 4 MOD Before O&M, LTM, and T&D	$314,178,000	
Operations and Maintenance	$3,340,000	
Long-Term Monitoring*	$8,733,000	
Total Cost of SED 9/FP 4 MOD before T&D	**$326,000,000**	**$228,000,000**
Transportation and Disposal (TD 1 RR)	$287,000,000	$183,000,000
Total Cost of Alternative SED 9/FP 4 MOD/TD 1 RR	**$613,000,000**	**$411,000,000**

*Includes the cost of institutional controls and EREs, as well as reach-wide environmental monitoring activities.

SECTION 3.0 - ADJUSTMENT OF PREFERRED REMEDY SED AND FP COMPONENT COSTS FROM 2010 DOLLARS TO 2014 DOLLARS (EXCLUDING T/D)

Several factors were evaluated with respect to cost increases since 2010. These factors include labor, equipment, materials, and fuel. In order to determine appropriate factors to apply to make these adjustments, research was conducted, including both interviews with construction professionals and a review of published data.

Labor prices – Typically, union contracts have wage increases built in every 6 months. Based upon this factor, craft labor has increased 10% to 12% over the past 4 years. Labor costs represent approximately 32% of the overall costs for each alternative.

Equipment prices – Prices of construction equipment (four pieces of equipment were specifically reviewed—an excavator, a long stick excavator, an off-road dump truck, and a loader) have increased by about 6% over the past 4 years. Equipment prices represent approximately 16% of the overall costs of the alternatives.

Materials – New prices were obtained for the most common materials needed for the project. These prices were then compared to the most similar materials represented in the RCMS. Although only two materials, sand and stone, are represented in the RCMS and CMS, the average cost increase is 8%. Materials represent approximately 31% of the overall cost of construction.

Fuel – Diesel fuel is currently near $4.10 per gallon, whereas in mid-2010 the prices were near $3.00 per gallon. This represents an increase of 37% for diesel fuel. Fuel is estimated to represent approximately 11% of the overall cost of the alternatives.

Transportation and disposal (staging area materials) **–** Due to the methods used by GE to estimate the costs of the alternatives, the item for disposal of staging area materials plays a significant role in the overall costs of the alternatives. This item represents approximately 10% of the overall costs. Based on current pricing received for T&D by trucking and rail, a decrease in T&D prices has occurred over the last 4 years. For purposes of updating the preferred remedy, the transportation and disposal of staging area materials was assumed to have decreased by 10%.

Weighted average increase – A single cost increase factor was then determined based upon the estimated increase in costs from 2010 to 2014, and the overall proportion of each component with respect to the total price. This weighted average approach yields a cost increase factor of 10%. Over the past 3.5 years, construction costs have gone up an average of 10%. This factor can now be applied to the overall construction costs that were developed based upon 2010 unit pricing. Table 27 summarizes the adjustment of the preferred remedy from 2010 dollars to 2014 dollars.

Table 27 – Preferred Remedy Adjusted to 2014 Dollars

Cost Item	Total Costs
Reach 5	$175,530,000
Reach 6 - Wood's Pond	$35,150,000
Reach 7	$24,018,000
Reach 8 - Rising Pond	$18,558,000
Subtotal Capital Costs (excluding T&D)	**$253,256,000**
Plus Project/Construction Management (5%)	$12,663,000
Plus Engineering and Administration (5%)	$12,663,000
Plus Contingency (25%)	$63,314,000
Total Capital Costs	**$342,000,000**
Operations and Maintenance	$3,707,000
Long-Term Monitoring*	$9,694,000
Total Operation and Maintenance and LTM	**$13,000,000**
Total Cost of Alternative before T&D	**$355,000,000**
Present Worth	**$248,000,000**

* Includes the cost of institutional controls and EREs as well as reach-wide environmental monitoring activities.

SECTION 4.0 – DEVELOPMENT OF RAIL TRANSPORT OPTION AND TOTAL REMEDY COSTS, INCLUDING T/D, IN 2014 DOLLARS

Railroad Infrastructure

In 2010, at EPA's request, GE confirmed in the RCMS that the existing track from Housatonic, MA to Pittsfield, MA was of sufficient design to handle rail cars loaded with up to approximately 110 tons of material and that hauling material by rail from the site was logistically feasible. EPA then further investigated the feasibility of the rail transport option, including the condition of the track in the vicinity of the site. Based upon GE's conclusions, and confirmation by EPA, no additional costs for upgrade of the existing track are considered necessary.

However, to enable loading of cars from the site staging areas, EPA investigated the infrastructure that would be needed. Based on discussions with rail logistics companies, approximately $300,000 in railroad infrastructure upgrades would be needed to construct several spurs to provide access to a transfer and loading station on the site. The costs associated with construction of rail spurs to access the rail staging areas from the main railroad line have been added to the TD 1 RR capital costs. The construction costs associated with the staging areas necessary to support the rail spurs and loading areas are included in the SED 9 Reach 5A staging area costs.

Transportation and Disposal Pricing Via Rail

Following confirmation that rail transport of site sediments was feasible, costs for railroad transport and disposal at rail-ready facilities were developed in 2011. As part of the Remedy Review Board Package development, these prices were re-confirmed in 2012. In the March and April 2014 timeframe, rail pricing was updated to provide a complete assessment of the preferred remedy costs in 2014 dollars. Table 28 summarizes the T&D pricing via rail transport from 2011 and 2014.

Table 28 – Summary of 2011 and 2014 Off-site Disposal Pricing via Rail

Year	**2010/2011**		**2014**	
Waste Type	Non-TSCA	TSCA	Non-TSCA	TSCA
Facility	Republic Services	EQ	Allied Waste/ Republic Services	EQ
Location	Niagara Falls, NY	Michigan	Niagara Falls, NY	Michigan
Transport Price	$43/ton	$110/ton	$32/ton	$75/ton
Disposal Price	$55/ton	$85/ton	$30/ton	$100/ton
Total T&D	$98/ton	$195/ton	$62/ton	$175/ton

Notes:

1. All prices are in $/ton.
2. Sources: 2011 Pricing – discussion with T&D firms specializing in rail disposal and rail logistics; 2014 Pricing – discussions with T&D firms specializing in both trucking and rail disposal, and rail logistics.
3. The above pricing is not intended to indicate an actual price quotation, but an indication of price levels at a point in time. For 2014 pricing, where appropriate, a single price point was selected from a range of pricing, to generate total costs. The prices that were given as ranges include "mid to high $20s" for non-TSCA disposal only by rail, and total T&D pricing ranged from $175 to $190. The $175 price level was chosen due to the quality and detail of the information provided.

Preferred Remedy with TD 1 RR Option for Disposal, 2014 Dollars[4]

Updated T&D pricing for 2014 was applied to the quantities for the preferred remedy to determine an updated T&D price. Table 29 summarizes the cost items using 2014 pricing.

Table 29 – SED 9/FP 4 MOD with TD 1 RR for Disposal in 2014 Dollars

Description	Units	Quantity	Unit Price	Total Cost
TRANSPORTATION AND DISPOSAL				
Transportation TSCA	Ton	557,324	$75.00	$41,799,000
Transportation Non-TSCA	Ton	1,046,476	$32.00	$33,487,000
Disposal TSCA	Ton	557,324	$100.00	$55,732,000
Disposal Non-TSCA	Ton	1,046,476	$30.00	$31,394,000
Waste Characterization Sampling	500 CY	2,138	$500.00	$1,069,000
Rail Spurs	Lump Sum	1	$300,000	$300,000
			Subtotal	**$163,782,000**
Project/Construction Management (5%)				$8,189,000
Engineering and Administration (5%)				$8,189,000
Contingency (25%)				$40,946,000
TOTAL COST OF ALTERNATIVE (ROUNDED)				**$221,000,000**
Total Present-Worth				**$141,000,000**

Notes:

1. Quantity is based upon a total volume of 990,000 CY with an overall density factor of 1.62 tons per CY. This density accounts for the addition of Portland to cement in varying ratios, which is generally 15% in SED alternatives and 10% in floodplain alternatives.
2. The fraction of TSCA material has been assumed to be 34.75%. The fraction of non-TSCA material is assumed to be 65.25%.
3. The MA hazardous waste transport fee is not included in these estimates and would apply only to TSCA material hauled by truck.

[4] Pricing in Table 29 reflects the current state of the T&D market for rail as of early April 2014 based upon information collected in the March and April 2014 timeframe. These prices are not intended to be indicative of pricing in the future due to multiple factors that can affect pricing, including but not limited to: diesel fuel pricing, the status of various facilities and their individuals disposal cells, and the number and availability of facilities to accept materials via rail.

Preferred Remedy with TD 1 via Trucking in 2014 Dollars

In addition to obtaining updated rail pricing for T&D, EPA obtained updated T&D pricing via truck. Table 30 provides backup information for the calculation of the preferred remedy combined with TD 1 via trucking for disposal using pricing information developed in 2014.

Table 30 – Costs for Preferred Remedy Combined with TD 1 via Trucking

Description	Units	Quantity	Unit Price	Total Cost
TRANSPORTATION AND DISPOSAL				
Transportation TSCA	Ton	557,324	$75.00	$41,799,000
Transportation Non-TSCA	Ton	1,046,476	$45.00	$47,091,000
Disposal TSCA	Ton	557,324	$135.00	$75,239,000
Disposal Non-TSCA	Ton	1,046,476	$35.00	$36,627,000
Waste Characterization Sampling	500 CY	2,138	$500.00	$1,069,000
			Subtotal	**$201,825,000**
			Project/Construction Management (5%)	$10,091,000
			Engineering and Administration (5%)	$10,091,000
			Contingency (25%)	$50,456,000
			TOTAL COST OF ALTERNATIVE (ROUNDED)	**$272,000,000**
			Total Present-Worth	**$173,000,000**

Notes:

1. Quantity is based upon a total volume of 990,000 CY with an overall density factor of 1.62 tons per CY. This density accounts for the addition of Portland to cement in varying ratios, which is generally 15% in SED alternatives and 10% in floodplain alternatives.
2. The fraction of TSCA material has been assumed to be 34.75%. The fraction of non-TSCA material is assumed to be 65.25%.
3. The MA hazardous waste transport fee is not included in these estimates. The fee would potentially apply to TSCA material hauled by truck from the site. The fee is current $56.25/ton, including a vehicle identification fee. For SED 9/FP 4 MOD, the total fee is estimated to be $31,349,000.
4. Pricing reflects price quotations received in March/April 2014 for TSCA and non-TSCA disposal via trucking and assumes disposal at Seneca Meadows, in Waterloo, NY, for non-TSCA material and CWM Model City in Model City, NY, for TSCA materials.

Total Costs of SED 9/FP 4 Mod Combined with TD 1 RR (Updated 2014 Pricing)

Table 31 presents the total capital costs of SED 9/FP 4 based upon the 2010 RCMS pricing updated to 2014 combined with TD costs developed in 2014 to provide comprehensive costs for EPA's preferred remedy reflective of the 2014 time frame.

Table 31 – SED 9/FP 4 MOD with TD 1 RR – 2014 Pricing

Cost Item	Total Costs	Present Worth Costs
Total Capital Costs SED 9/FP 4 MOD Before O&M, LTM, and T&D	$341,896,000	
Operations and Maintenance	$3,707,000	
Long-Term Monitoring*	$9,694,000	
Total Cost of SED 9/FP 4 MOD before T&D	**$355,000,000**	**$248,000,000**
Transportation and Disposal (TD 1 RR)	$221,000,000	$141,000,000
Total Cost of Alternative SED 9/FP 4 MOD/TD 1 RR	**$576,000,000**	**$389,000,000**

* Includes the cost of institutional controls and EREs as well as reach-wide environmental monitoring activities.

ATTACHMENT 9
POST-EAST BRANCH REMEDIATION BOUNDARY CONDITIONS

MEMORANDUM

TO:	SUSAN SVIRSKY SCOTT CAMPBELL DICK MCGRATH	DATE:	JULY 23, 2012
FROM:	EDWARD GARLAND	RE:	POST-EAST BRANCH REMEDIATION BOUNDARY CONDITIONS
CC:		FILE:	WSTN - 153624

As part of the PCB fate and transport model calibration and validation, relationships were developed describing total suspended solids (TSS) and PCBs entering the upstream boundary of Reach 5A from the East Branch of the Housatonic River as a function of river flow conditions (Appendix B.2 of the FMDR (EPA, 2006)). These estimates were based on data collected prior to remediation of the East Branch. In the early stages of the Corrective Measures Study (CMS), GE developed estimates of East Branch PCB boundary conditions for the post-East Branch remediation period (Arcadis, et.al., 2007) for use in simulations of future conditions. For the purpose of the CMS, GE assumed that the relationship between TSS and East Branch river flow was representative of future conditions.

GE has an ongoing monthly monitoring program, and in the fall of 2010, an analysis was performed to compare the post-East Branch remediation boundary condition estimates to post-remediation data available at that time. Differences between the 2006-2010 data and earlier boundary condition estimates were noted and model simulations were performed to evaluate if these differences affect the model projections, particularly the relative effectiveness of the different alternatives. The results of these analyses were presented at a technical team meeting in December 2010 and are described below to document the analysis and conclusions

East Branch TSS and PCB Concentrations

TSS and PCB boundary concentrations are highly dependent on river flow conditions, which complicates comparison of data collected in different time periods, because flow conditions at the time of sampling can vary substantially between two different periods (i.e. pre- and post-remediation). Data collected between April 27, 2006 and August 26, 2010 are plotted versus East Branch flow and superimposed on boundary conditions used in the CMS (Figure 1). Both TSS and

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Fax: (201) 529-5728
www.hdrinc.com

PCB concentrations from the post-East Branch remediation period tend to fall below the original boundary condition estimates used in the CMS. Lower TSS concentrations may be the result of changes in the cross sectional shape of the East Branch introduced as part of the remediation to help stabilize the riverbanks. Armor stone placed on the riverbed of the East Branch could also contribute to a temporary reduction in TSS boundary conditions, due to infilling of the voids between the armor stone and a reduction in resuspension of bed sediment. In each of these cases, the change in solids loading from the East Branch may be a transient condition as a new equilibrium morphology develops. The effect of the reduction in TSS on PCB boundary conditions was investigated by performing equilibrium partitioning calculations to estimate particulate PCB concentrations (i.e. mg PCB/Kg TSS).

Relationships between particulate PCB concentrations and East Branch flow, for different time periods are shown on Figure 2 (Arcadis, et.al. Supplement to Model Input Addendum, Figure 4-1). The upper dotted line represents the function derived from pre-East Branch remediation data, which was used in the calibration and validation modeling. The solid line represents the function derived by Arcadis, et.al. in 2007, using post-East Branch remediation data. Additional post-East Branch remediation data (June 14, 2007- August 26, 2010), which supplement Arcadis, et.al. 2007 analysis (Figure 2), were used to calculate particulate PCB concentrations and are shown on Figure 3. These more recent data are in general agreement with Arcadis, et.al. 2007 relationship, suggesting that the mass of PCBs per mass of solids entering Reach 5A from the East Branch has not changed relative to Arcadis, et.al. 2007 estimates. Rather, the reduction in total PCB concentrations expressed on a volumetric basis (i.e. ug/l) is primarily related to the reduction in TSS concentrations from the East Branch.

Projections with Boundary Concentrations based on 2006-2010 Data

The conclusions of the data analysis that:

- 2006-2010 East Branch TSS concentrations were lower than historical levels,
- the lower TSS carry sorbed PCB per mass of TSS similar to Arcadis' 2007 estimate, and
- lower TSS concentrations and similar sorbed PCBs result in lower total PCB loading

led to the question, "How would the model projections, particularly the relative effectiveness of the different alternatives be affected by replacing the previous estimated boundary concentrations with TSS and PCB concentrations based on the 2006-2010 data?". The lower total PCB concentrations (relative to the original CMS estimates) would not necessarily result in an acceleration of natural recovery simply because TSS inputs from the East Branch represent a source of solids with lower PCB concentrations than the existing sediment in Reaches 5 and 6. The TSS mass loading is also reduced relative to the original estimates, which reduces the dilution effects of sedimentation.

Model simulations were performed with TSS and PCB boundary conditions based on the 2006-2010 data to determine the affect on simulated future concentrations, relative to those simulated with higher TSS and PCB concentrations estimated in 2007 for the CMS. Two alternatives, SED1/2 and SED5, were used for this evaluation because they include a wide range in remedial activities, from no active remediation in SED1/2 to bank stabilization and removal and/or capping in all of the sub-reaches from Reach 5A through Reach 6 in SED5.

Pre-remediation data in the East Branch were collected in both routine monthly and storm-event monitoring programs, which allowed the data to be separated into groups based on flow conditions (rising, falling, and neutral). The same type approach could not be applied to the more-limited post-remediation data. Instead, log-log regressions were developed for the TSS concentrations above and below 250 cfs (Figure 4) and used to derive an alternate TSS time series input to Reach 5A from the East Branch. An alternate PCB boundary concentration time series was developed from GE's post-remediation particulate PCB versus flow relationship (Figures 2 and 3), the alternate TSS time series, and equilibrium partitioning calculations. Note that all of the other assumptions incorporated in the CMS (effect of remediation in Silver Lake, Unkamet Brook, GE plant site, half life) were retained in developing the alternate PCB boundary conditions.

Reach-average sediment PCB concentration results from simulations performed with the alternate TSS and PCB boundary conditions are compared to original CMS results on Figures 5-9. In all reaches, a comparison of the SED1/2 results with the original and revised boundary conditions shows a small reduction in the rate of natural recovery, which is due to a reduction in the loading of solids from the East Branch with PCB concentrations lower than the in-place sediments. Results from the SED5 simulations show little sensitivity in Reaches 5A and 5C (Figures 5 and 7). In these reaches, the relatively gradual change in sediment PCB concentrations for both the original and revised boundary condition simulation indicates that deposition of upstream boundary solids is less than in other reaches, and therefore, the change in boundary conditions has less of an impact. In reaches 5B and 5D (Figure 6 and 8) the more-rapid increase in sediment PCB concentrations following remediation in in the original SED5 results indicates that deposition of boundary solids and PCBs is more significant in these reaches. The result of the reduction in boundary solids concentrations slows the rate of recontamination; however, the resulting sediment concentrations differ by less than a factor of two.

In Reach 6, sediment concentrations at the beginning of remediation in SED5 are higher in the simulation with the reduction in East Branch solids concentrations, compared to the original SED5 simulation, because of the slower rate of natural recovery caused by the lower solids inputs from the East Branch. As a result, the post-remediation concentration in the revised simulation is slightly higher than the original SED5 simulation. The slower rate of natural recovery in the revised simulation results continues following remediation because of the reduced source of solids from the East Branch. The post-remediation Reach 6 sediment concentrations differ by less than 20 percent in the two SED5 simulations.

Given the relatively small effect of the alternate East Branch boundary conditions on Reach 5A-6 sediment concentrations, and the uncertainty in whether the change in the East Branch TSS concentrations represent a short-term transient or permanent change, it is concluded that application of the revised boundary conditions to the remaining SED alternatives is not warranted. Comparisons among the alternatives should not be affected by the uncertainty in the estimates of East Branch boundary conditions.

References:

ARCADIS BBL and QEA. 2007d. Housatonic Rest of River Model Input Addendum Supplement, August 2007.

EPA. 2006. Final Model Documentation Report: Modeling Study of PCB Contamination in the Housatonic River. Prepared by Weston Solutions, Inc., West Chester, PA, for the U.S. Army Corps of Engineers, New England District, and the U.S. Environmental Protection Agency, New England Region, November 2006.

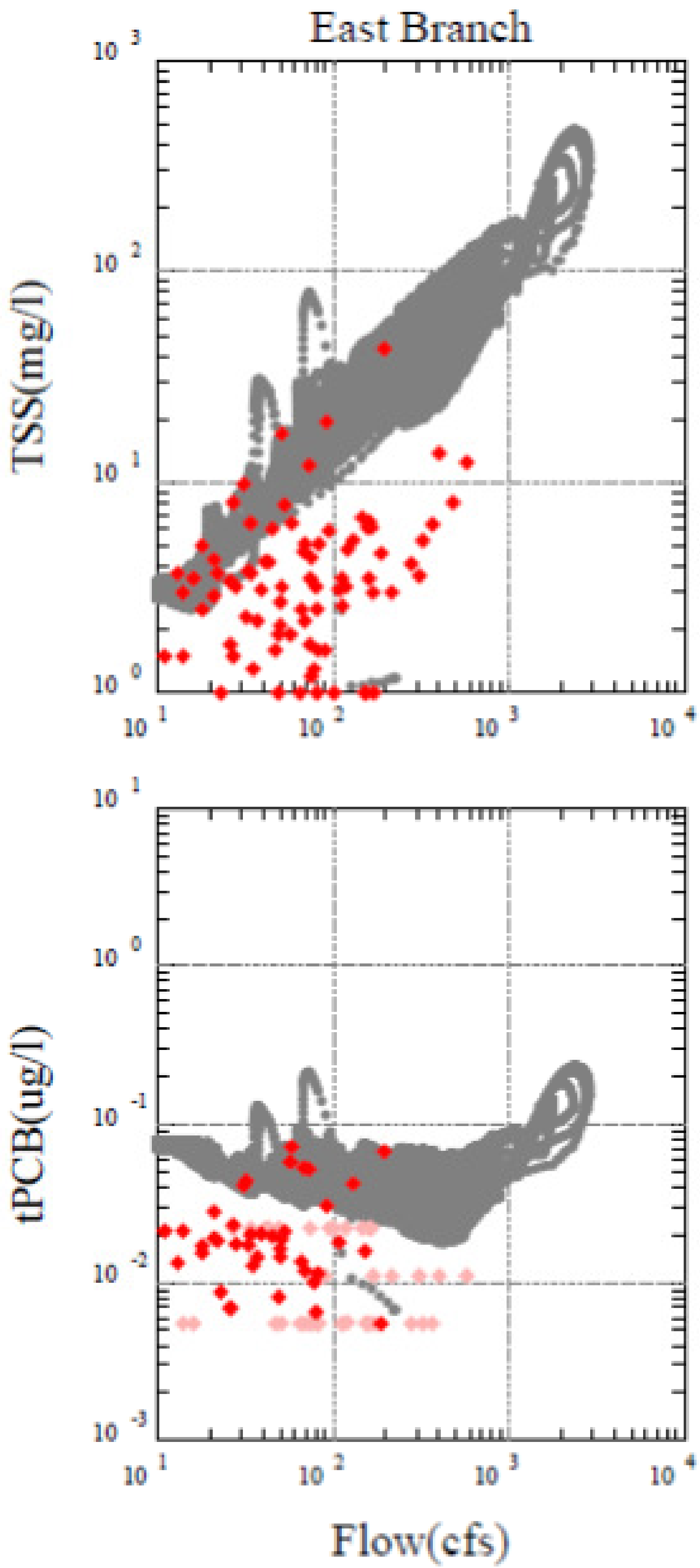


Figure 1. Comparison of original (●) TSS and PCB estimates and post-East Branch remediation period data (♦) versus river flow (♦ - non-detect plotted at detection limit)

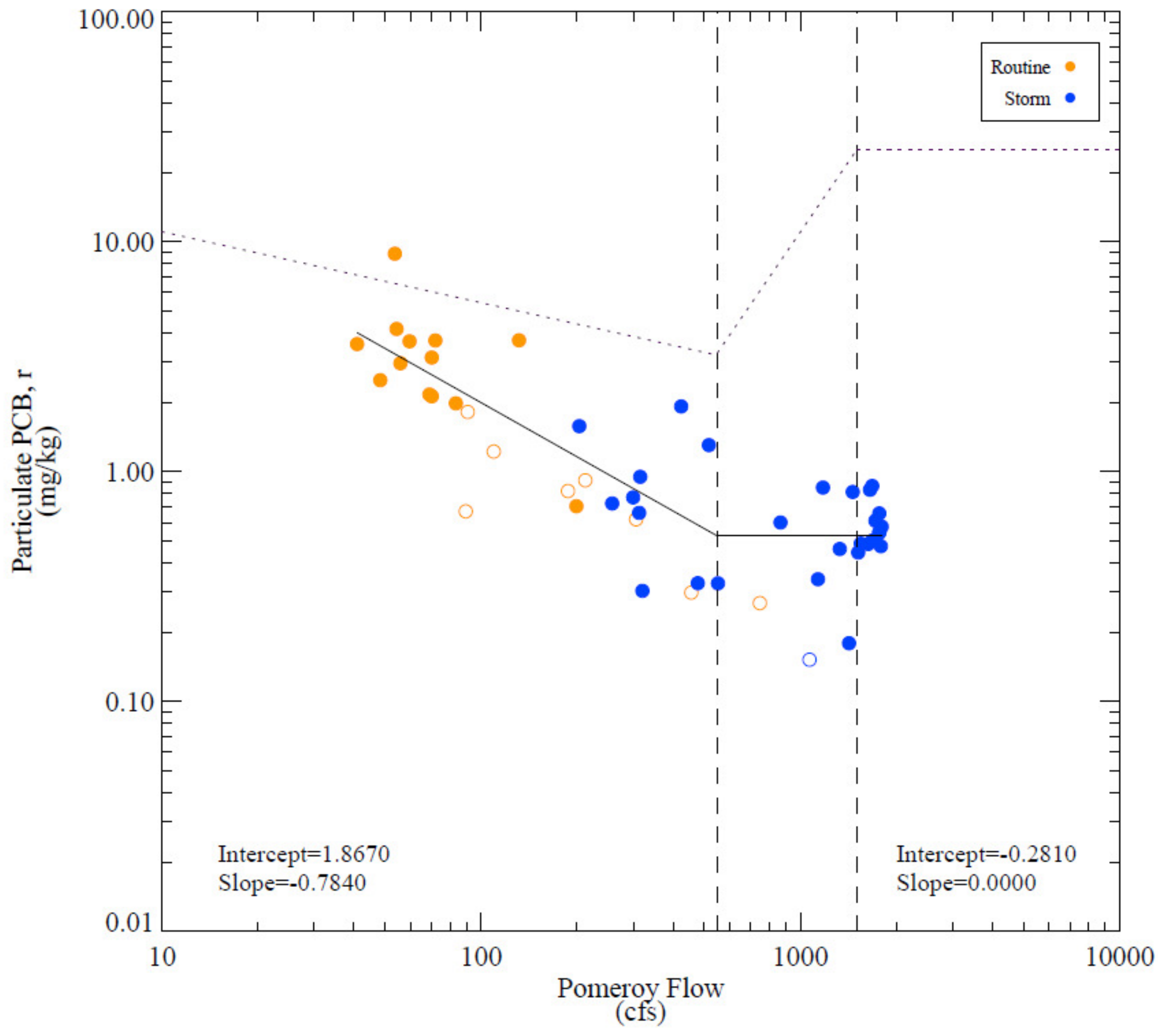


Figure 2. East Branch boundary particulate PCBs versus River Flow (- - - - Calibration/Validation, —— Arcadis, et.al. 2007 estimate of post-East Branch Remediation period) (Figure 4-1 of Arcadis, et.al., 2007 Supplement to Model Input Addendum) (● Routine Monitoring, ● GE 2007 Supplemental Storm Event Monitoring; filled symbol = detected, open=non-detect).

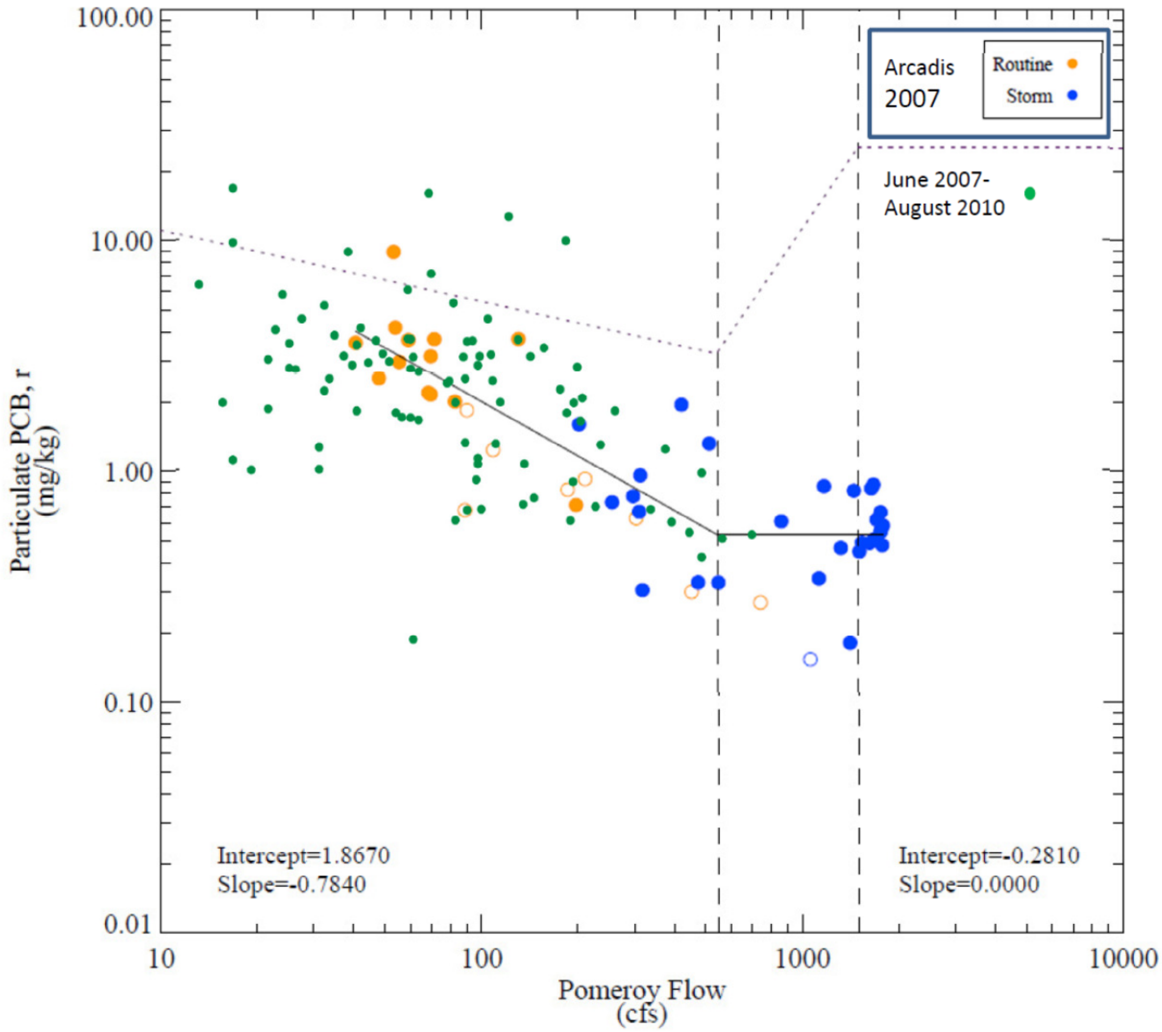


Figure 3. Additional post-remediation data (●) added to East Branch boundary particulate PCBs versus River Flow (- - - - Calibration/Validation, Arcadis, et.al. 2007 estimate of post-East Branch Remediation period) (Figure 4-1 of Arcadis, et.al., 2007 Supplement to Model Input Addendum) (● Routine Monitoring, ● 2007 Storm Event - GE 2007 Supplemental Monitoring Program; filled symbol = detected, open=non-detect).

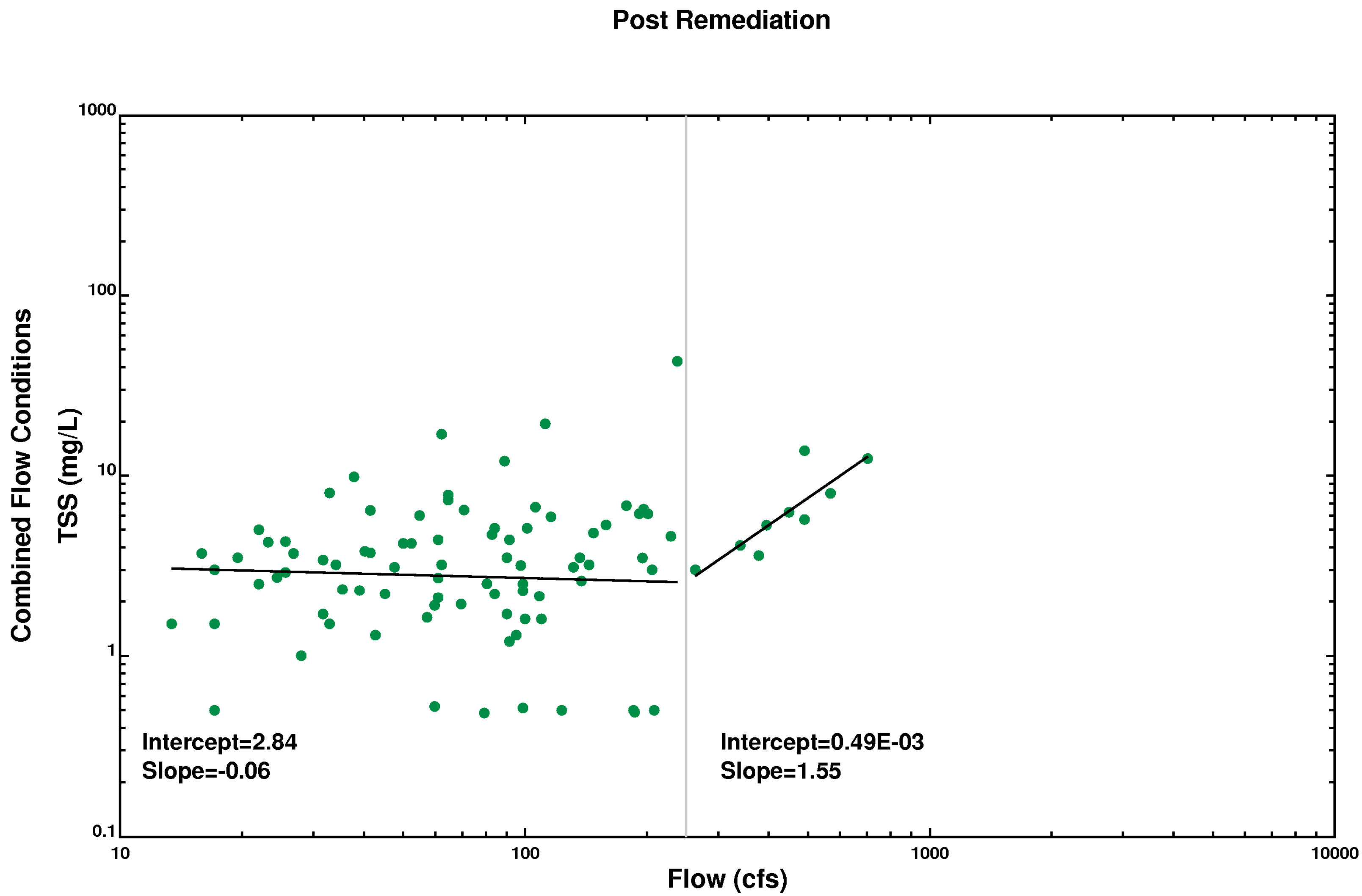


Figure 4. East Branch total suspend solids versus flow - Post-East Branch remediation period data

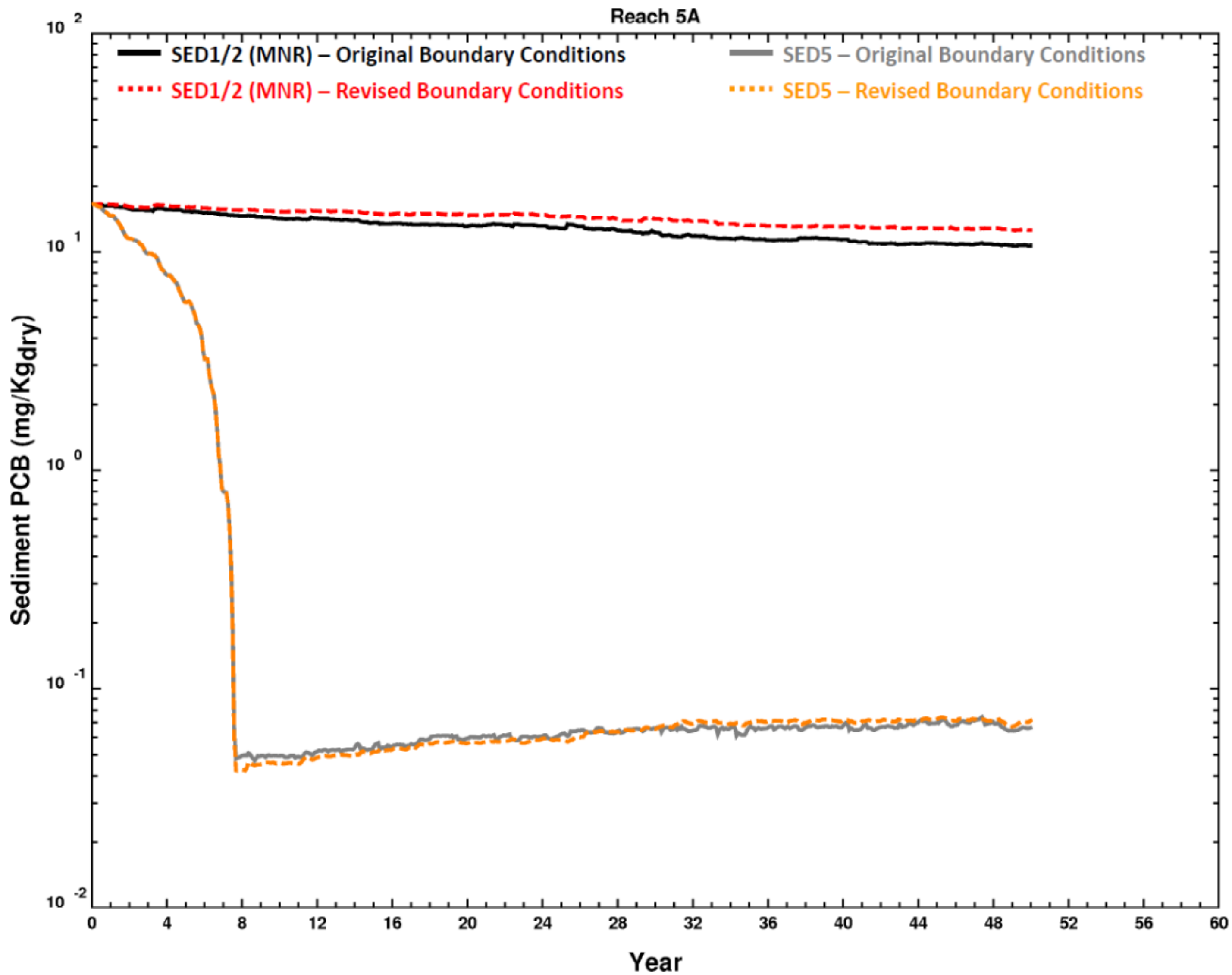


Figure 5. Reach 5A average sediment PCB concentrations from original and revised simulations

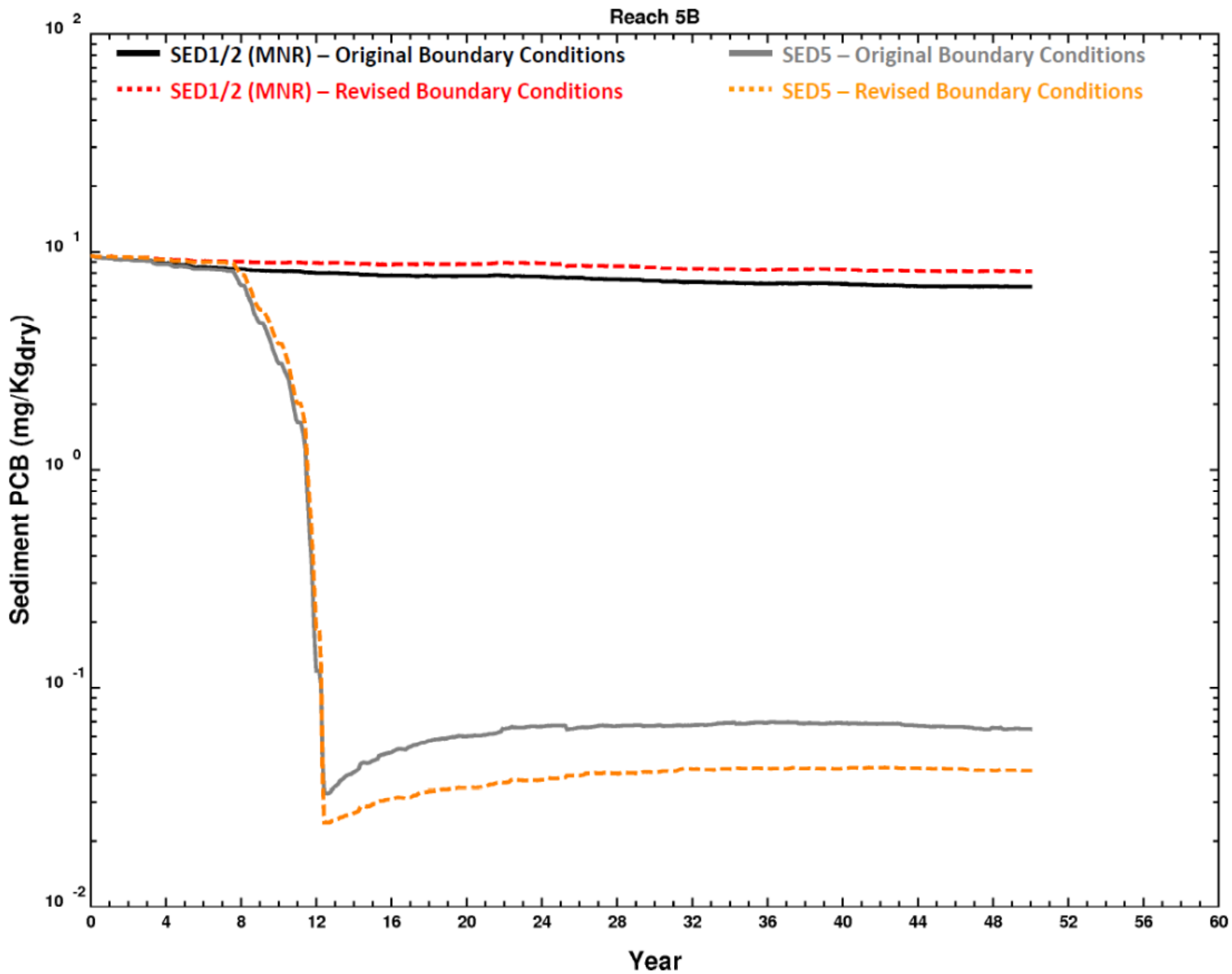


Figure 6. Reach 5B average sediment PCB concentrations from original and revised simulations

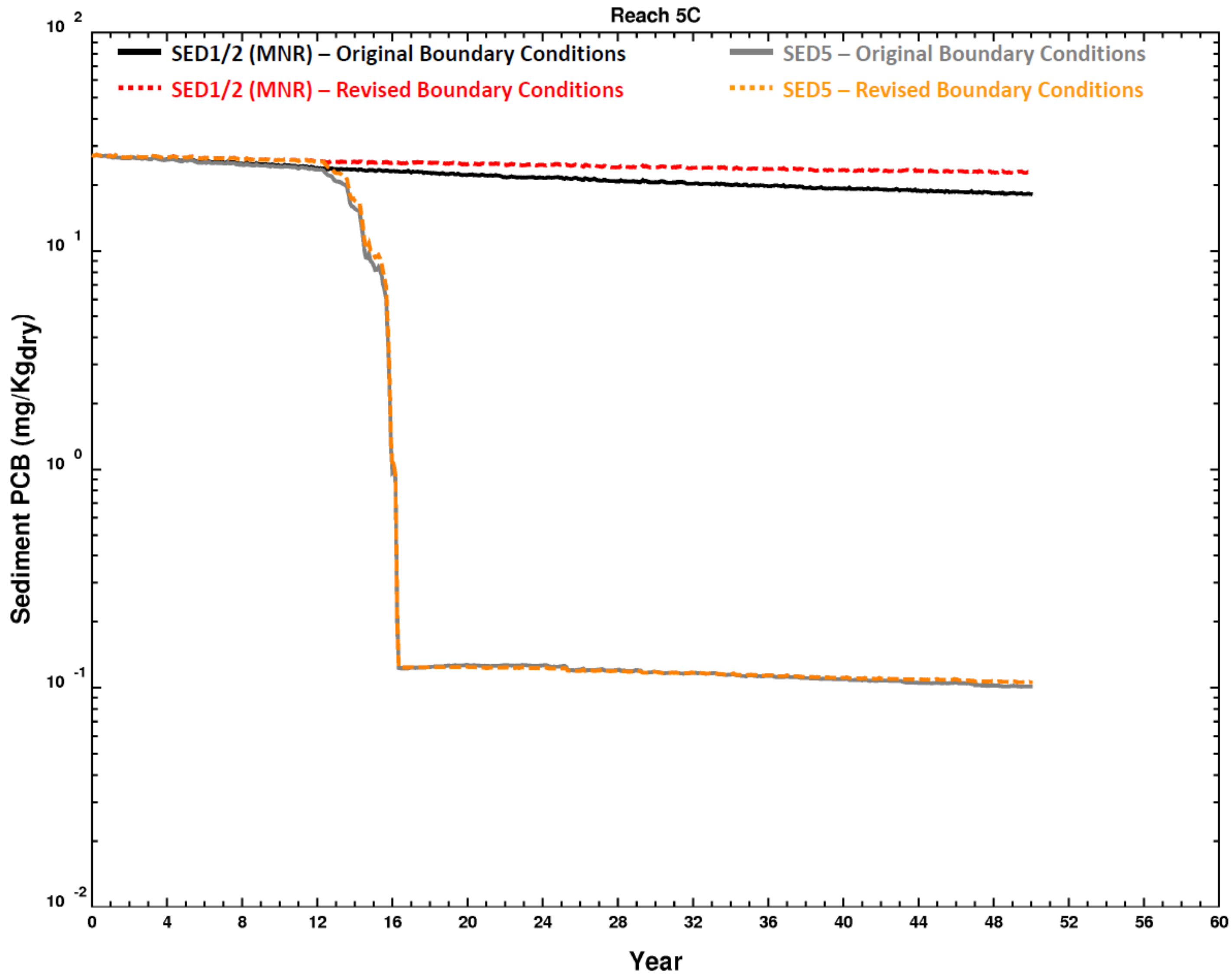


Figure 7. Reach 5C average sediment PCB concentrations from original and revised simulations

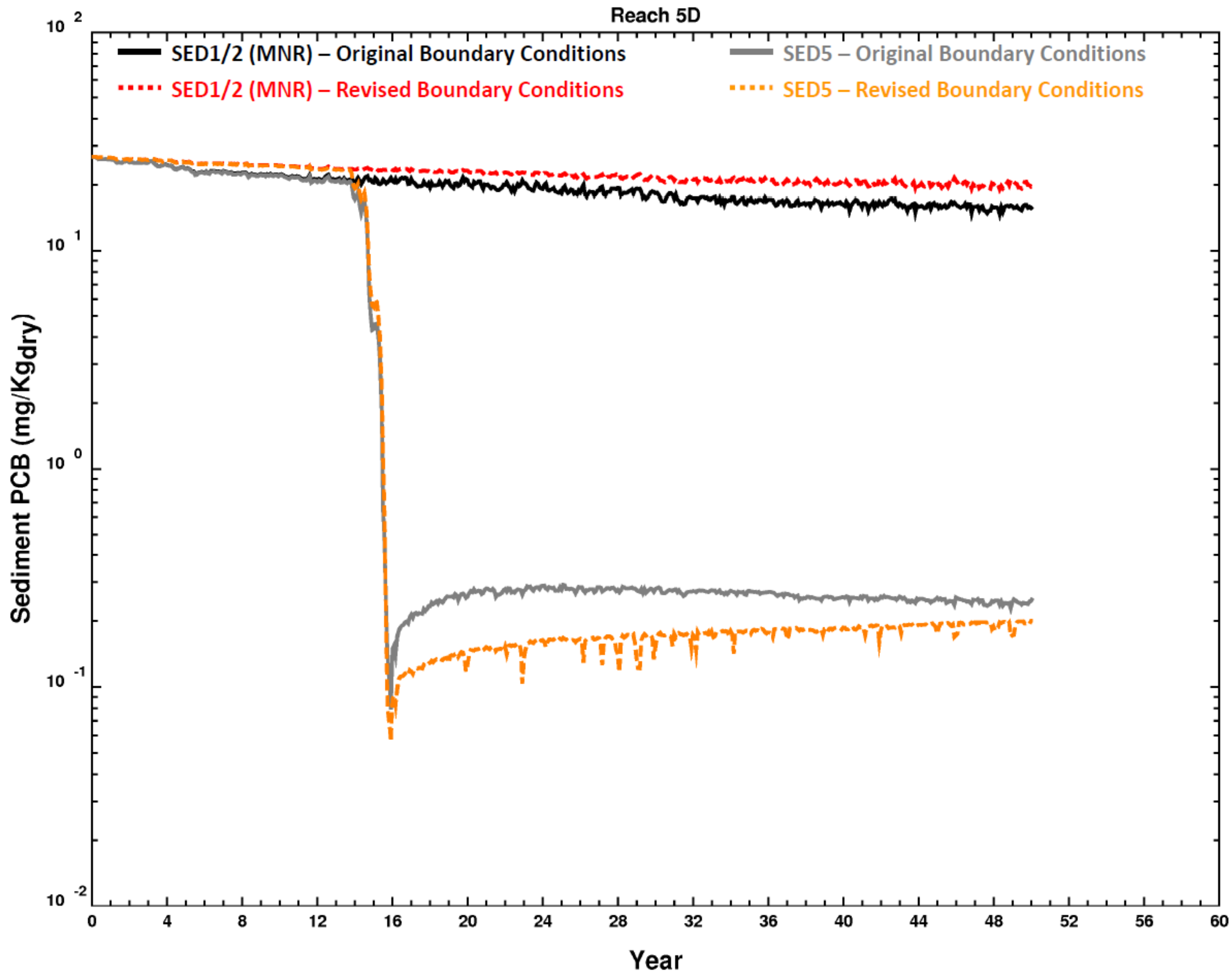


Figure 8. Reach 5D average sediment PCB concentrations from original and revised simulations

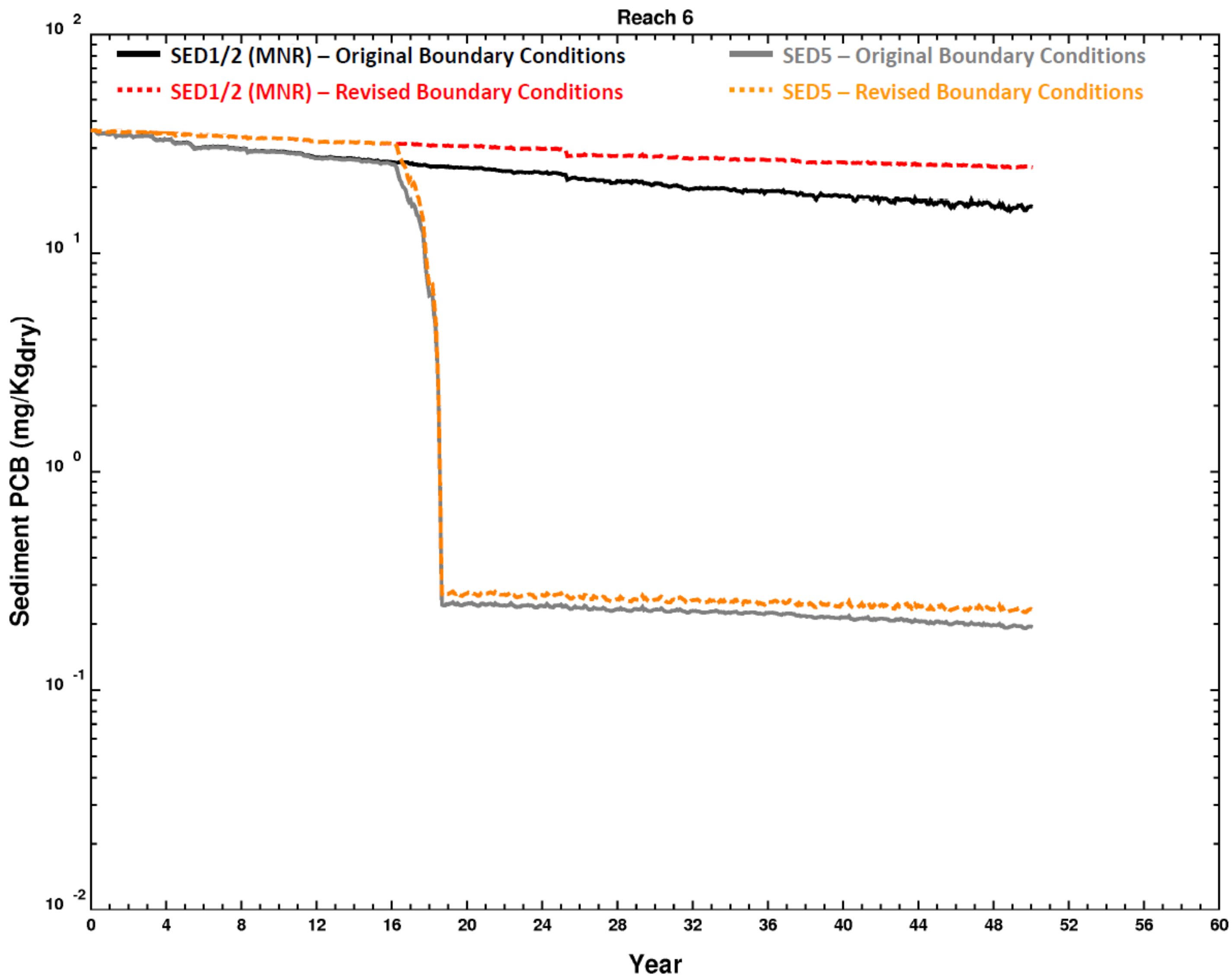


Figure 9. Reach 6 average sediment PCB concentrations from original and revised simulations

ATTACHMENT 10
FOOD CHAIN MODEL OUTPUT

Attachment 10
Food Chain Model Output

The following table is provided to indicate the relationship between the combination numbers, which are used in the figures presented in this attachment, and the Sediment/Floodplain (SED/FP) designations, which are used in the Comparative Analysis of Alternatives text.

Combination Numbers and SED/FP Designations

Combination Numbers	1	2	3	4	5	6	7	8	9
SED/FP Designations	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

FCM Runs
June 12, 2012

- Graphs show “Combination 1” to “Combination 9”
  (with options 1 and 2 for Combination 9)

Further Notes:
X axis set to 60 years

Contents

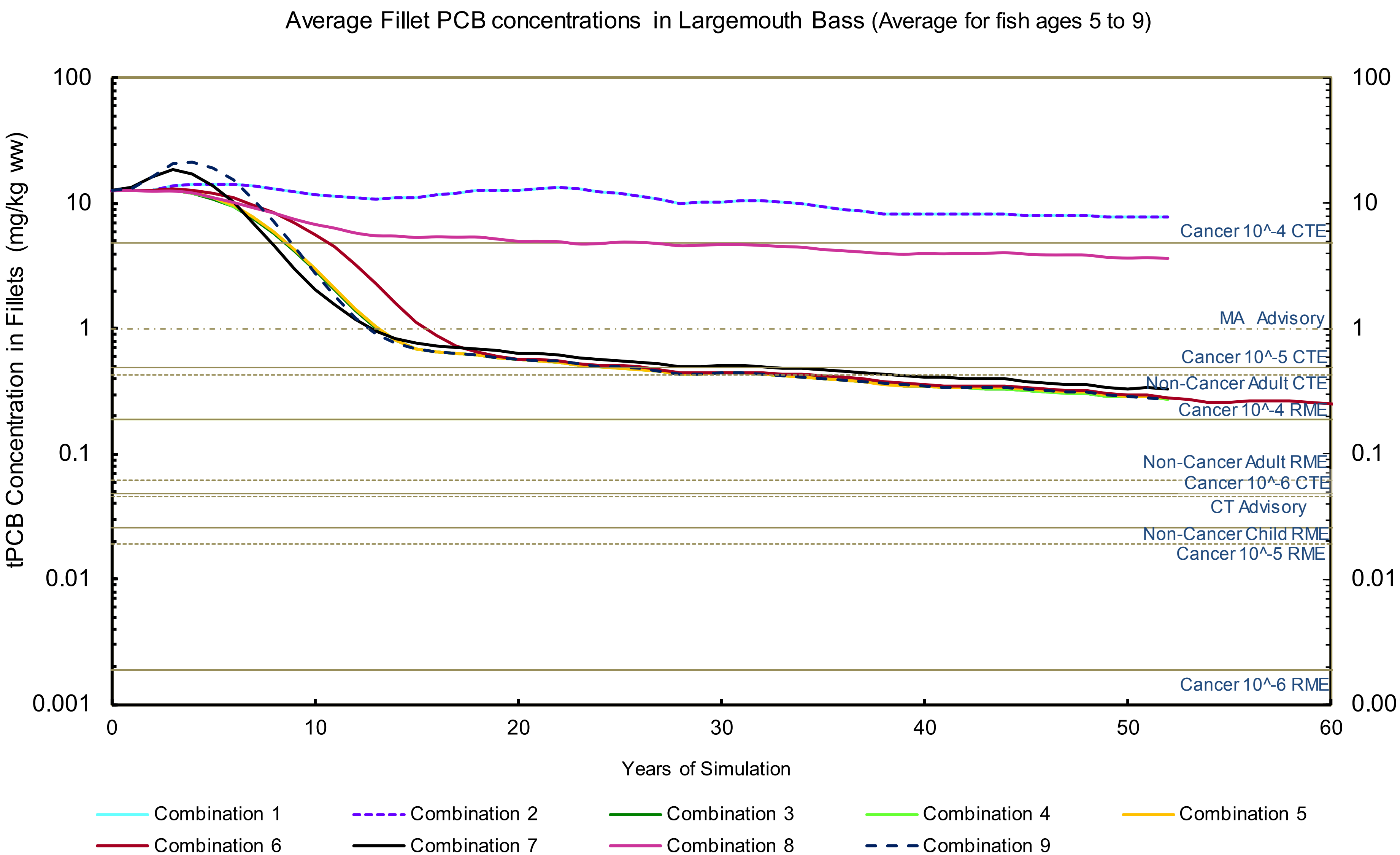
warren pinnacle consulting, inc.

IMPG Assumptions within plots:

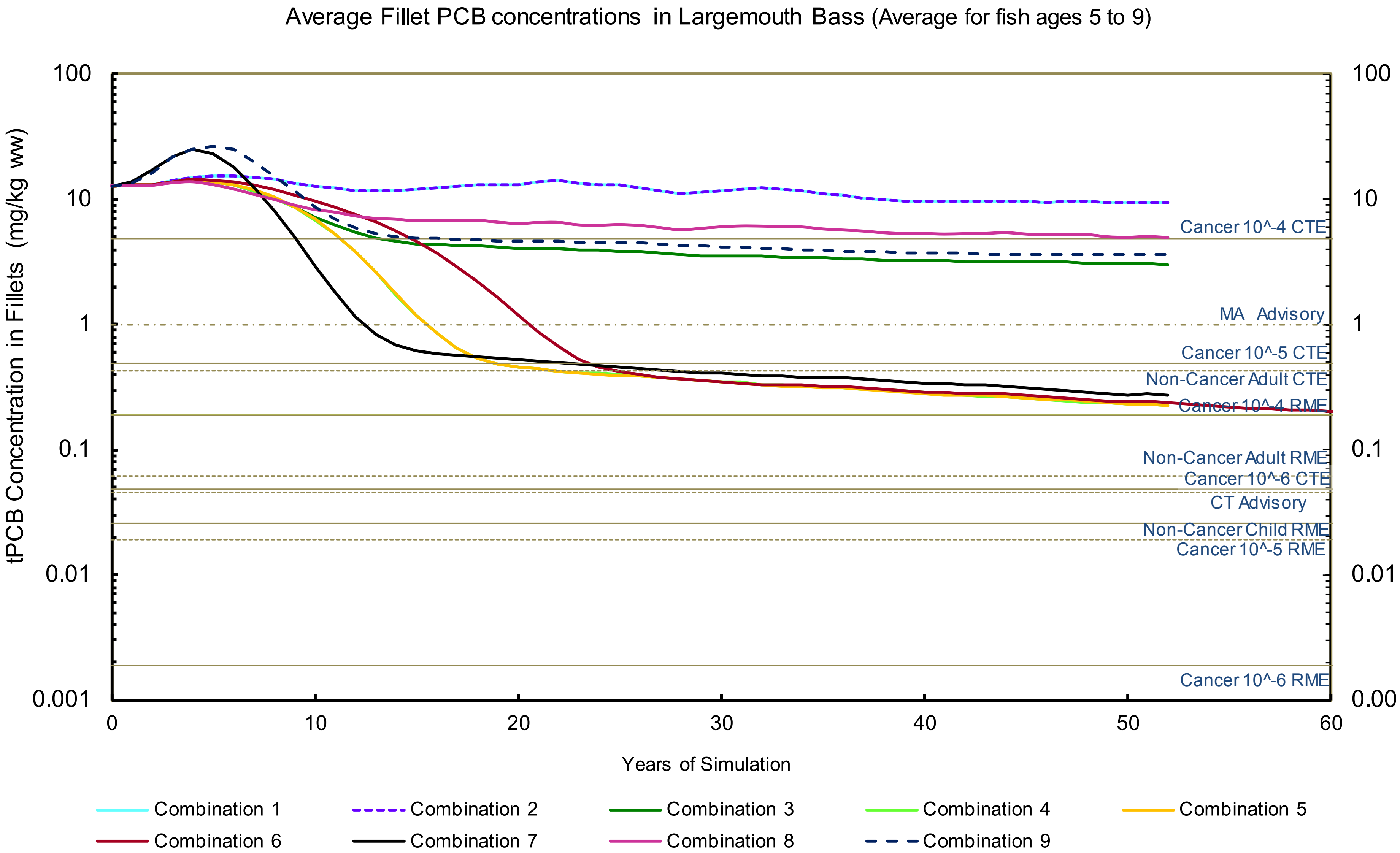
Receptor	Protection	Type	Deterministic tPCB IMPG (mg/kg skinless fillet)	Probabilistic (mg/kg skinless fillet)	IMPG Tissue Type	FCM Surrogate
Human health	Cancer 10E-06	RME	0.0019	0.0064	fillet ww	"Blended" Fish Fillet
Human health	Cancer 10E-06	CTE	0.049	0.057	fillet ww	"Blended" Fish Fillet
Human health	Cancer 10E-05	RME	0.019	0.064	fillet ww	"Blended" Fish Fillet
Human health	Cancer 10E-05	CTE	0.49	0.57	fillet ww	"Blended" Fish Fillet
Human health	Cancer 10E-04	RME	0.19	0.64	fillet ww	"Blended" Fish Fillet
Human health	Cancer 10E-04	CTE	4.9	5.7	fillet ww	"Blended" Fish Fillet
Human health	Non-cancer (adult)	RME	0.062	0.12		"Blended" Fish Fillet
Human health	Non-cancer (adult)	CTE	0.43	1.5		"Blended" Fish Fillet
Human health	Non-cancer (child)	RME	0.026	0.059	fillet ww	"Blended" Fish Fillet
Human health	Non-cancer (child)	CTE	0.19	0.71	fillet ww	"Blended" Fish Fillet
Human Health	CT Advisory Unlimited Consum.	-	0.046		Converted to fillet ww from fillet ***with skin*** ww	"Blended" Fish Fillet
Human Health	MA Advisory	-	1		fillet ww	"Blended" Fish Fillet

IMPG Notes: Source Table 2-2-- http://www.epa.gov/region1/ge/thesite/restofriver/reports/impg/248143.pdf

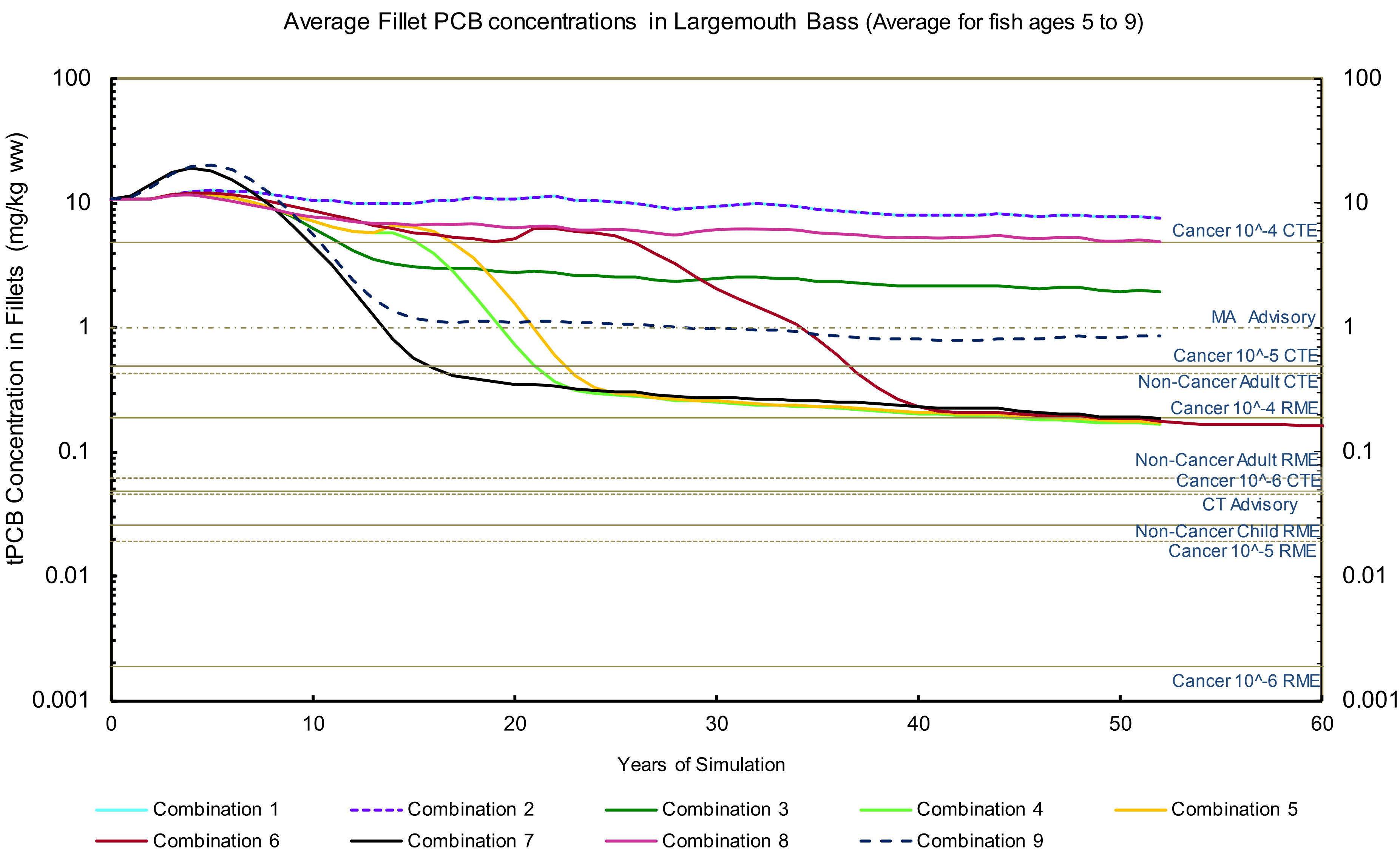
- FCM Results are converted to skinless fillet concentrations using the 5:1 conversion method per CMS dispute resolution letter.
- For the CT Advisory line, to convert "fillet with skin" to "fillet without skin" the concentration is multiplied by 2.3 to achieve whole body concentrations (Bevelheimer et al. 1997) and then divided by 5 to achieve skinless fillet concentrations (per CMS dispute resolution letter).



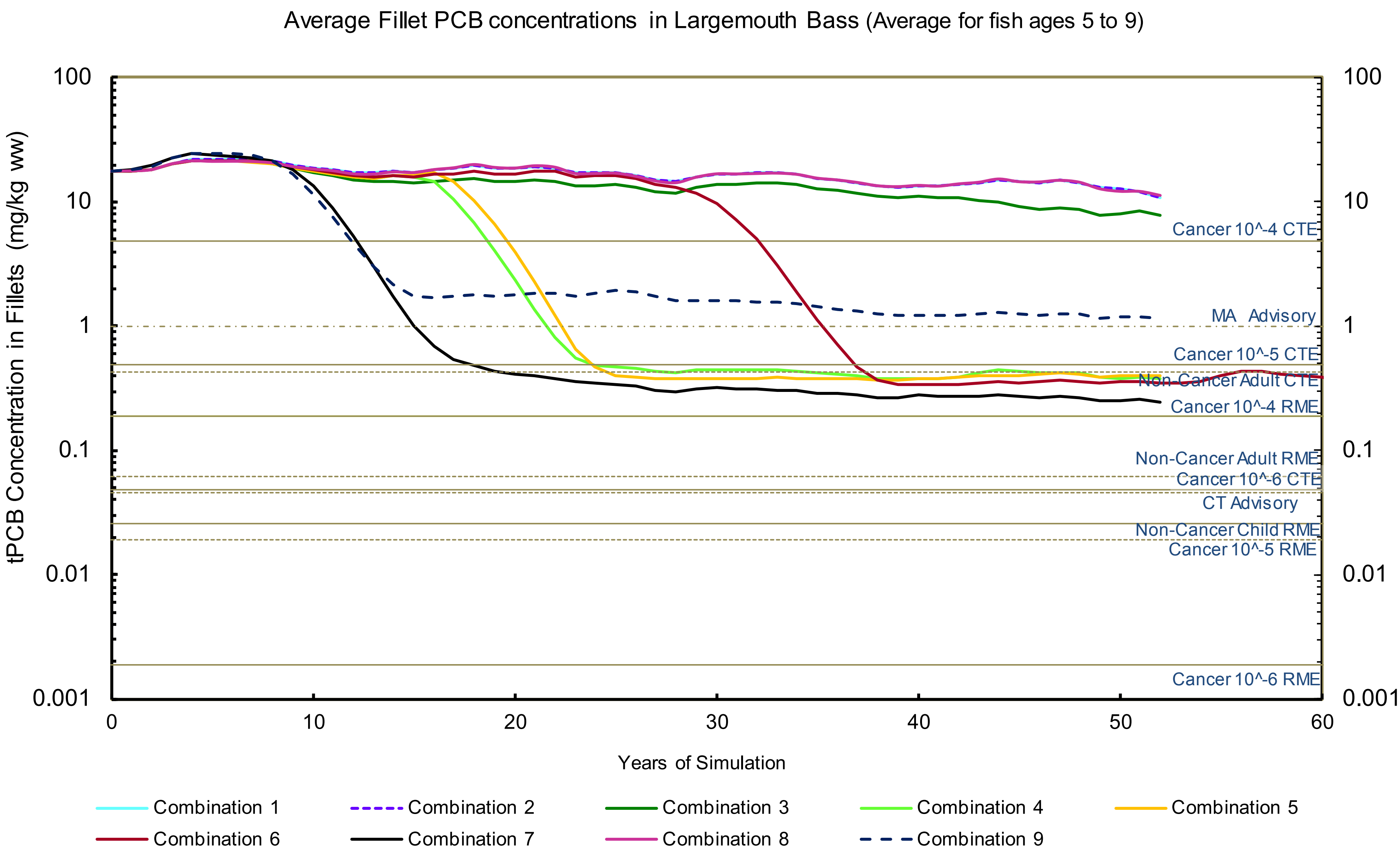
Largemouth Bass, Reach 5A



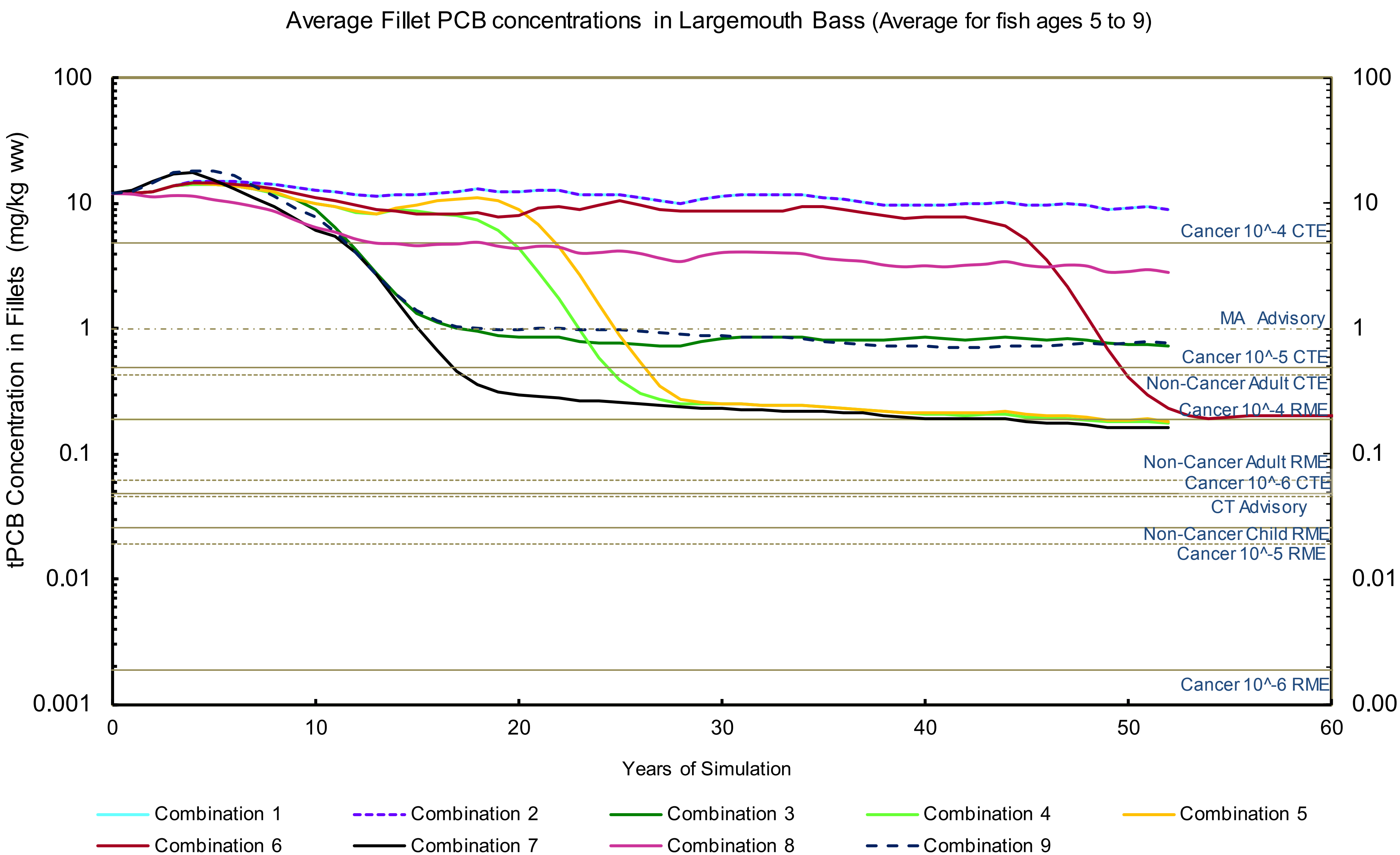
Largemouth Bass, Reach 5B



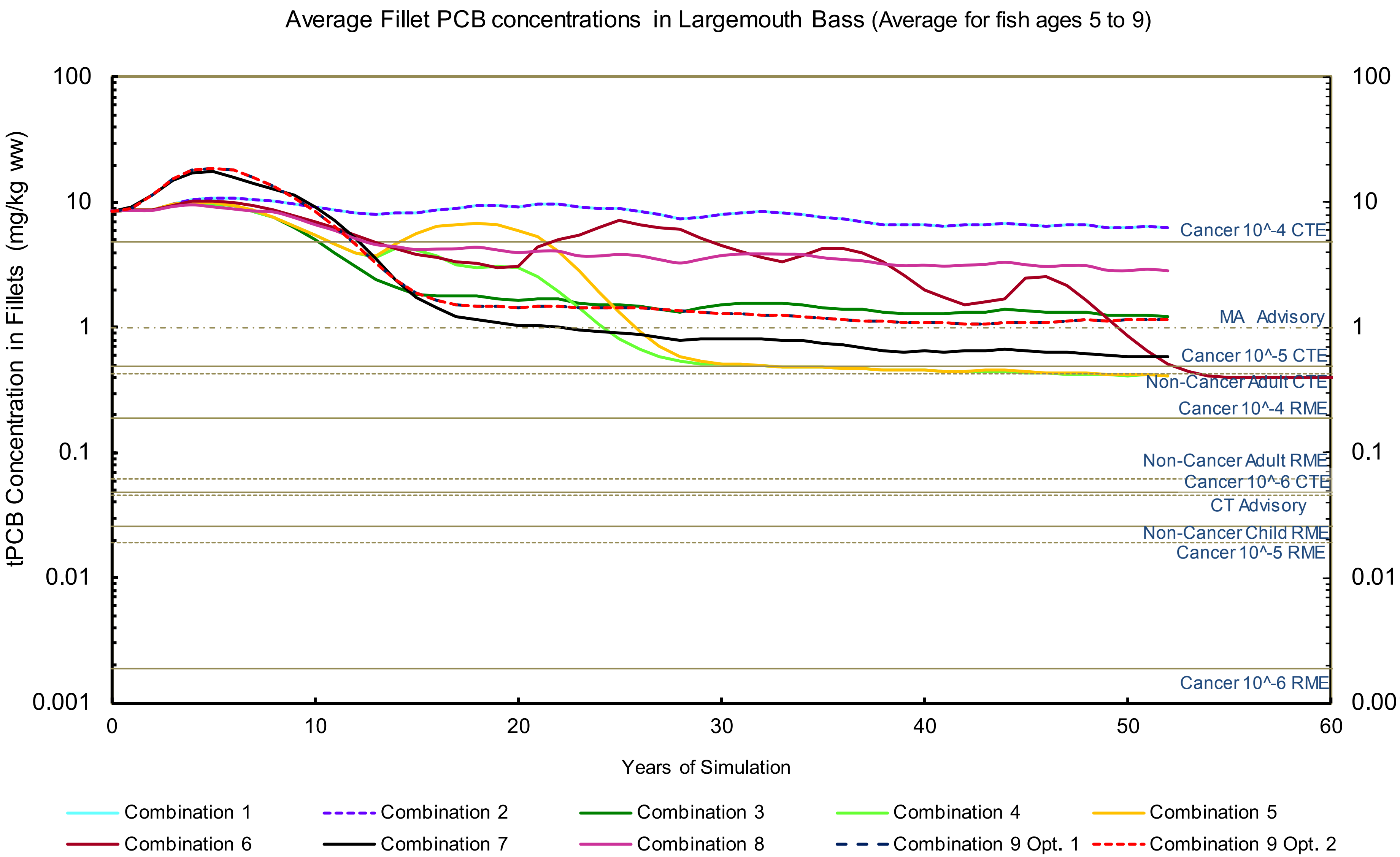
Largemouth Bass, Reach 5C



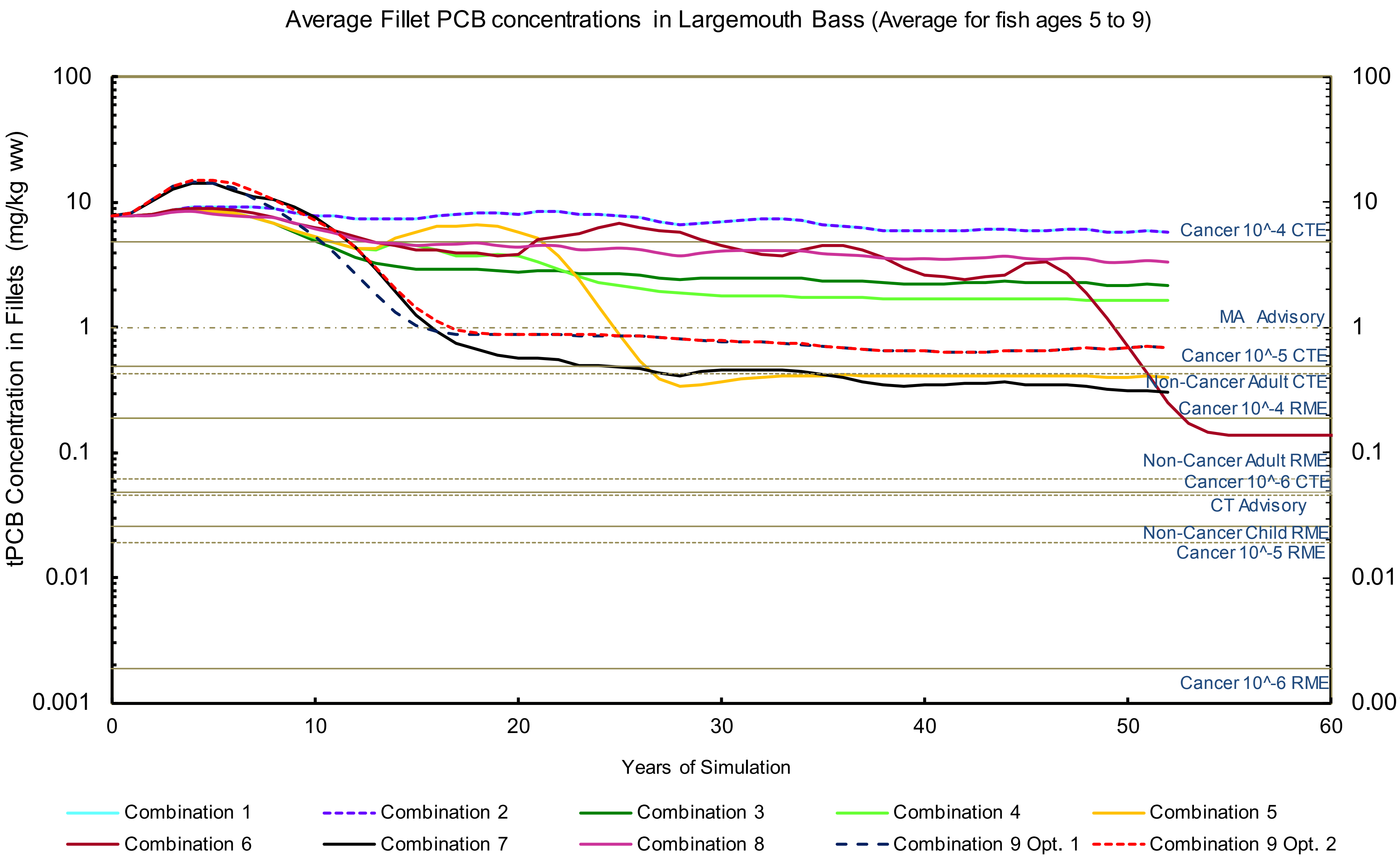
Largemouth Bass, Reach 5D



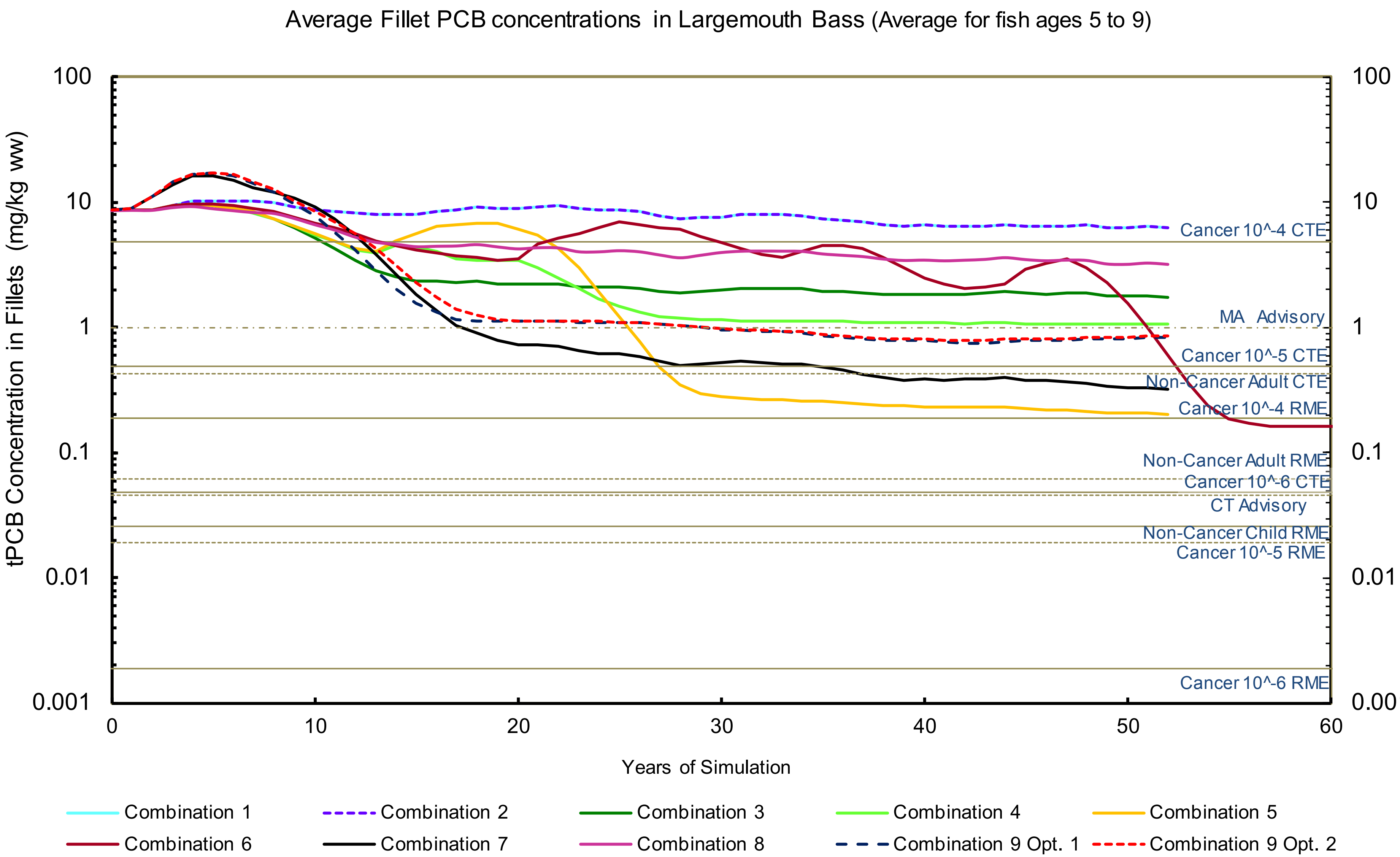
Largemouth Bass, Reach 6



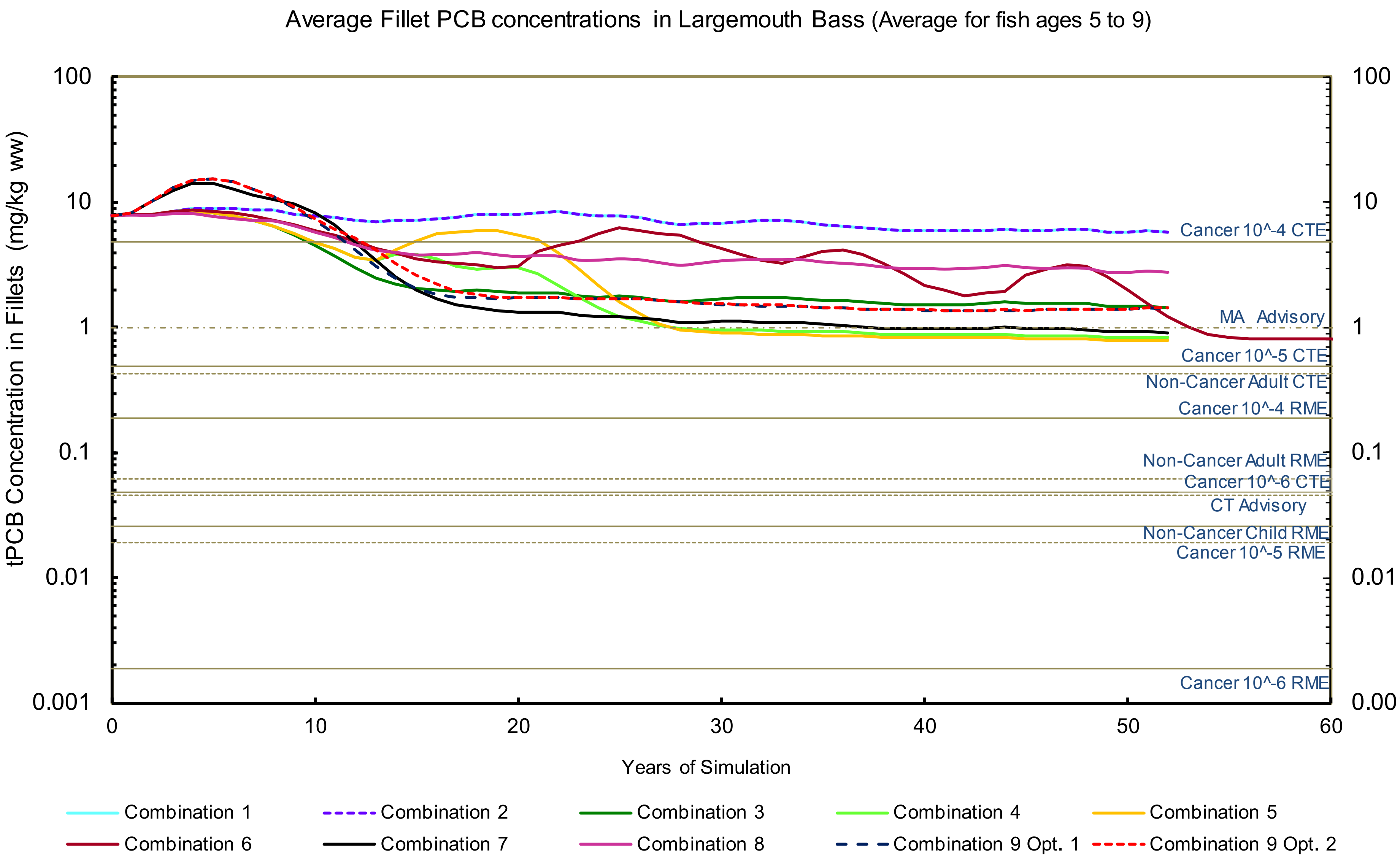
Largemouth Bass, Reach 7A



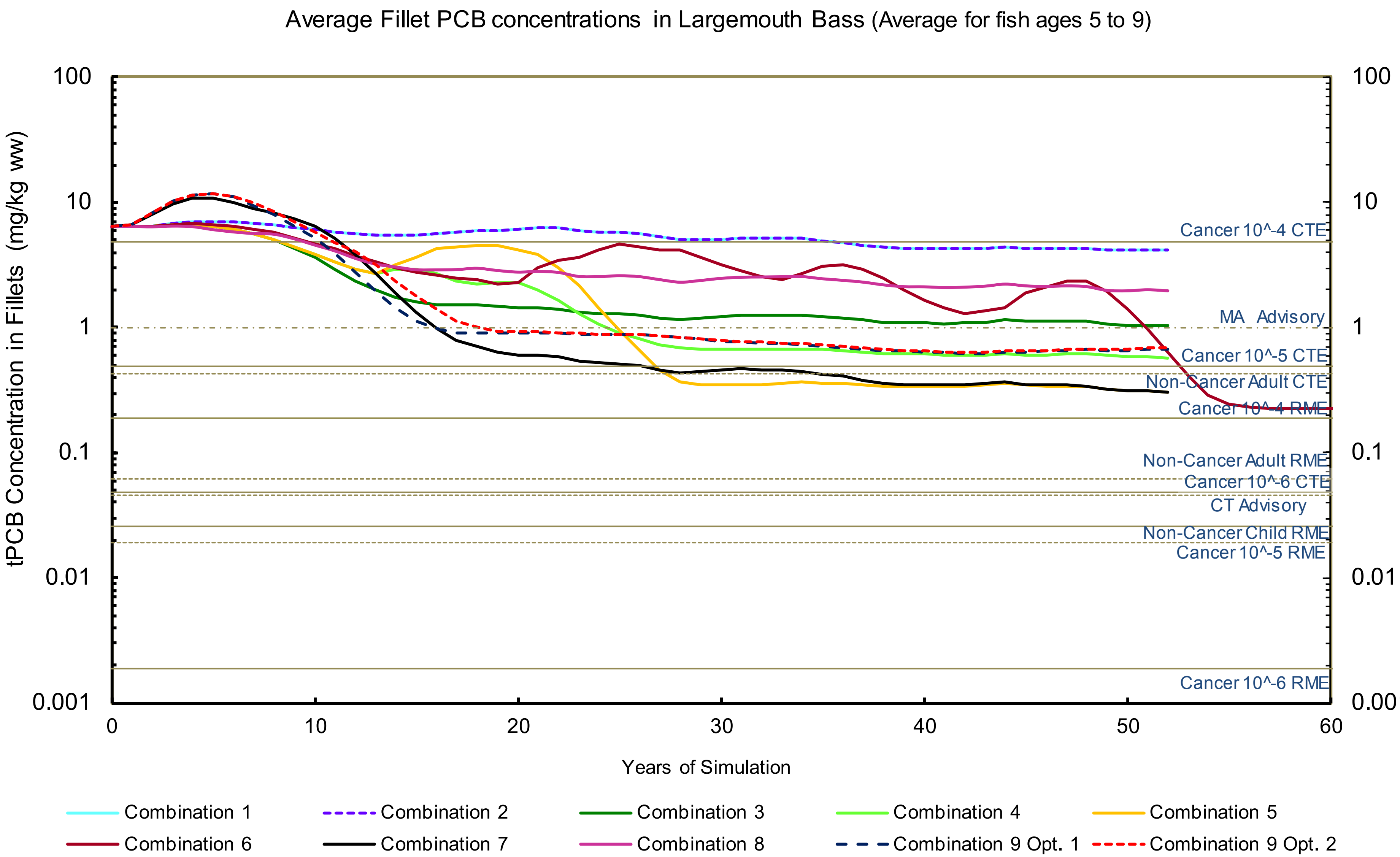
Largemouth Bass, Reach 7B



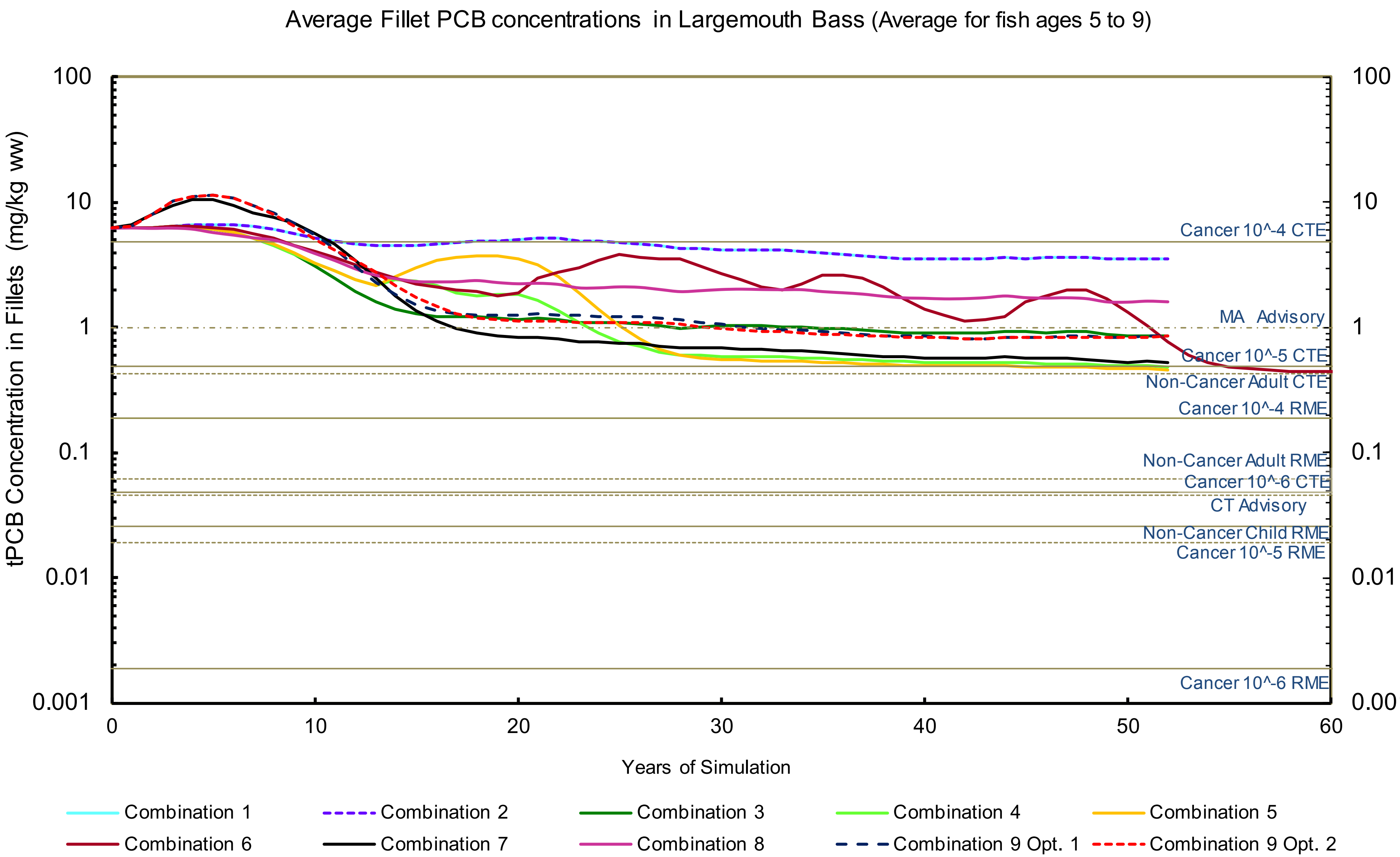
Largemouth Bass, Reach 7C



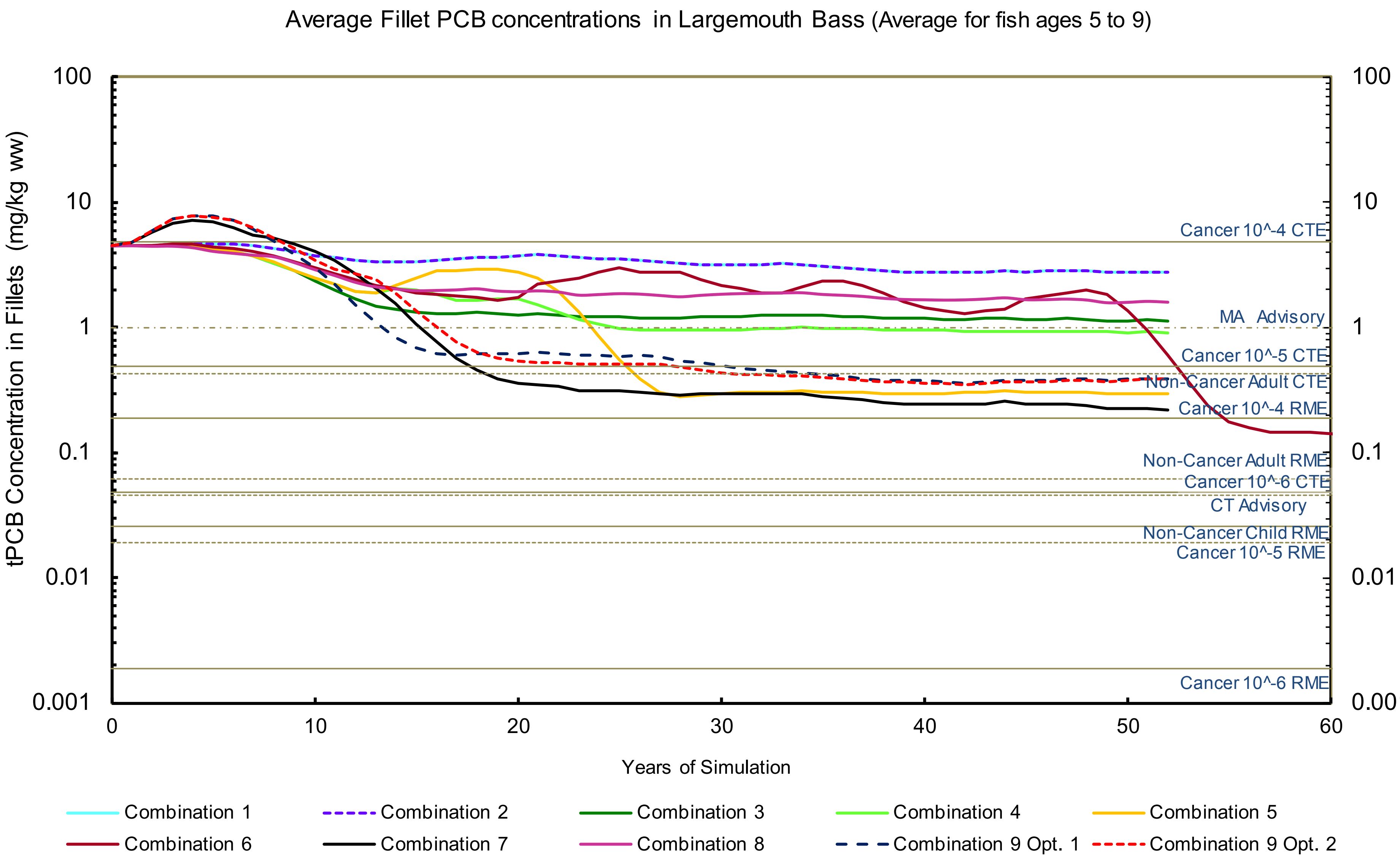
Largemouth Bass, Reach 7D



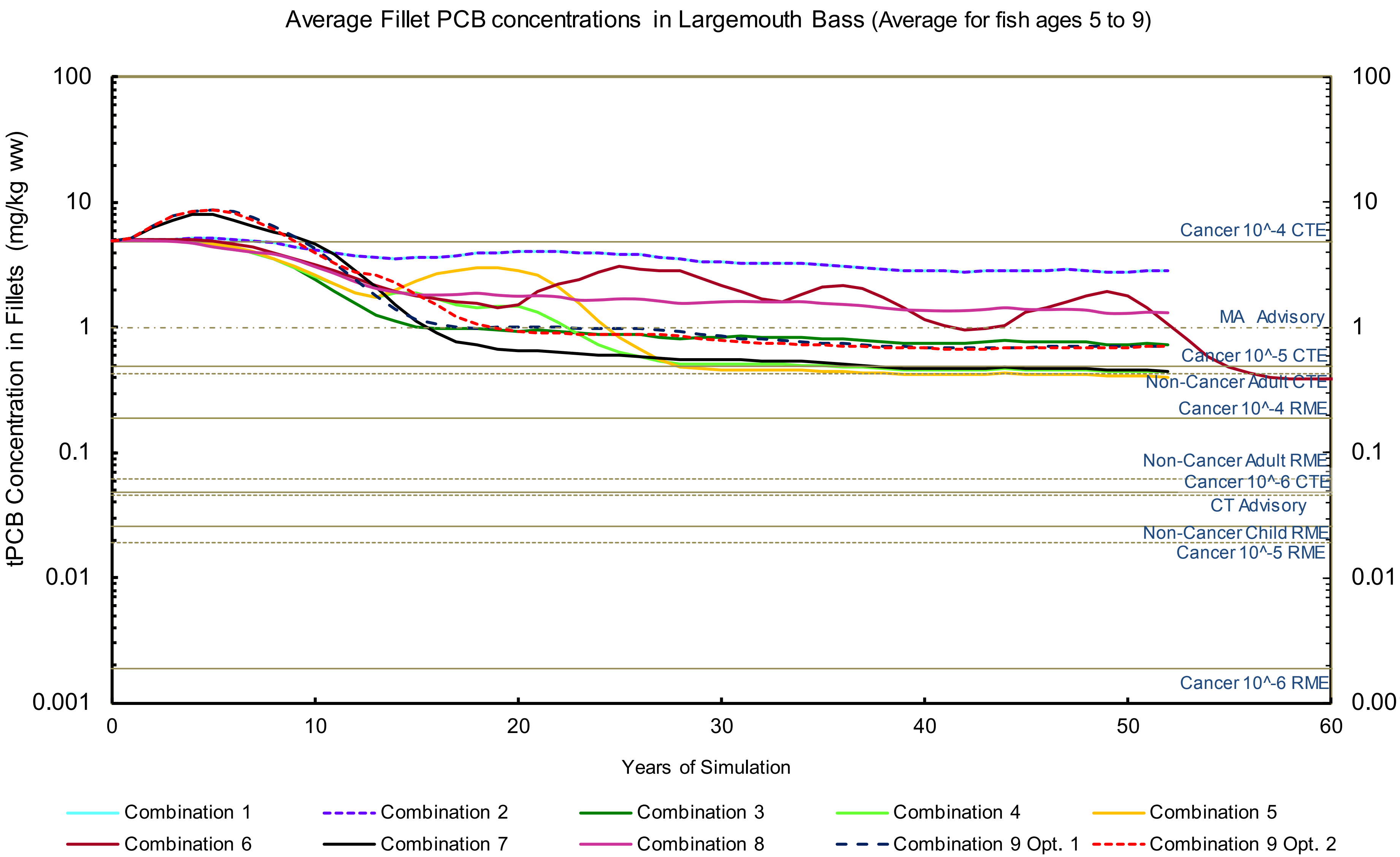
Largemouth Bass, Reach 7E



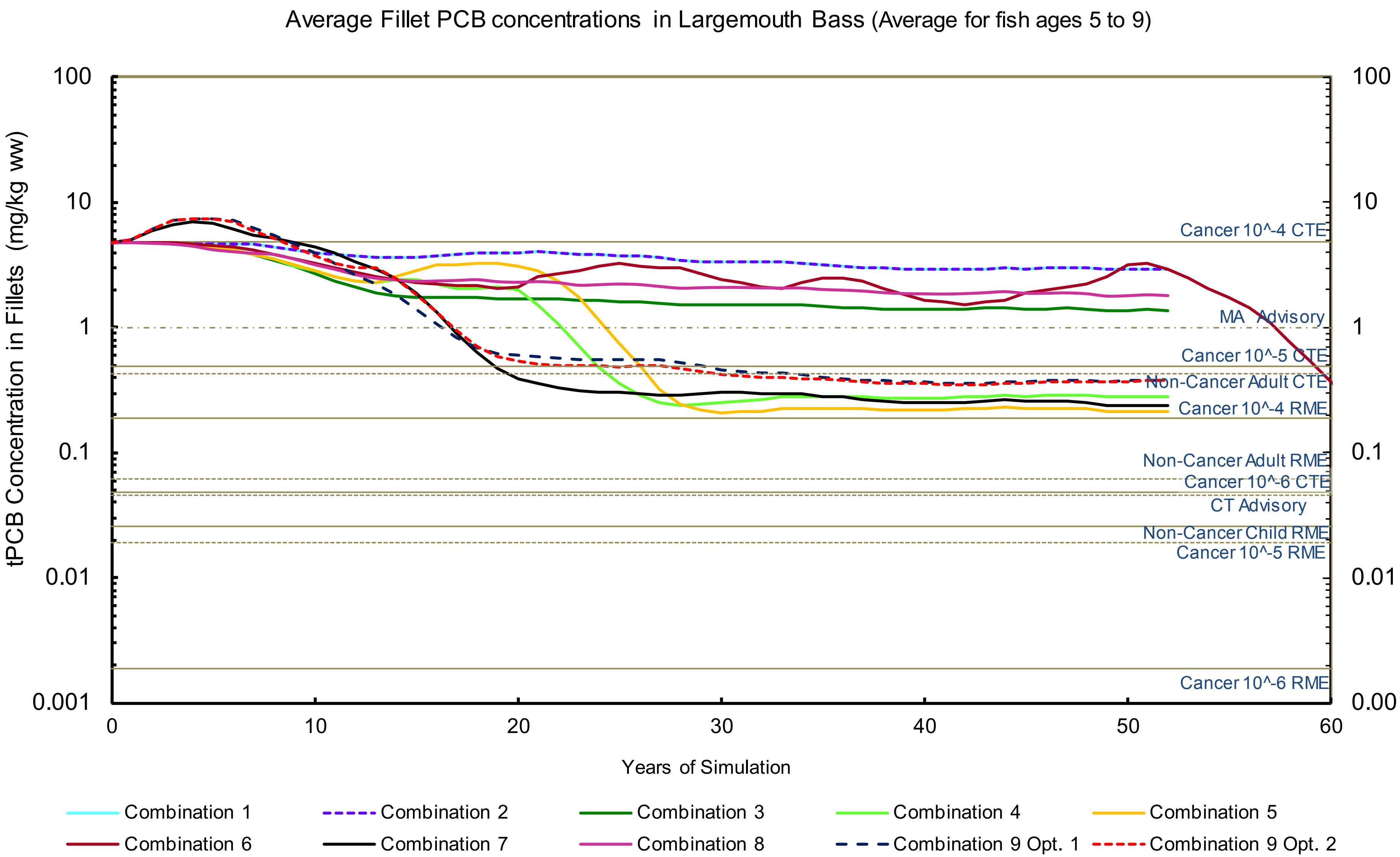
Largemouth Bass, Reach 7F



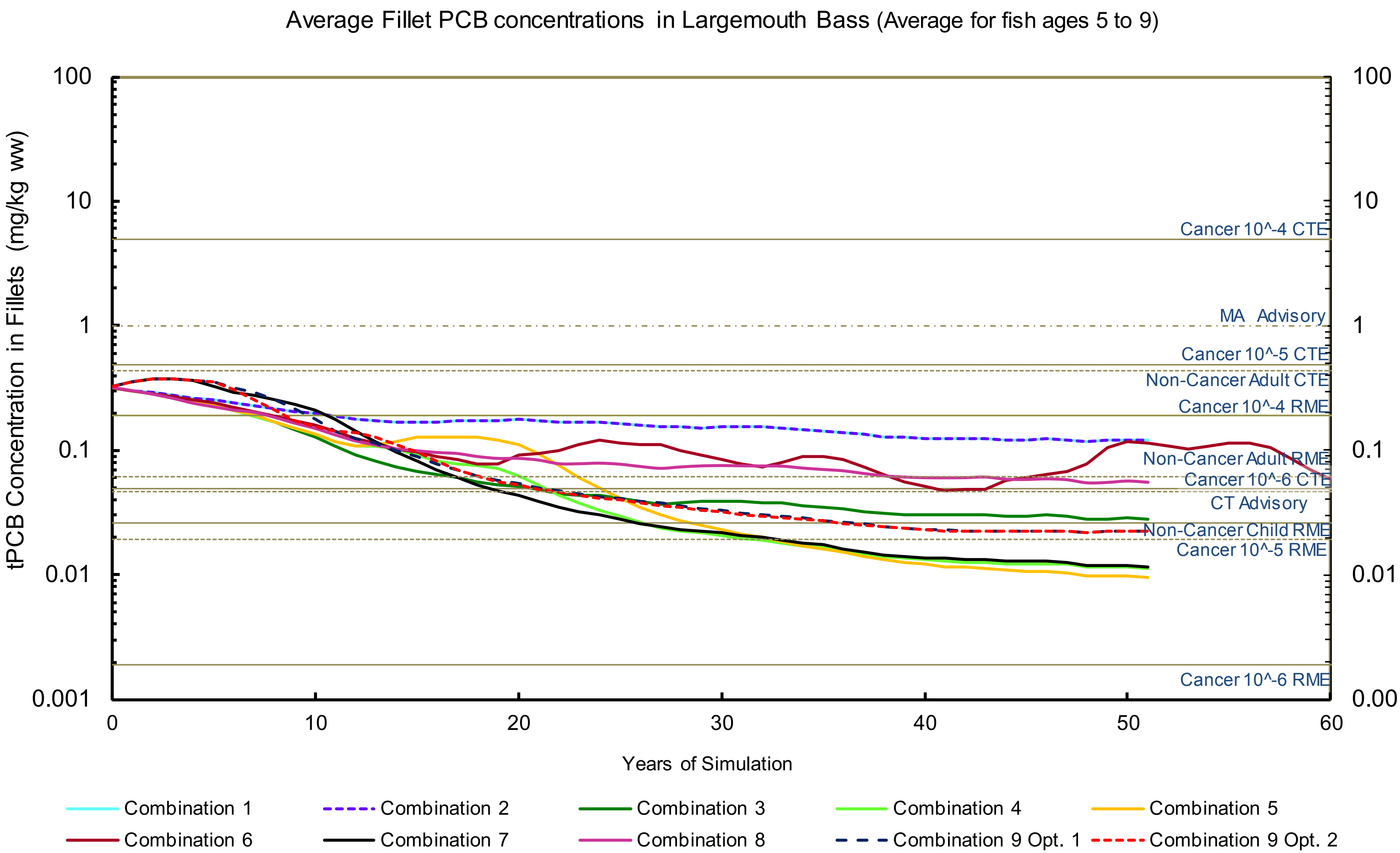
Largemouth Bass, Reach 7G



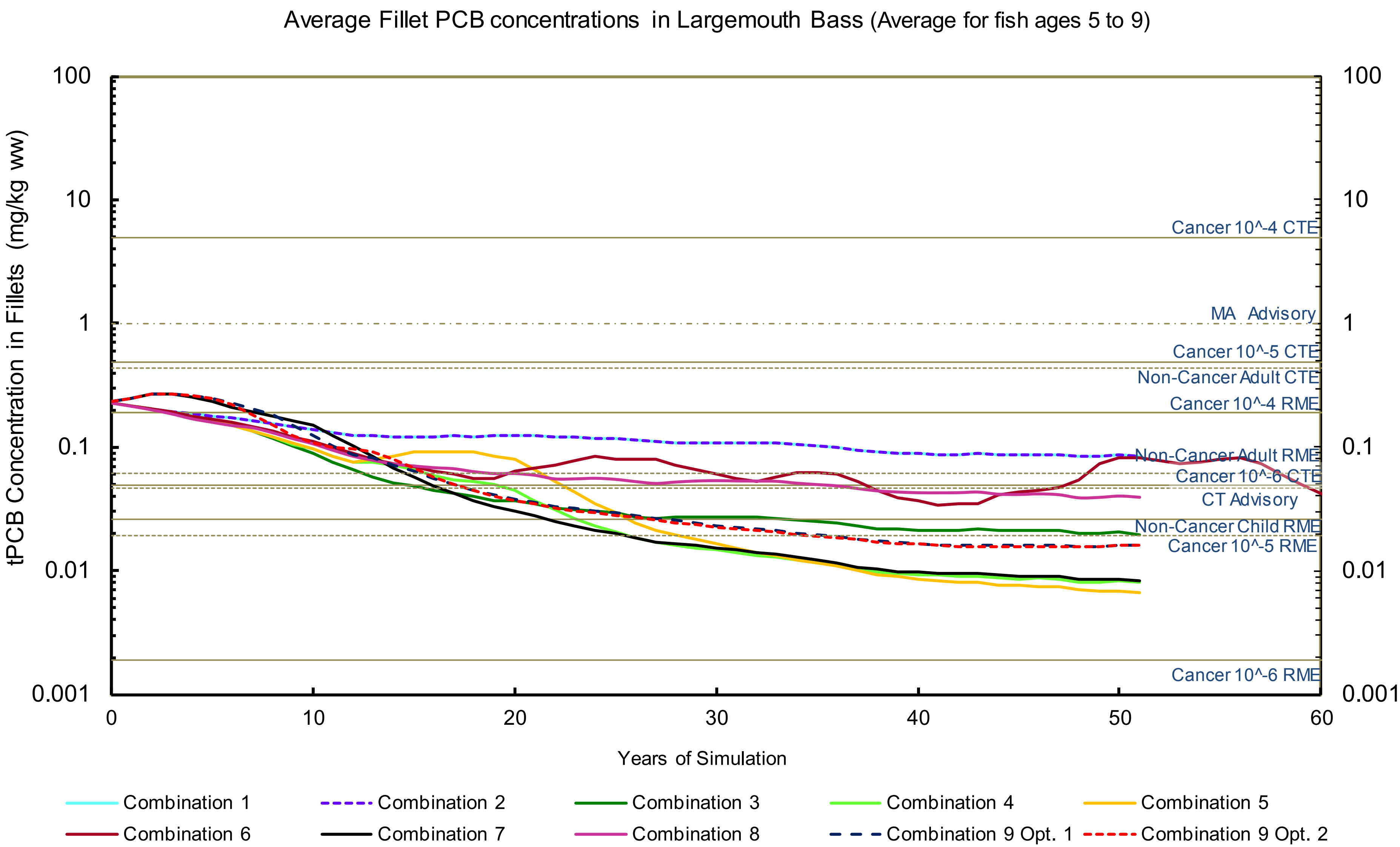
Largemouth Bass, Reach 7H



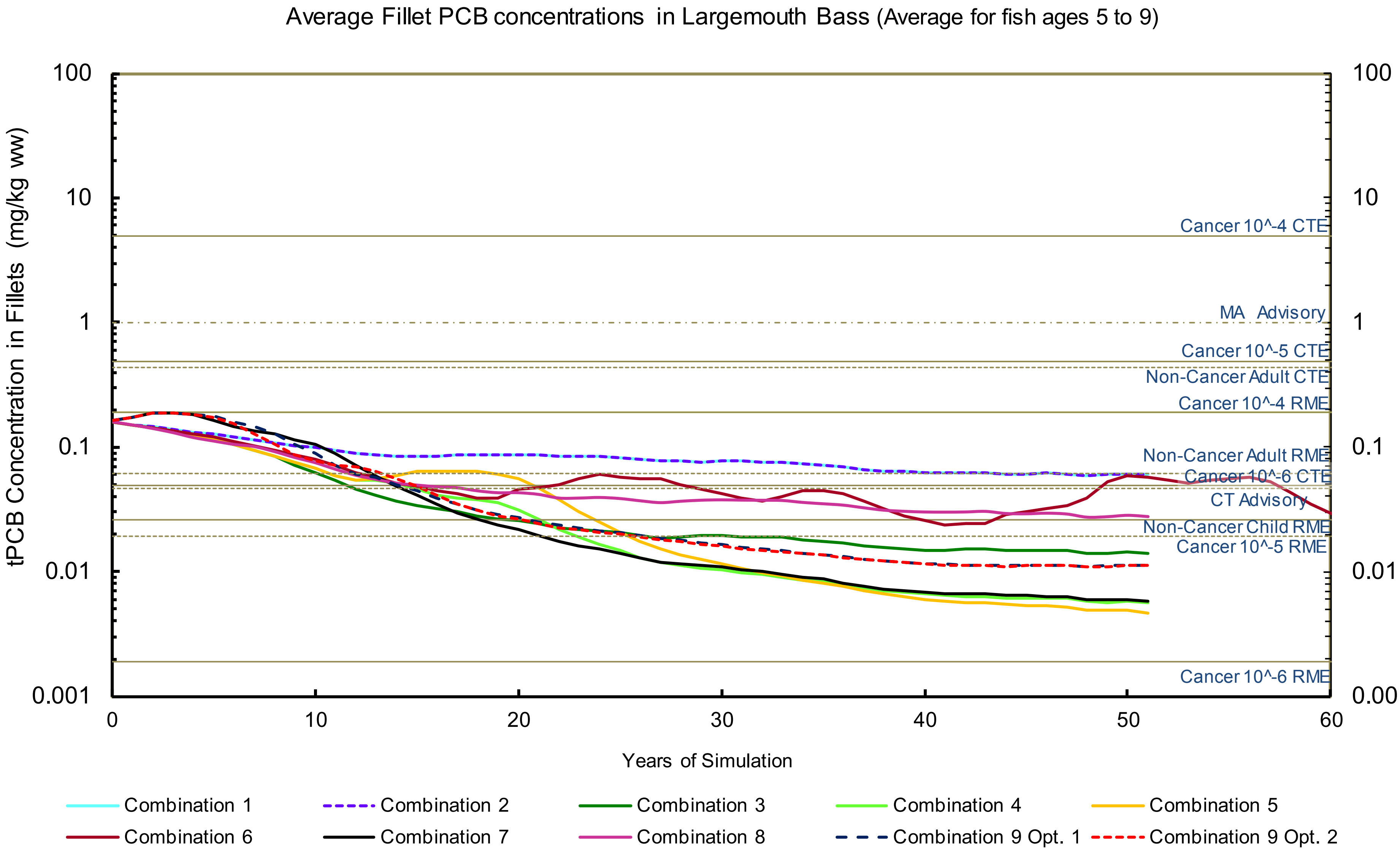
Largemouth Bass, Reach 8



Largemouth Bass, Bulls Bridge

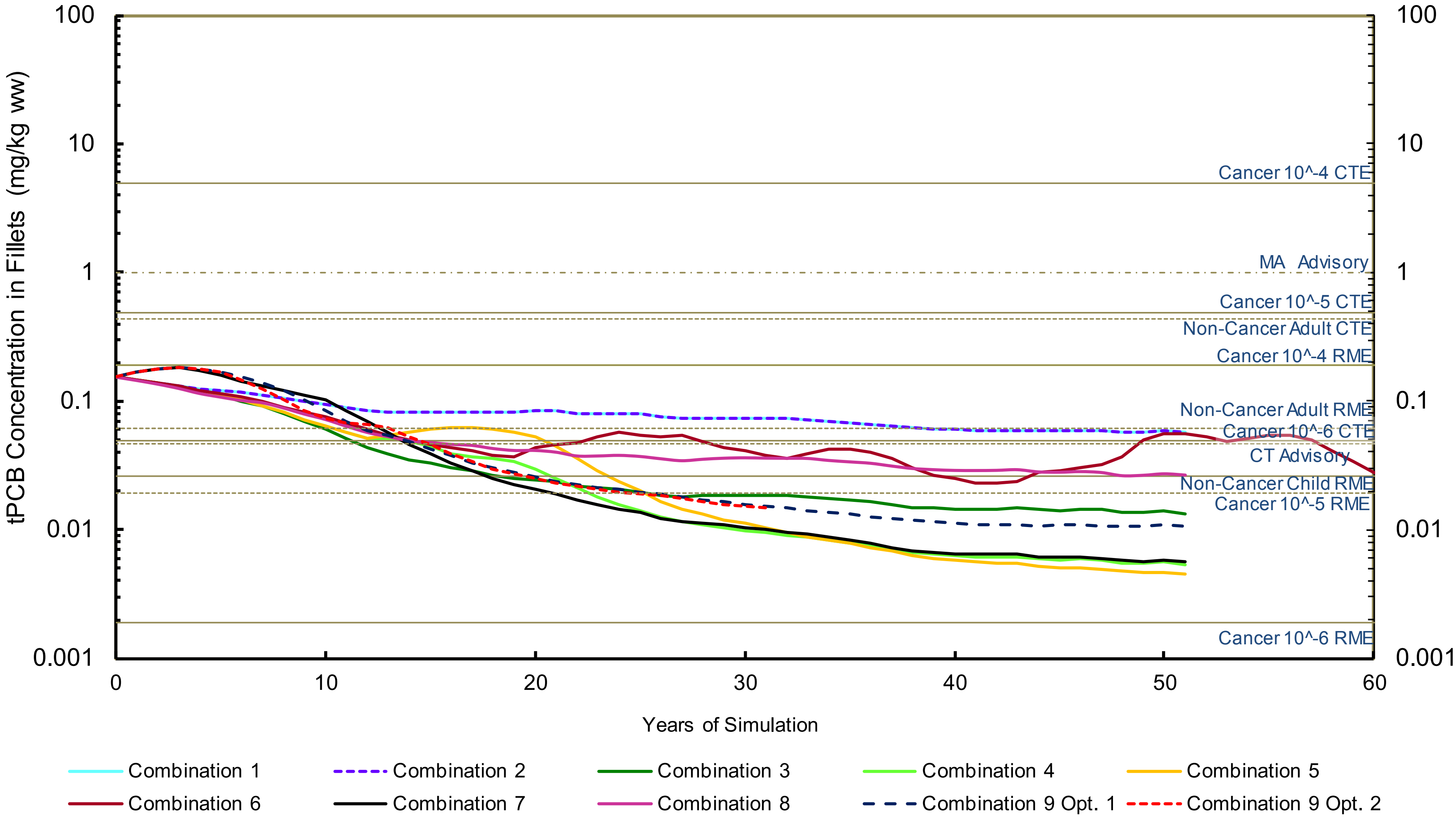


Largemouth Bass, Lake Lillinonah

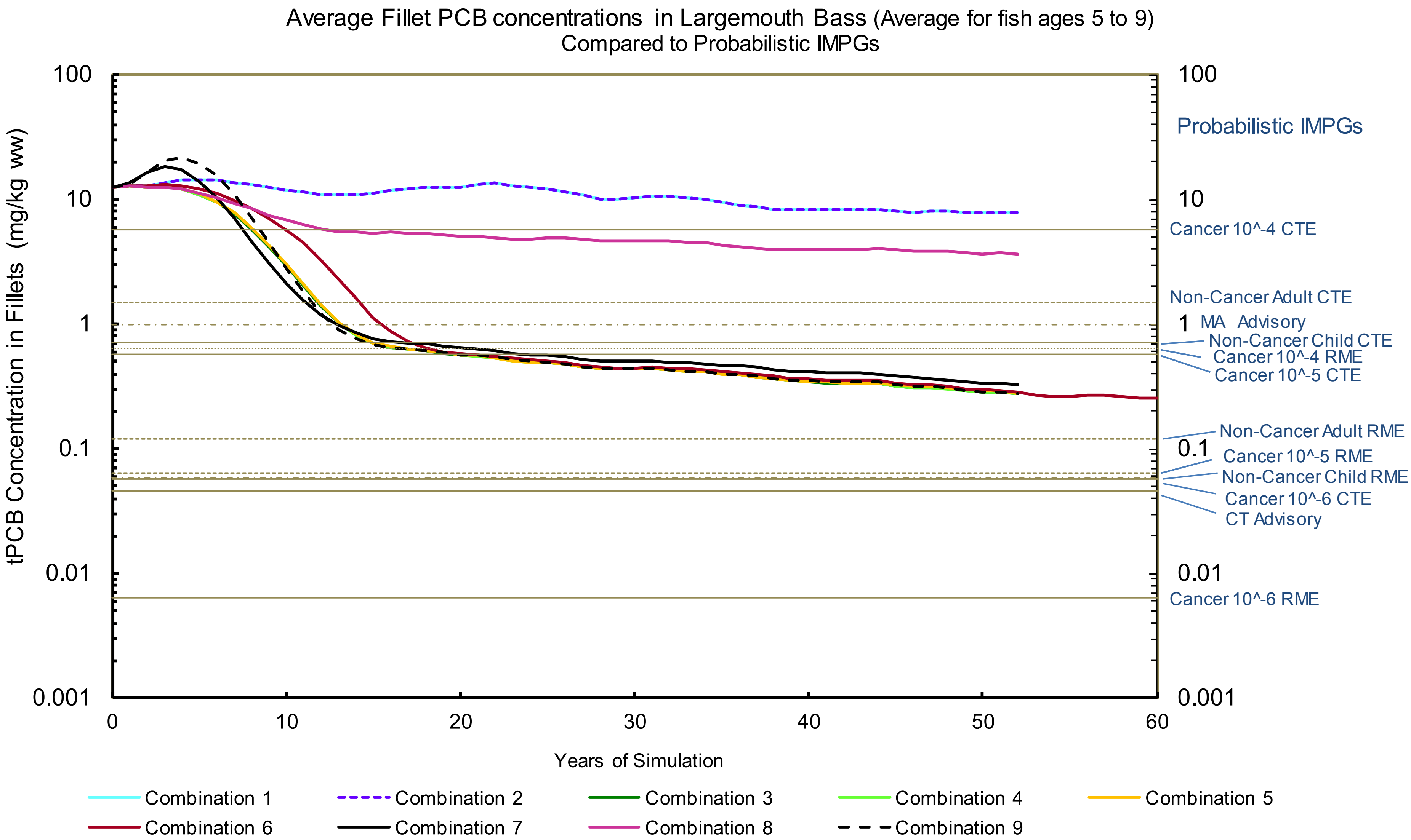


Largemouth Bass, Lake Zoar

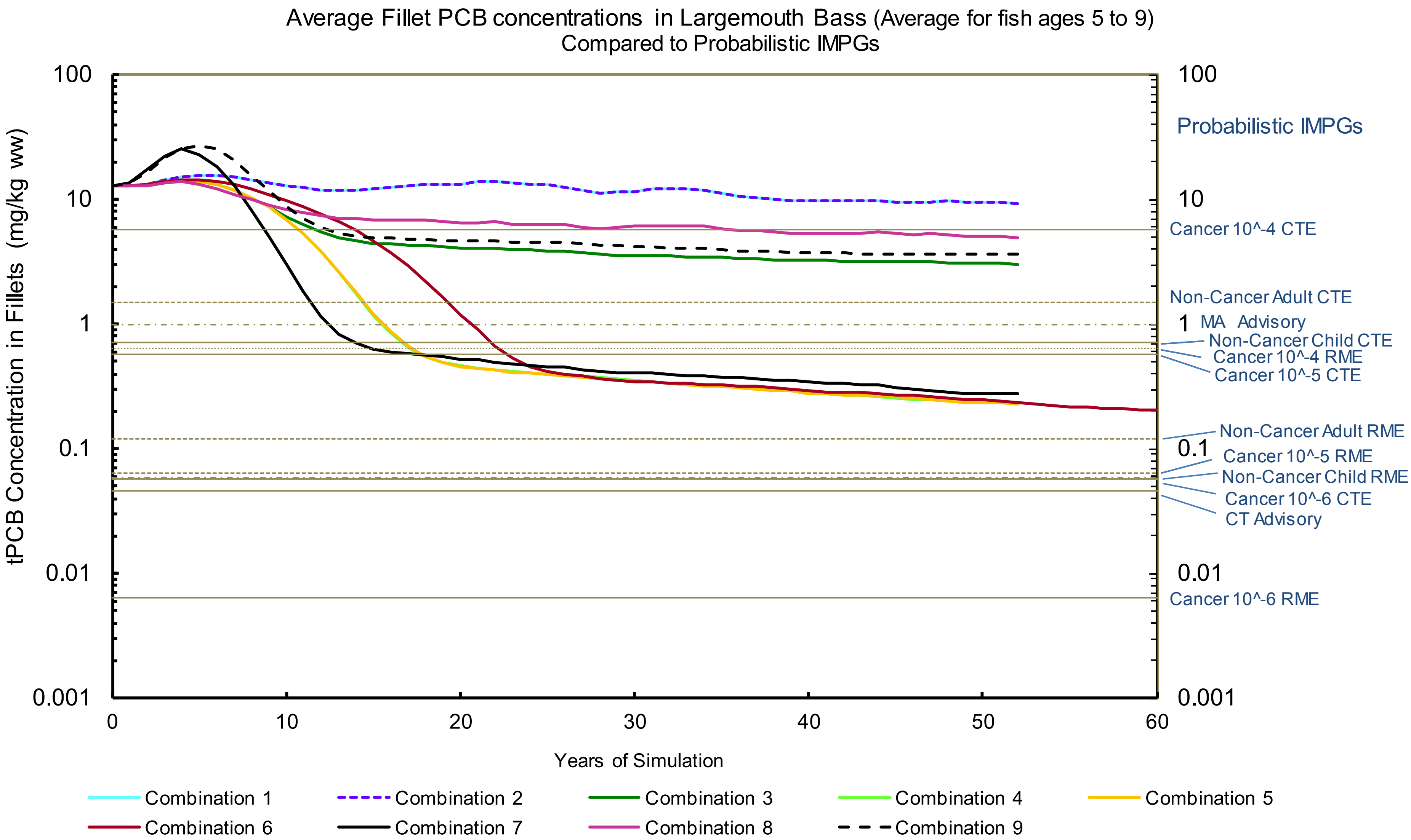
Average Fillet PCB concentrations in Largemouth Bass (Average for fish ages 5 to 9)



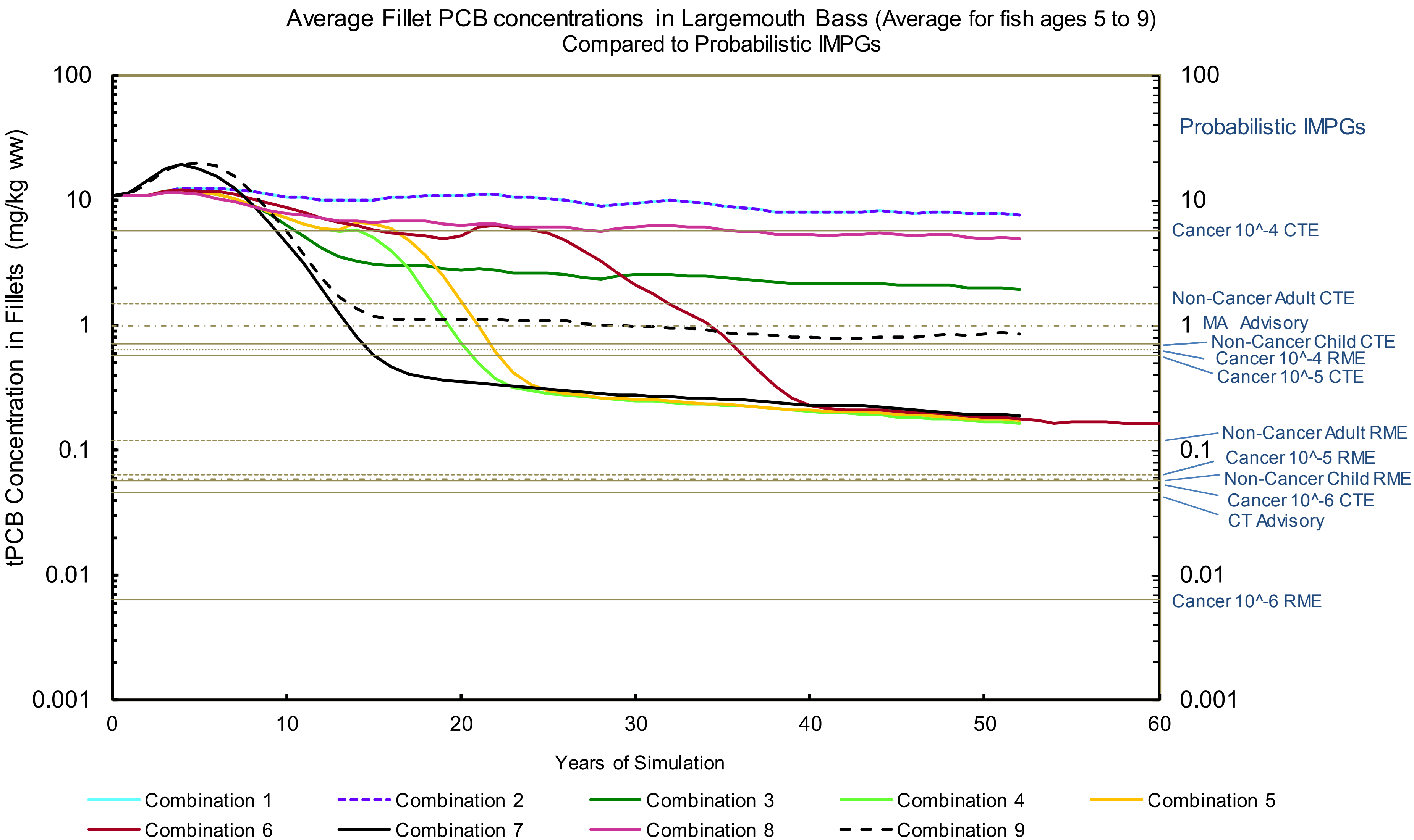
Largemouth Bass, Lake Housatonic



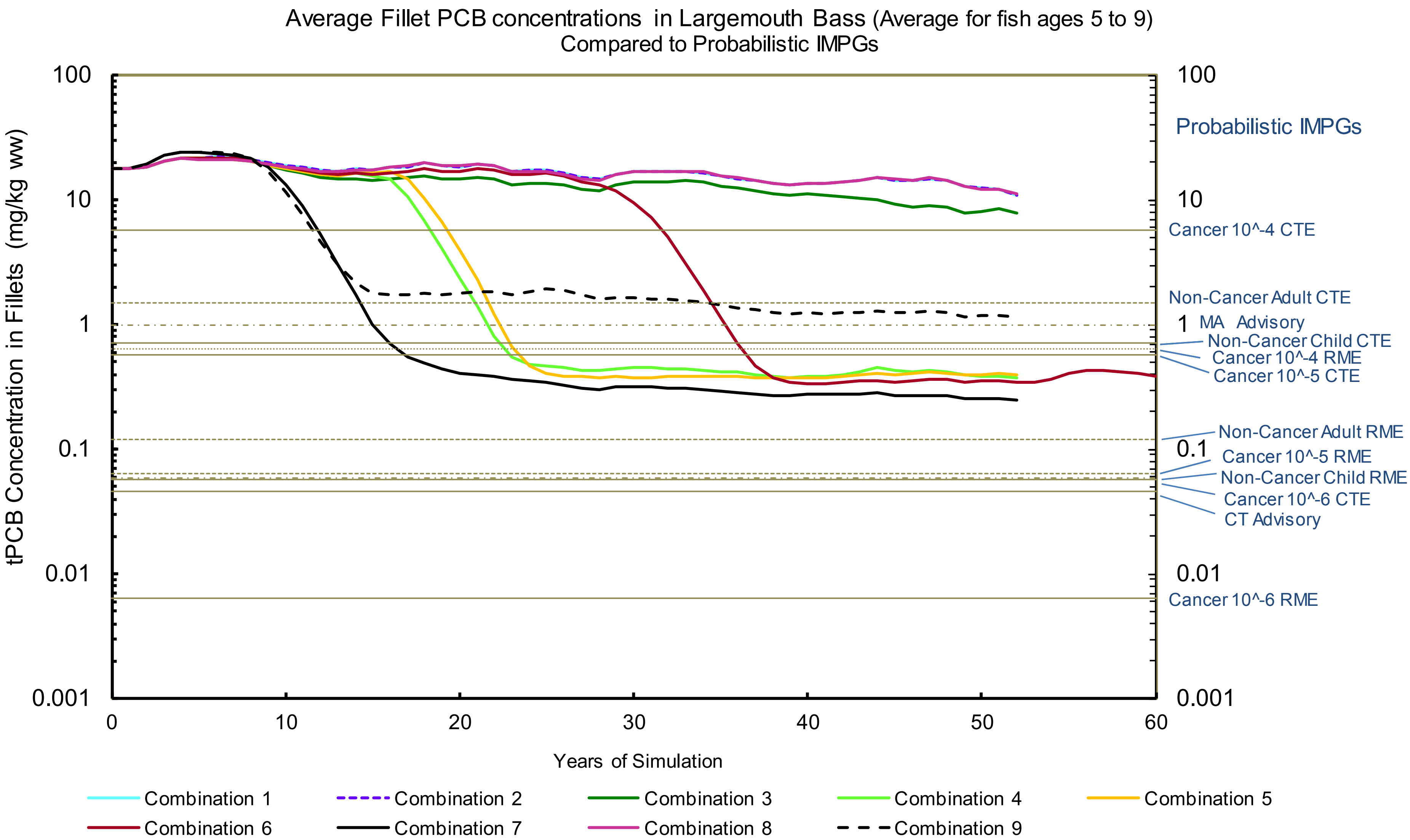
Largemouth Bass, Reach 5A, Probabilistic IMPGs



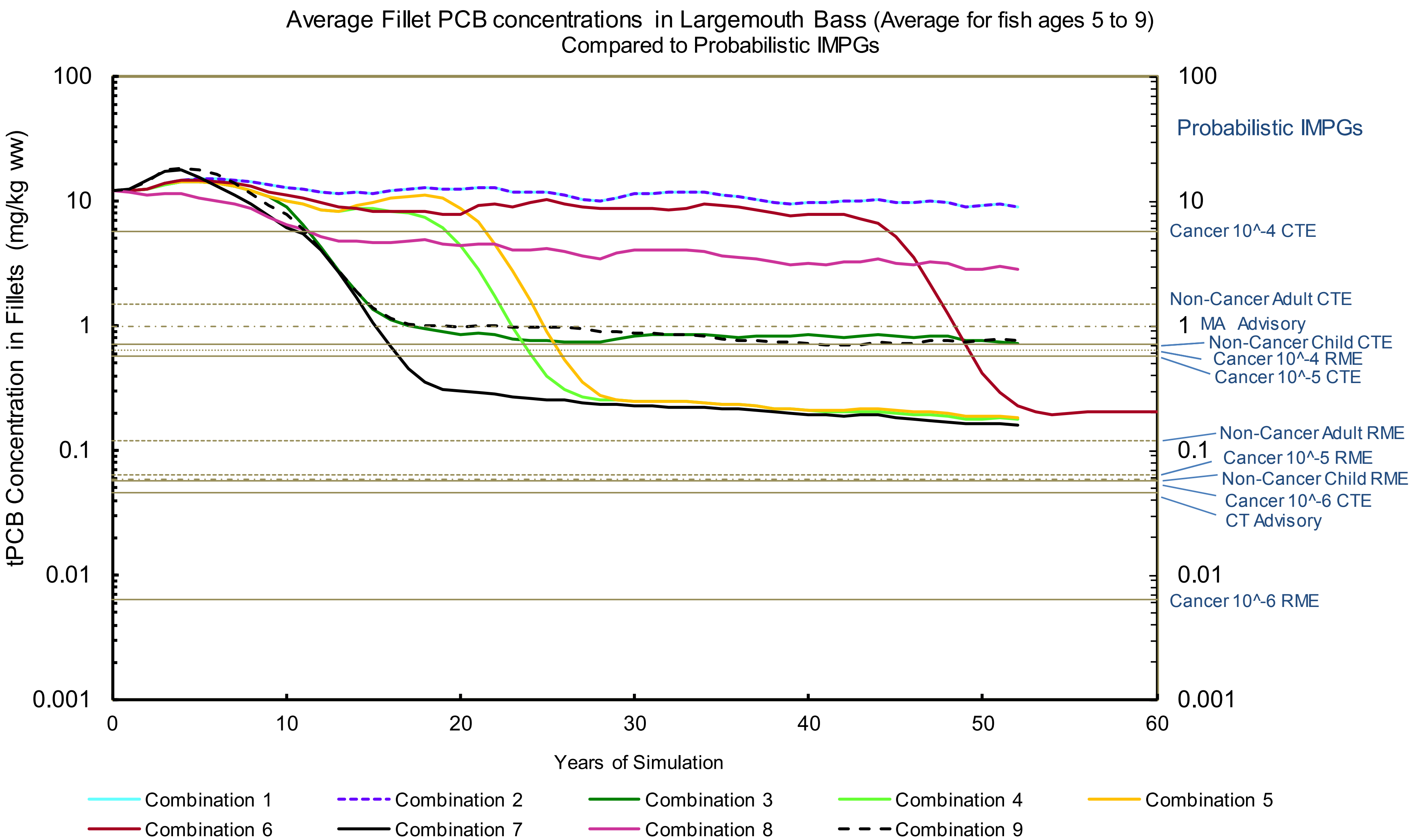
Largemouth Bass, Reach 5B, Probabilistic IMPGs



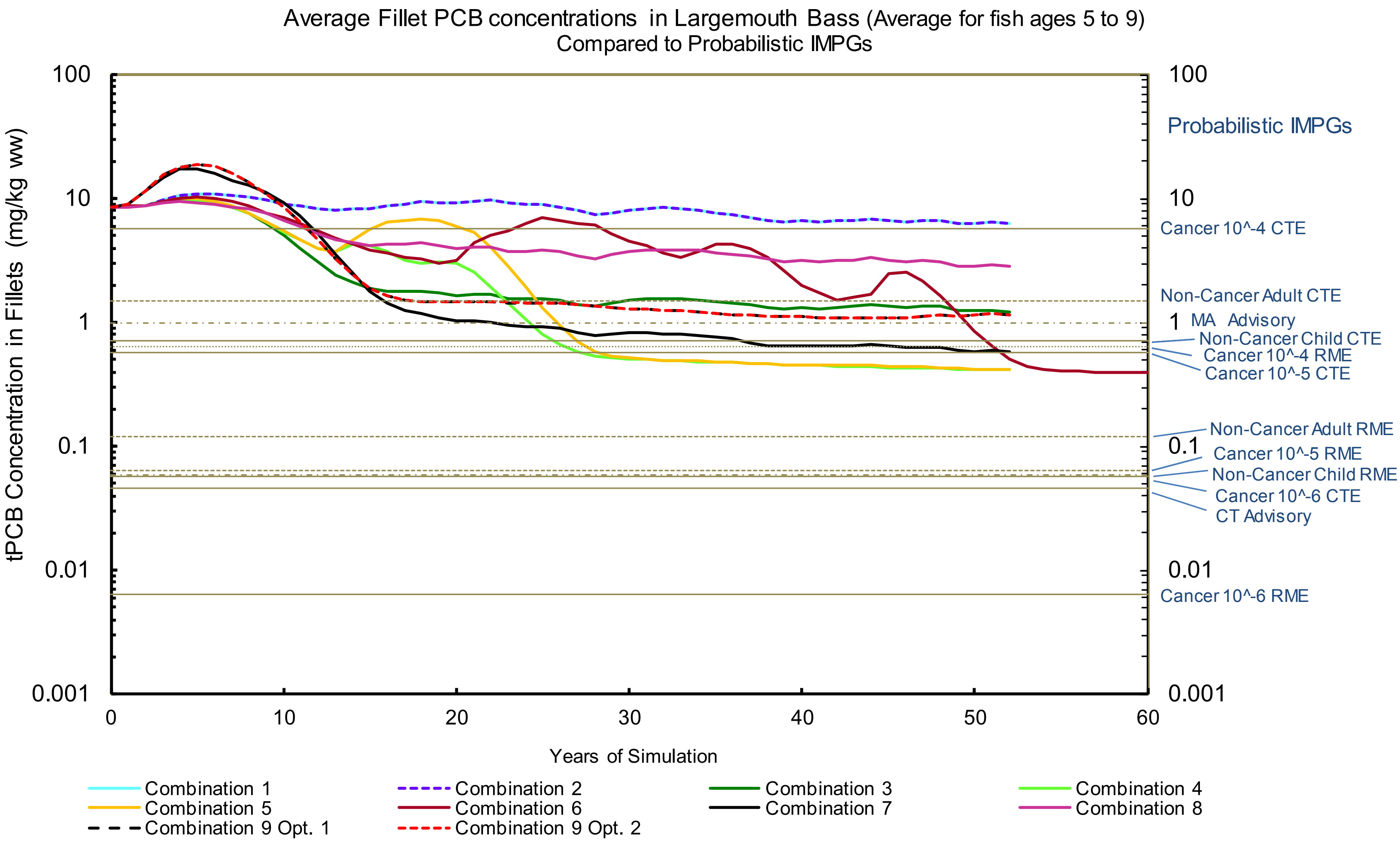
Largemouth Bass, Reach 5C, Probabilistic IMPGs



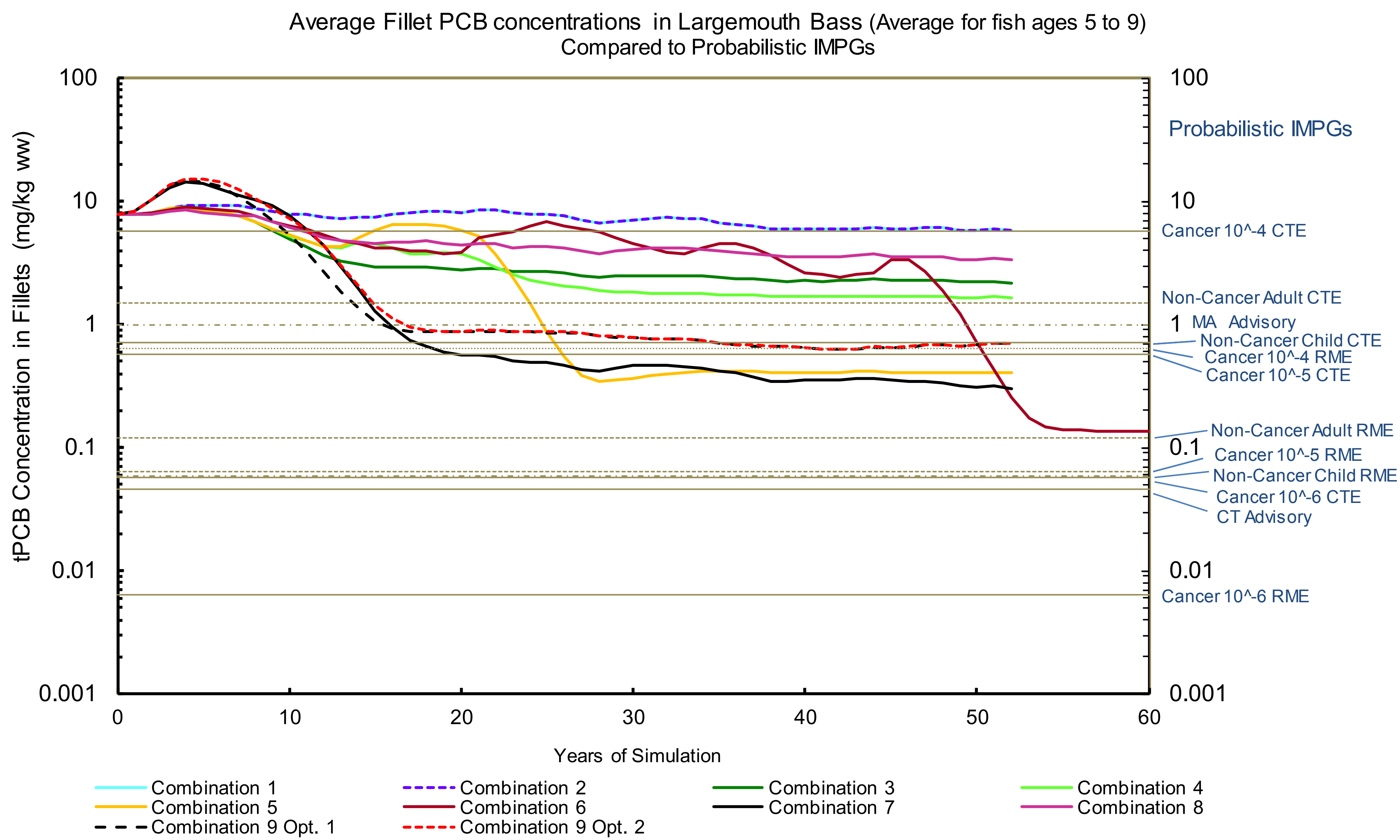
Largemouth Bass, Reach 5D, Probabilistic IMPGs



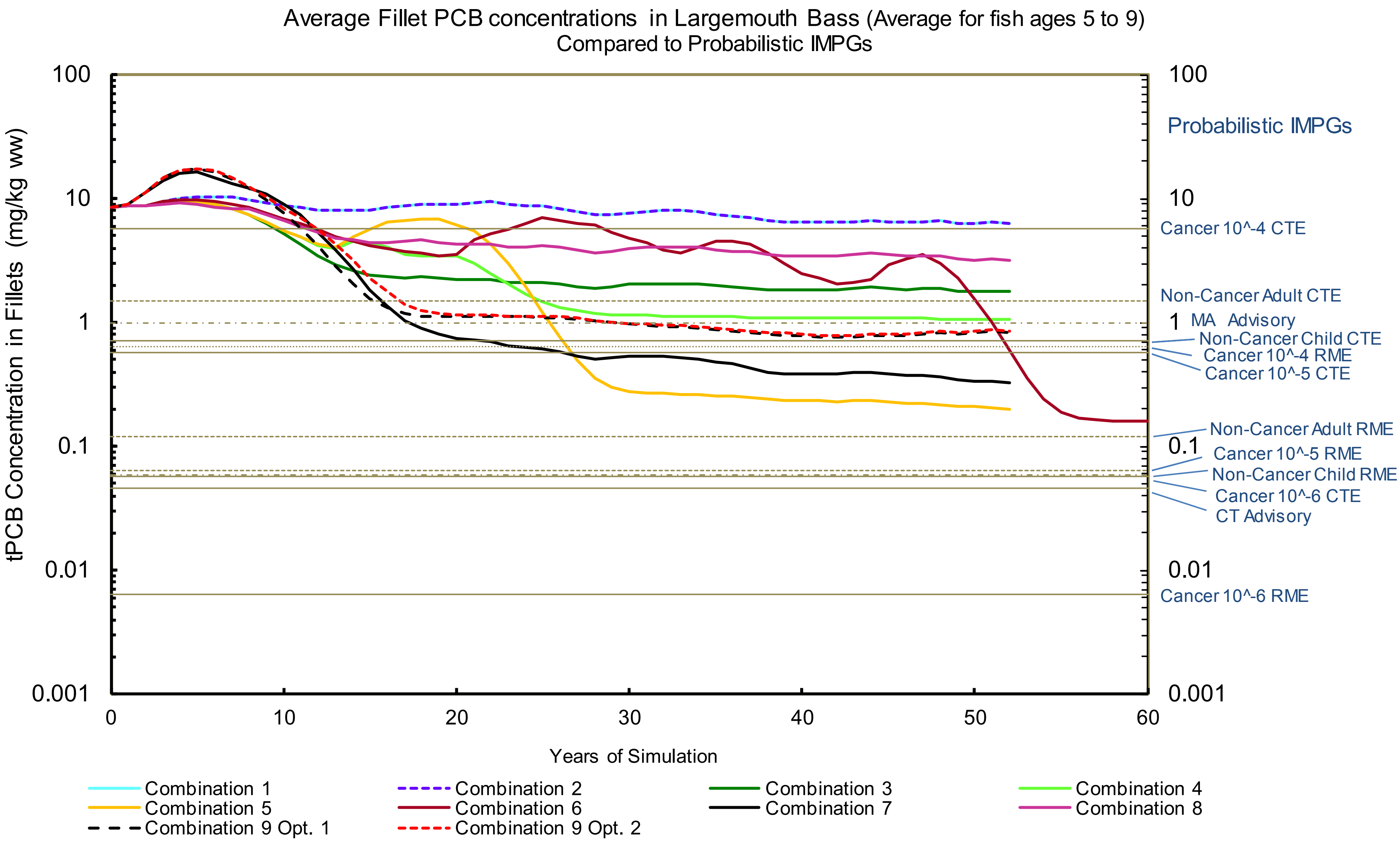
Largemouth Bass, Reach 6, Probabilistic IMPGs



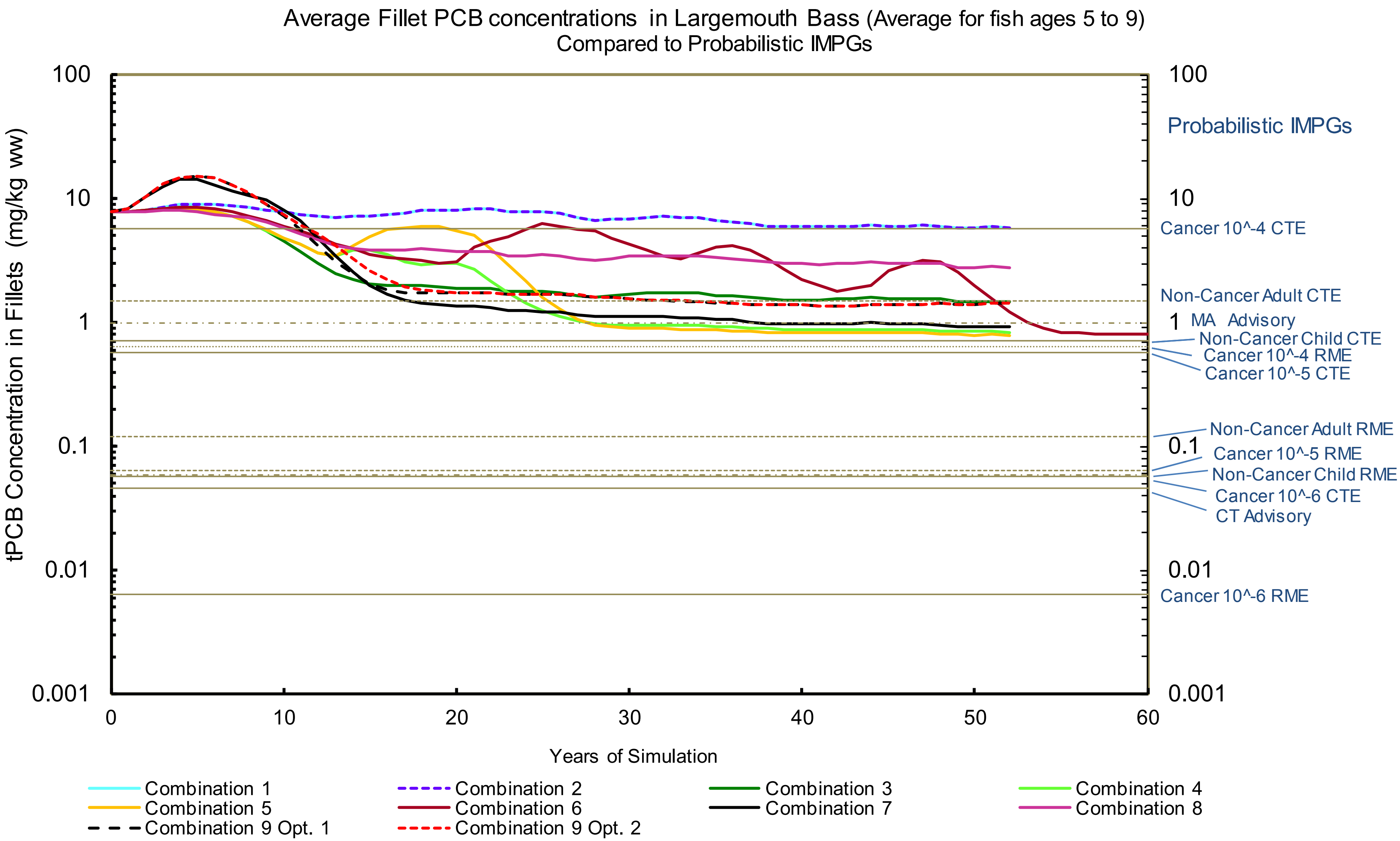
Largemouth Bass, Reach 7A, Probabilistic IMPGs



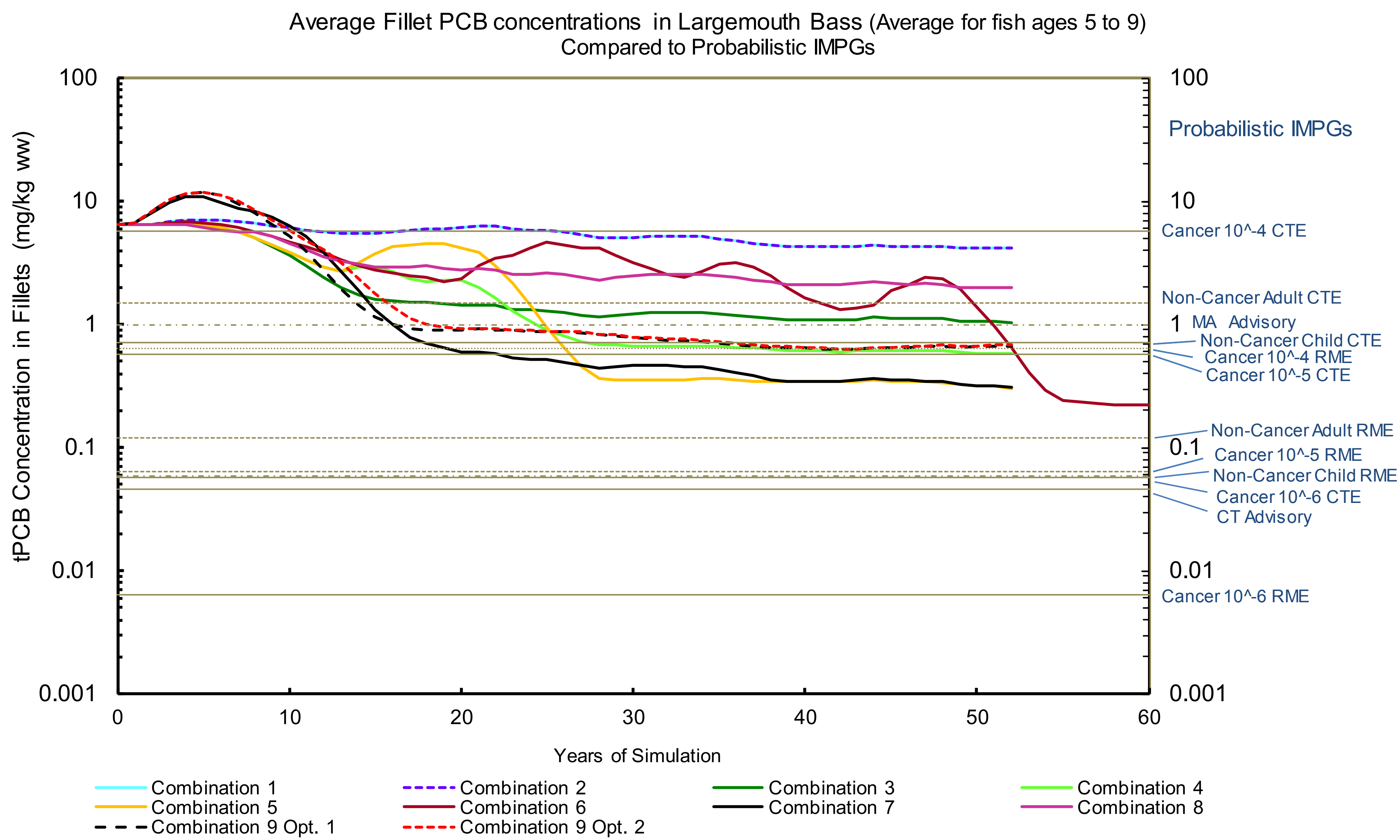
Largemouth Bass, Reach 7B, Probabilistic IMPGs



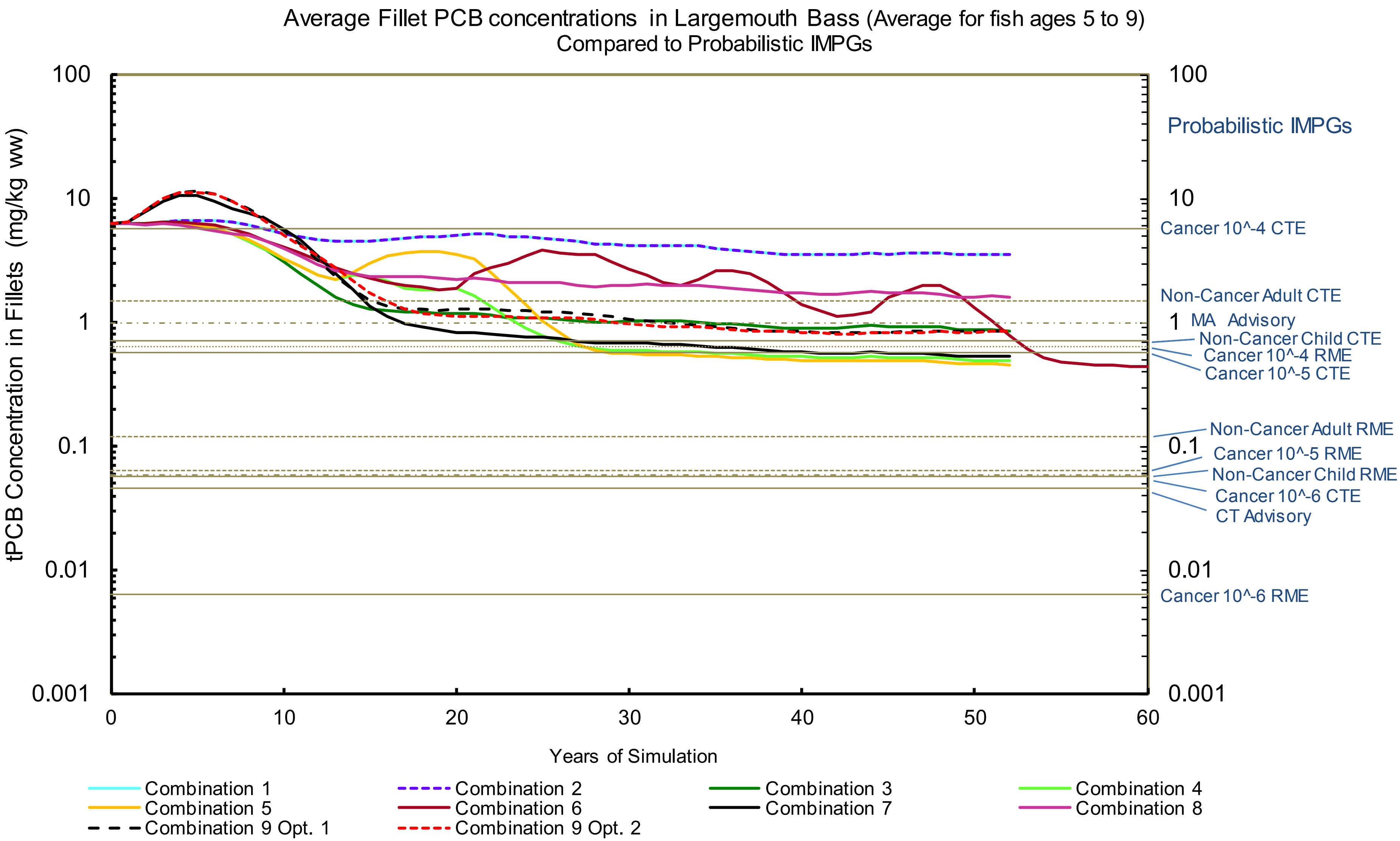
Largemouth Bass, Reach 7C, Probabilistic IMPGs



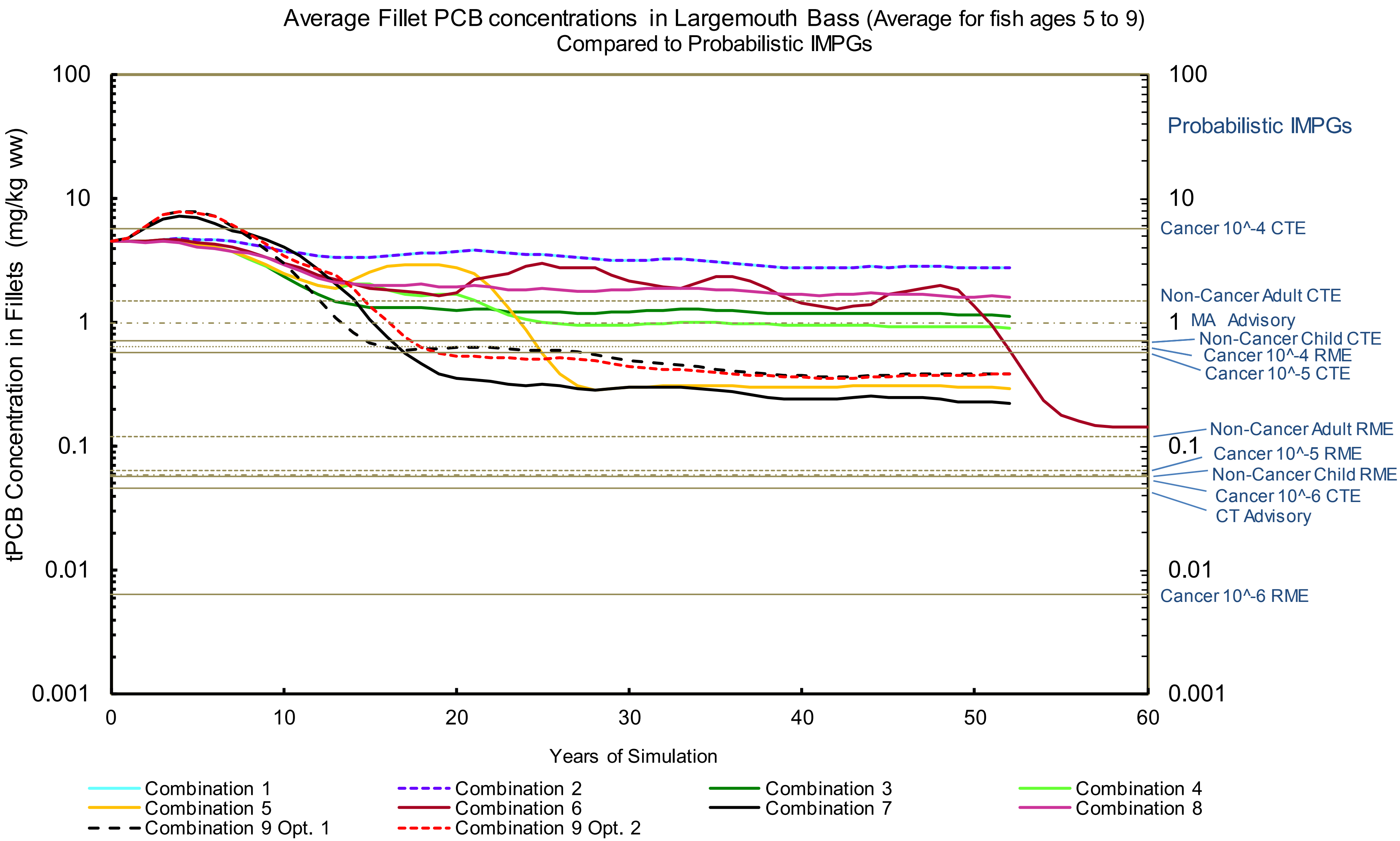
Largemouth Bass, Reach 7D, Probabilistic IMPGs



Largemouth Bass, Reach 7E, Probabilistic IMPGs



Largemouth Bass, Reach 7F, Probabilistic IMPGs



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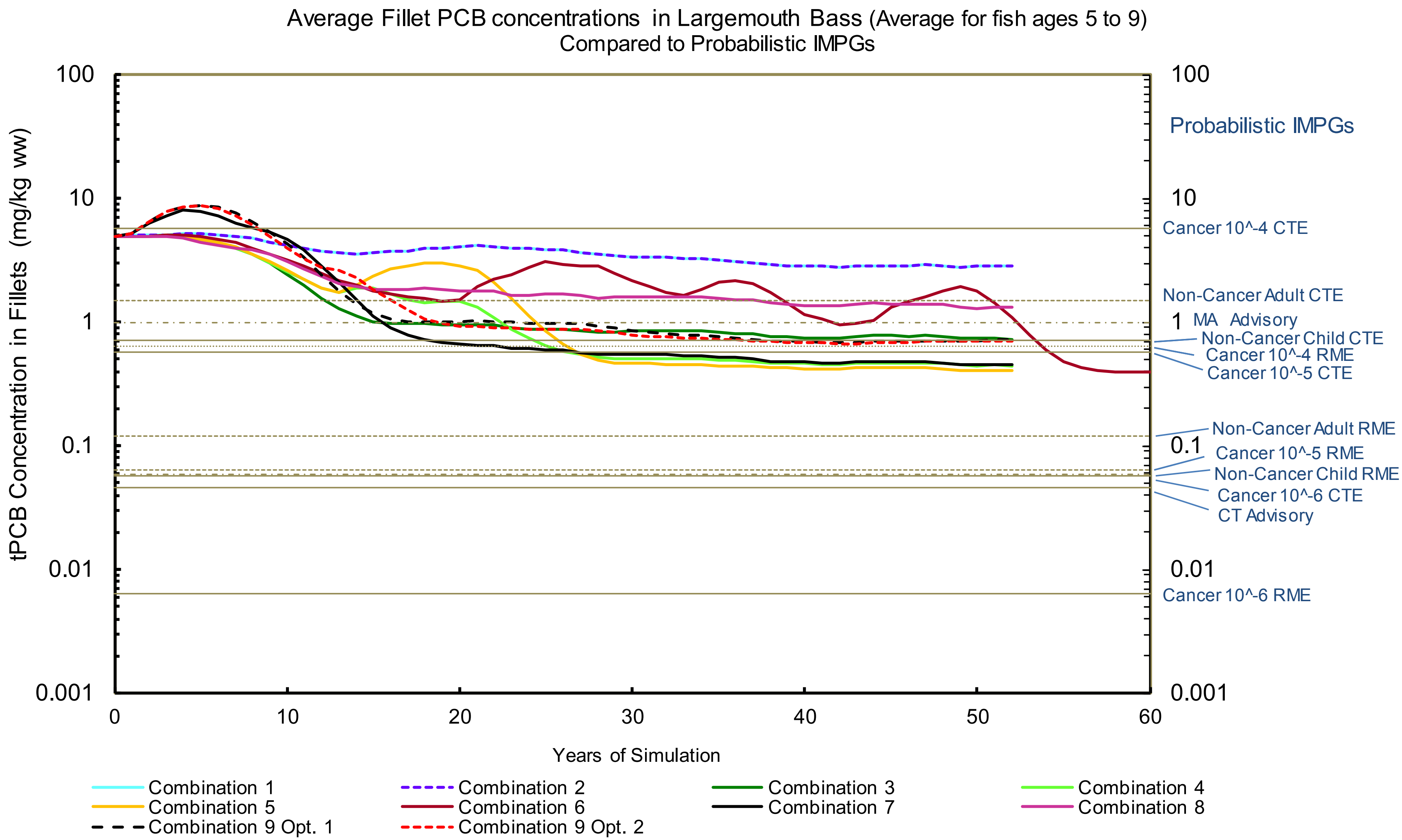
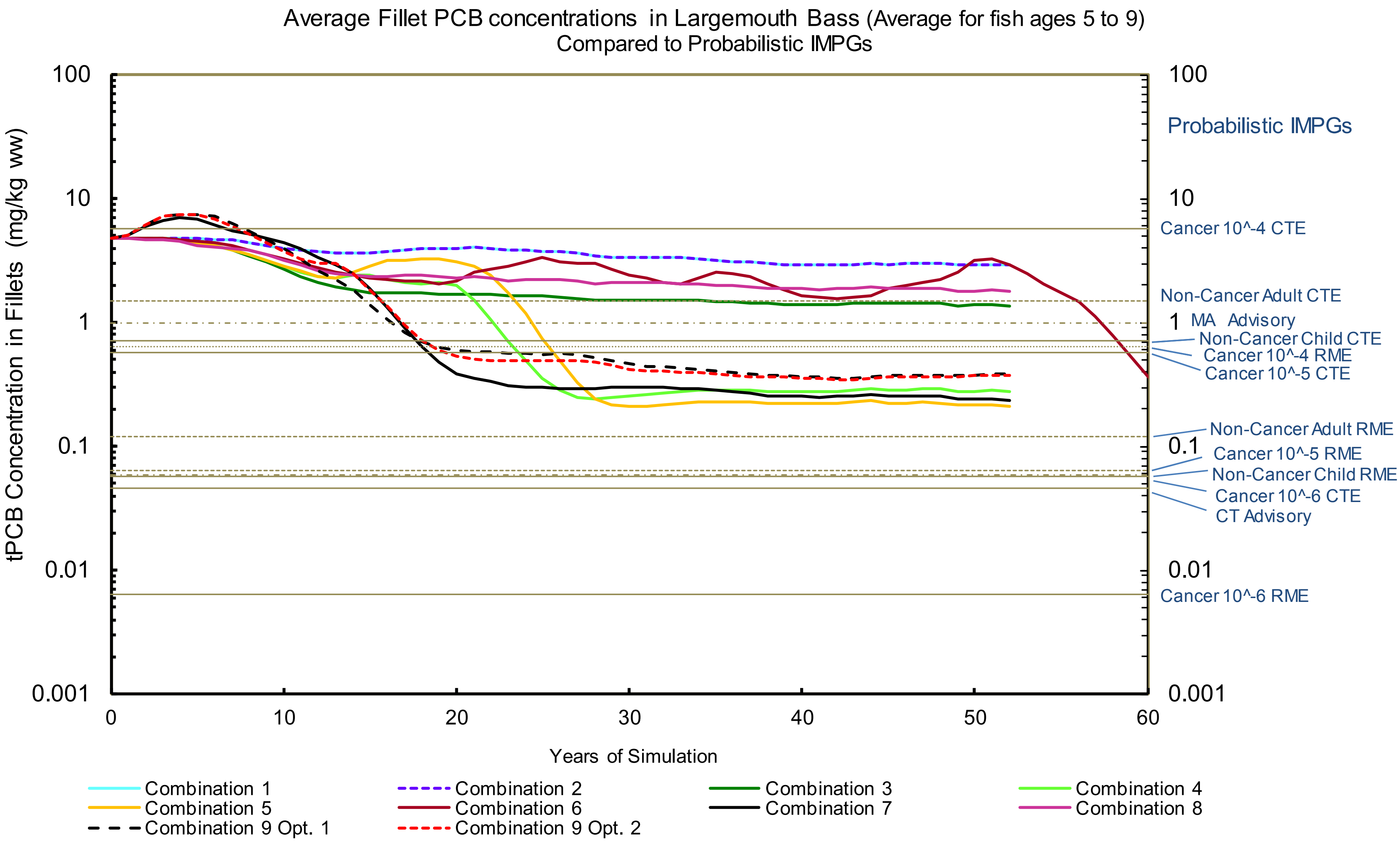
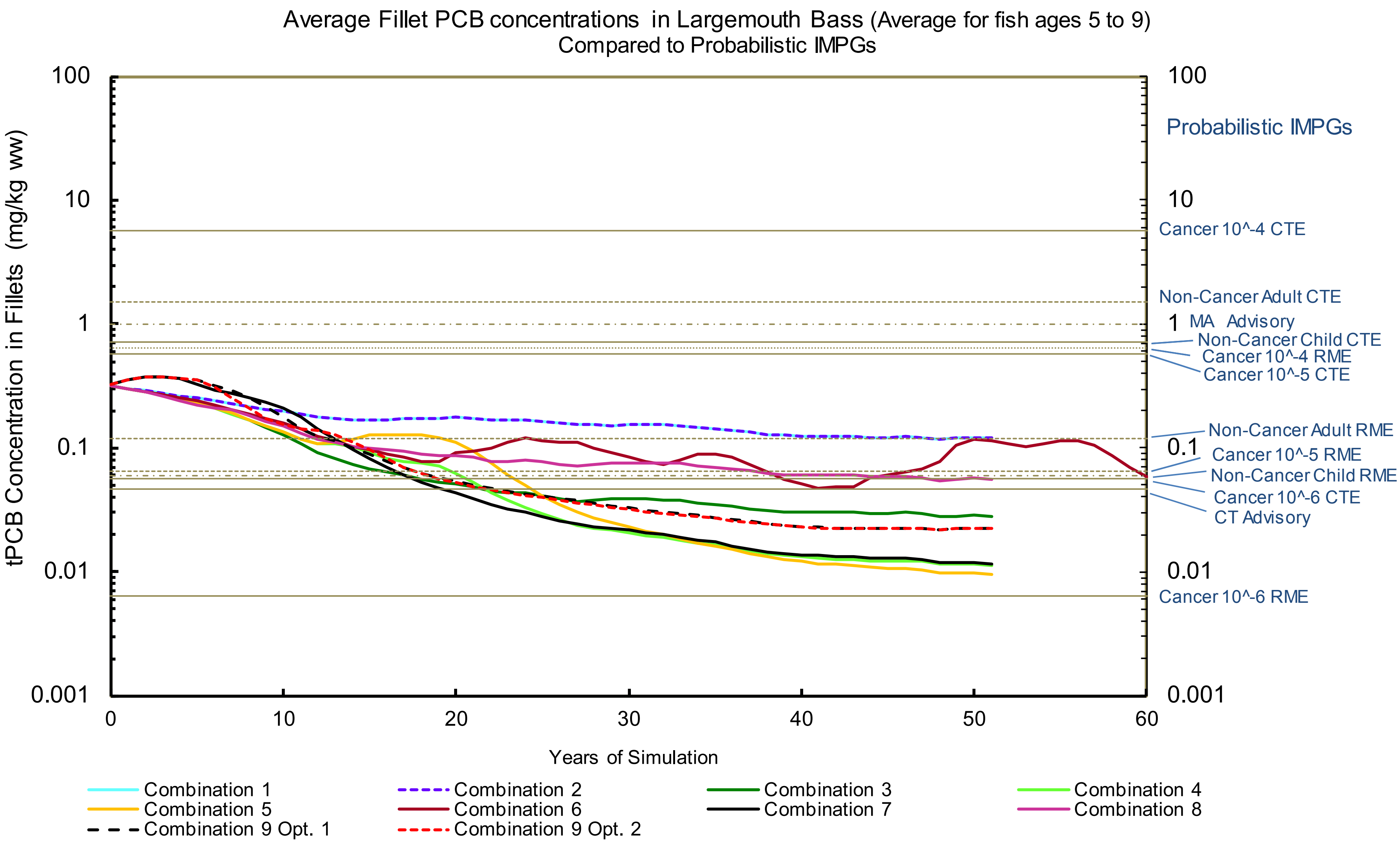


Largemouth Bass, Reach 7H, Probabilistic IMPGs



Largemouth Bass, Reach 8, Probabilistic IMPGs



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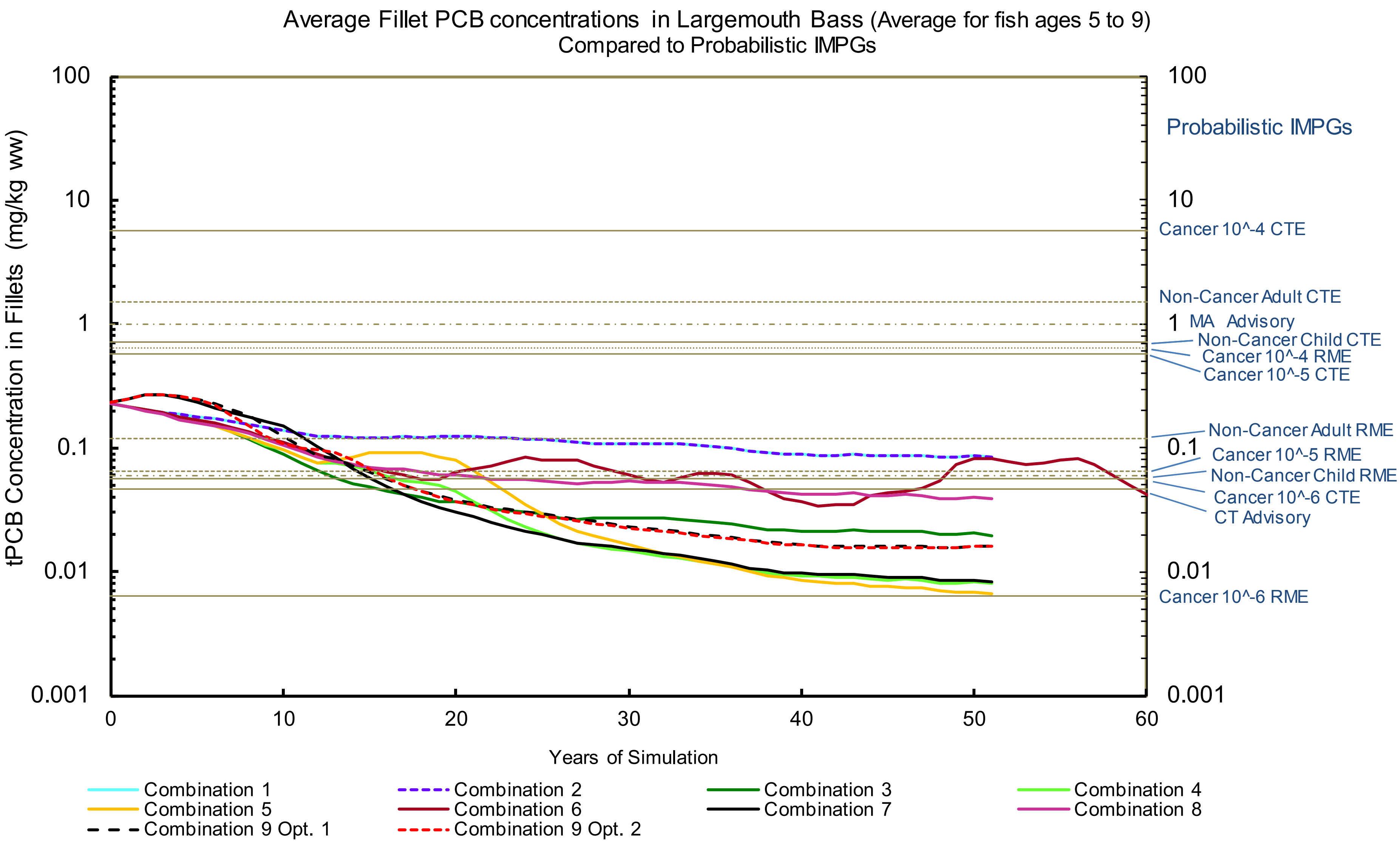
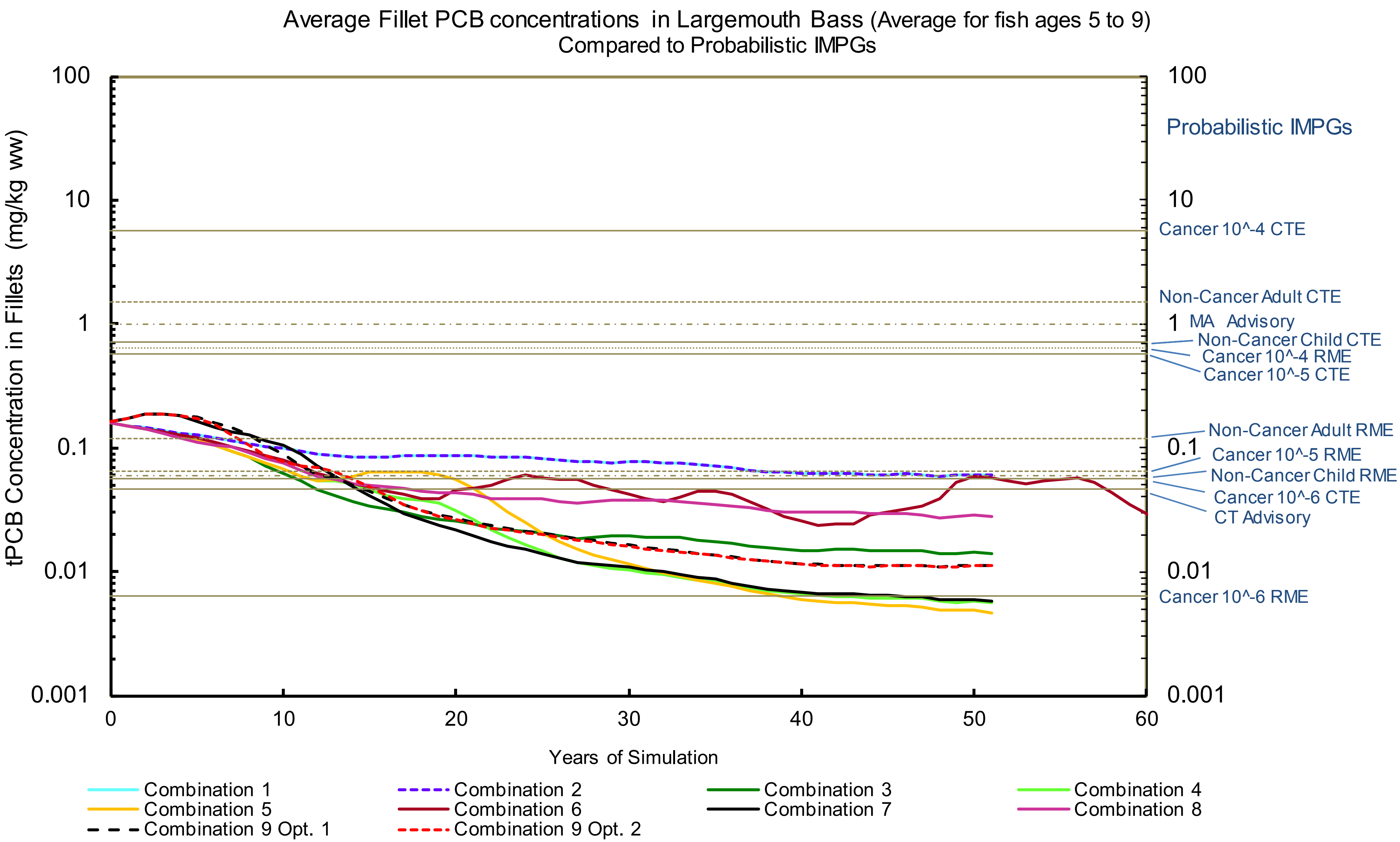


Largemouth Bass, Lake Lillinonah, Probabilistic IMPGs



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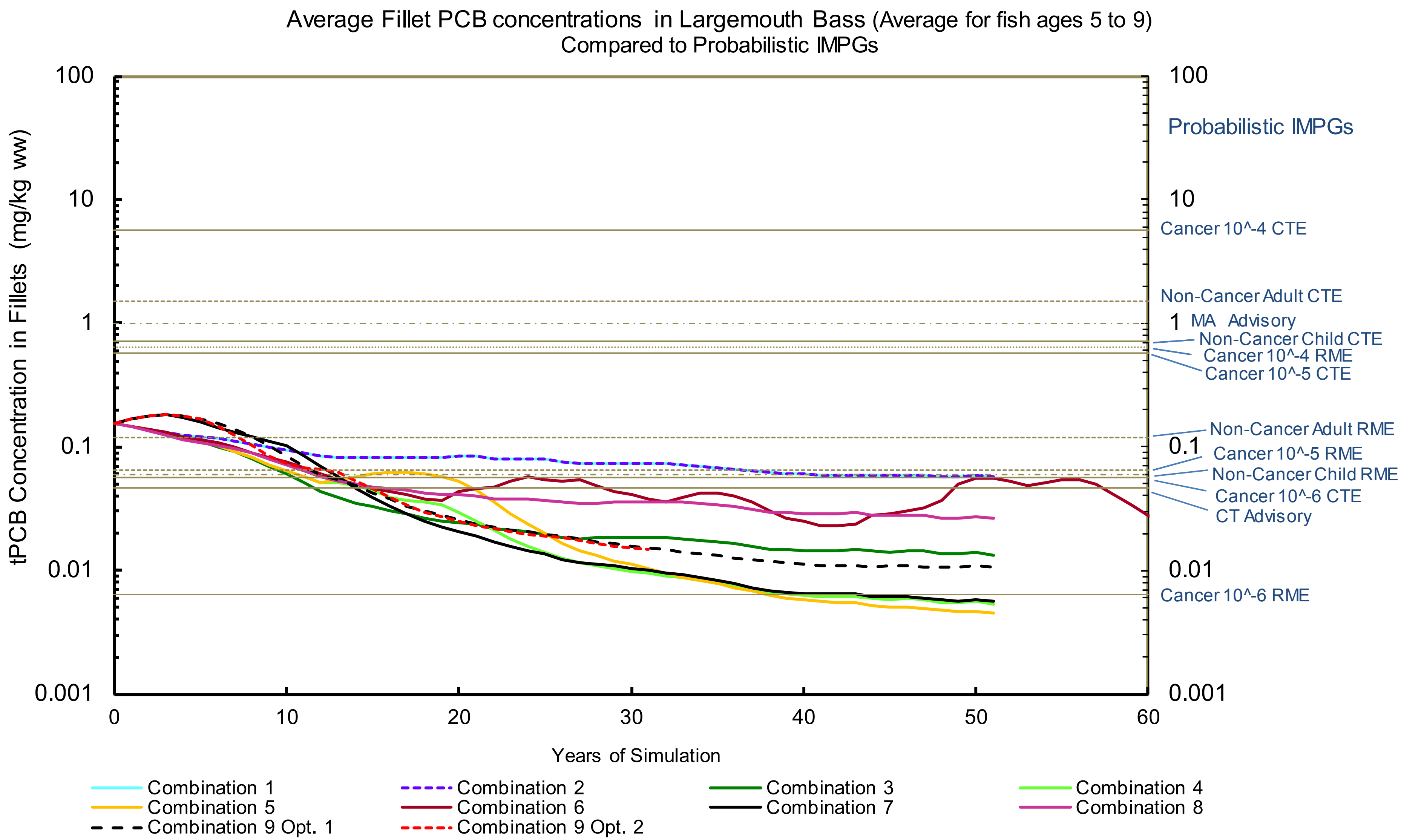
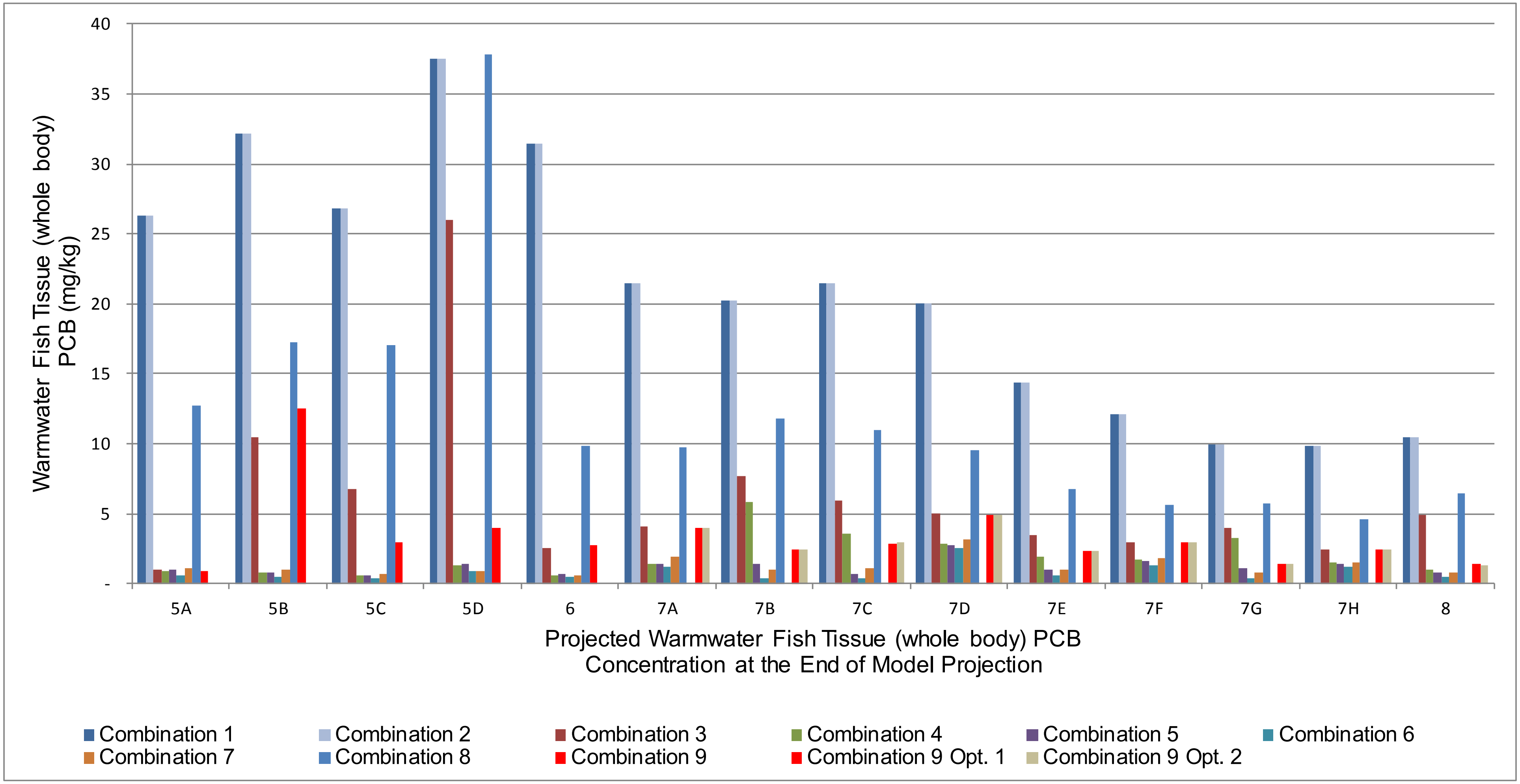
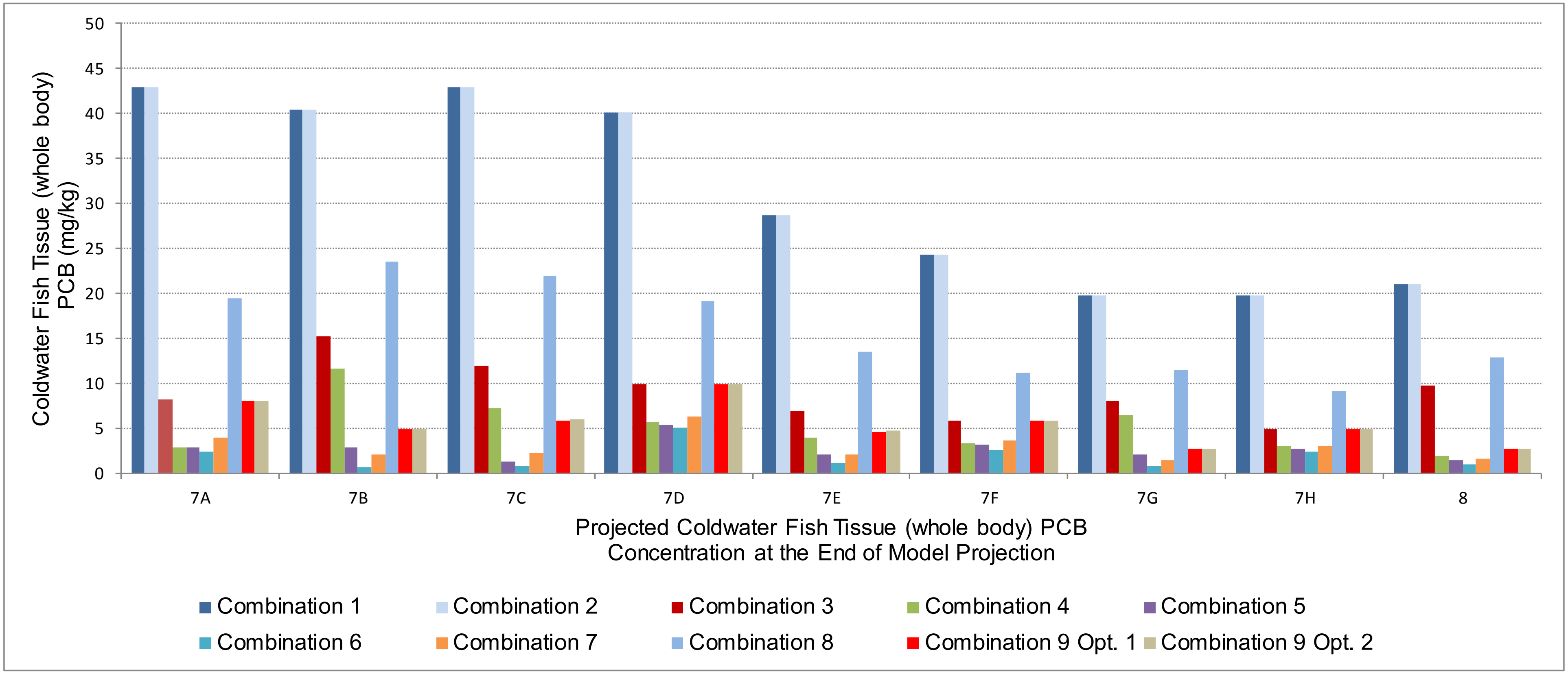


Largemouth Bass, Lake Housatonic, Probabilistic IMPGs



Warmwater Metric

Fish tissues are averaged LMB age class 1 to 10 as specified on page 3-55 of the revised CMS.



Coldwater Metric

Fish tissues are averaged LMB age class 1 to 10 multiplied by 2 as specified on page 3-55 of the revised CMS.

Reach	Combination 1	Combination 2	Combination 3	Combination 4	Combination 5	Combination 6	Combination 7	Combination 8	Combination 9 Opt. 1	Combination 9 Opt. 2
Fish PCB Concentration (mg/kg wet weight)										
Reach 5A	7.44	7.44	0.27	0.26	0.27	0.17	0.32	3.53	0.26	0.26
Reach 5B	8.99	8.99	2.92	0.22	0.22	0.14	0.26	4.80	3.48	3.48
Reach 5C	7.37	7.37	1.85	0.16	0.17	0.12	0.18	4.69	0.82	0.82
Reach 5D	10.31	10.31	7.38	0.36	0.38	0.26	0.23	10.64	1.10	1.10
Reach 6	8.64	8.64	0.69	0.17	0.18	0.14	0.15	2.90	0.74	0.74
Reach 7A	6.03	6.03	1.17	0.40	0.40	0.35	0.56	2.74	1.12	1.12
Reach 7B	5.56	5.56	2.10	1.60	0.39	0.10	0.29	3.22	0.67	0.67
Reach 7C	6.03	6.03	1.69	1.02	0.19	0.12	0.31	3.09	0.81	0.83
Reach 7D	5.60	5.60	1.40	0.81	0.76	0.71	0.88	2.67	1.37	1.38
Reach 7E	4.00	4.00	0.99	0.55	0.29	0.17	0.29	1.90	0.64	0.66
Reach 7F	3.38	3.38	0.82	0.47	0.44	0.37	0.51	1.56	0.82	0.82
Reach 7G	2.66	2.66	1.08	0.88	0.29	0.11	0.21	1.54	0.38	0.37
Reach 7H	2.73	2.73	0.70	0.43	0.39	0.35	0.43	1.27	0.69	0.69
Reach 8	2.82	2.82	1.31	0.27	0.20	0.13	0.23	1.74	0.37	0.37
BBD	0.113	0.113	0.035	0.018	0.016	0.014	0.011	0.020	0.022	0.022
LL	0.080	0.080	0.025	0.013	0.011	0.010	0.008	0.014	0.015	0.015
LZ	0.056	0.056	0.017	0.009	0.008	0.007	0.006	0.010	0.011	0.011
LH	0.054	0.054	0.017	0.009	0.008	0.007	0.005	0.010	0.010	0.010

Modeled Subreach Average Fish (Fillet) PCB Concentrations at End of Project Period

(Compare Revised CMS Table 8-3)

- Average of largemouth bass fish ages 5-9;
- Model endpoint concentrations after projection (autumn average);
- Whole body concentrations divided by a factor of 5.0 to convert to fillet basis.

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).

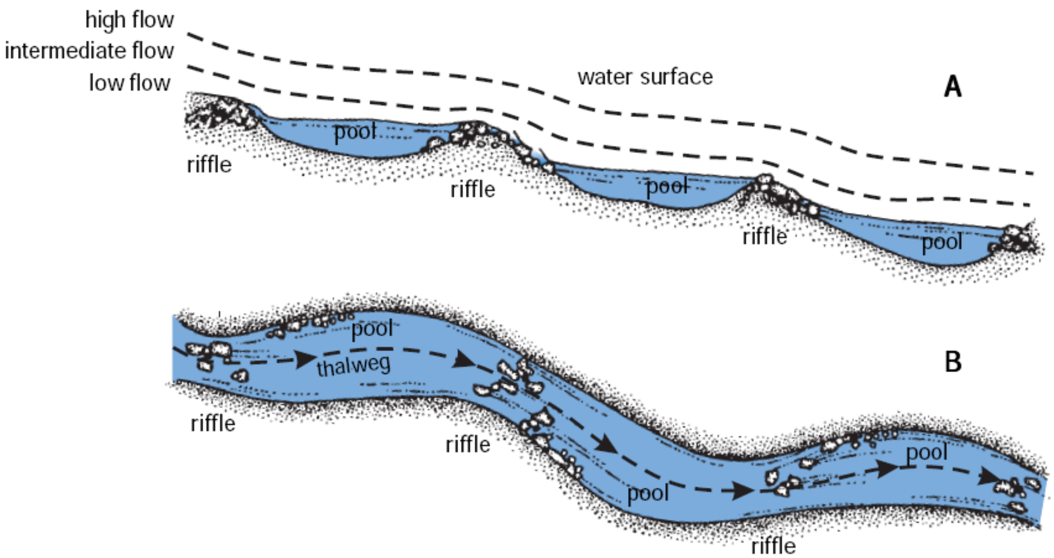

Figure 3: (A) Bed and Water Surface Slope at Baseflow and Stormflow; (B) Riffle/Pool Sequence

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.

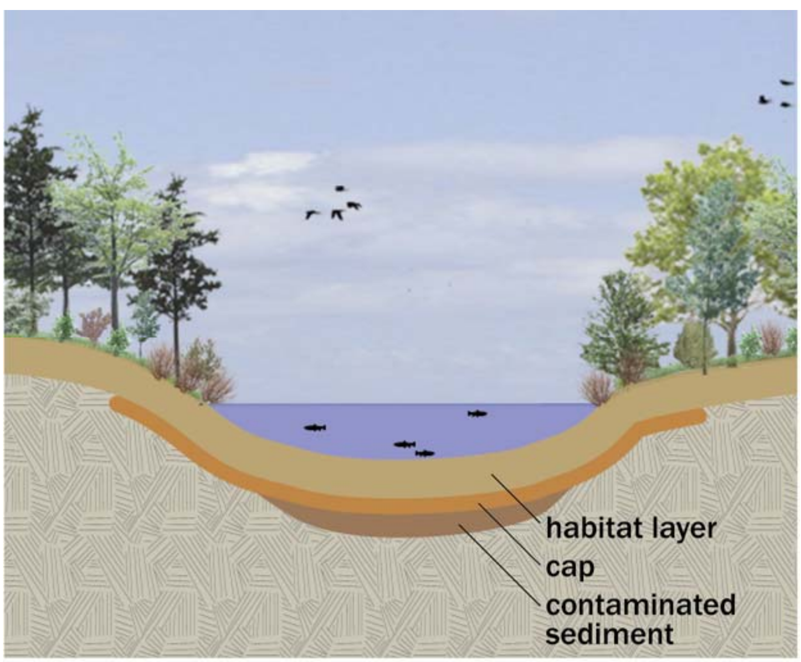

Figure 4: Riffle Cross Section

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.

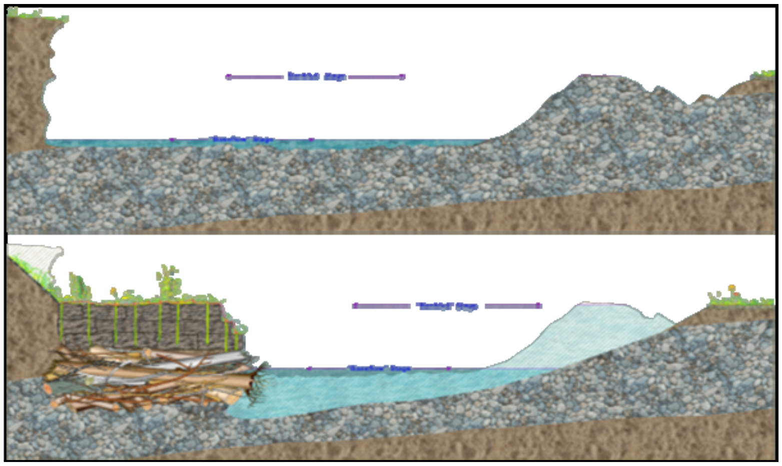

Figure 5: Woody Debris Toe Protection Detail (courtesy of Wildland Hydrology)

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.

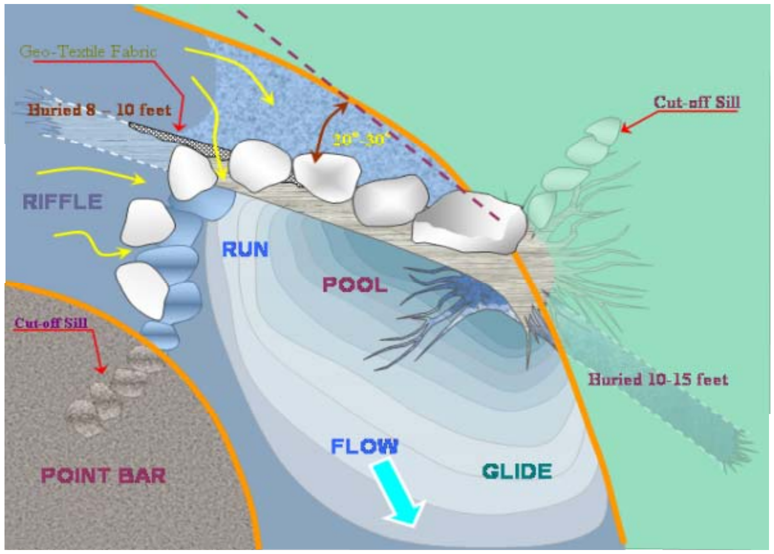

Figure 7: J-Hook Log Vane (courtesy of Wildland Hydrology)

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.

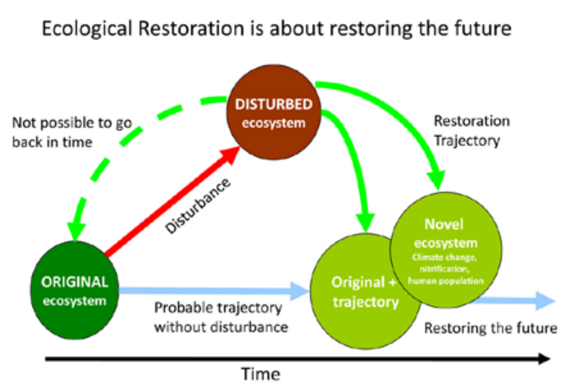
2. ECOLOGICAL RESTORATION

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.

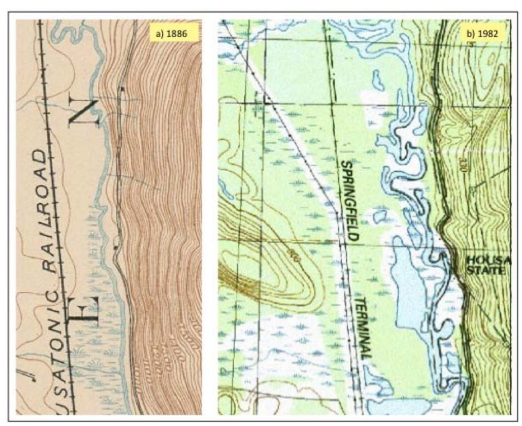
3. Resiliency is increased: the river ecosystem is more self-sustaining than before.

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.

Boulder Bank Protection - Courtesy of Stantec

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).

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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ATTACHMENT 13
ARAR TABLES FOR SED 9/FP 4 MOD

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
CHEMICAL-SPECIFIC ARARs				
Federal ARARs				
Clean Water Act, National Recommended Water Quality Criteria for PCBs	National Recommended Water Quality Criteria: 2002, EPA-822-R-02-047, USEPA, Office of Water, Office of Science and Technology (Nov. 2002)	Freshwater chronic aquatic life criterion (based on protection of mink): 0.014 ug/L. Human health criterion based on human consumption of water and organisms: 0.000064 ug/L.	Relevant and appropriate	The freshwater chronic aquatic life criterion of 0.014 ug/L will be met by the proposed alternative. Regarding the human health criterion based on human consumption of water and organisms of 0.000064 ug/L: In Massachusetts, the criterion is being waived on the grounds that achievement of this ARAR is technically impracticable, given that based on current data, it is not predicted to be met by this or any sediment alternative in Massachusetts. As a modified Performance Standard for this waived criterion, the remedy will be required to meet the Biota Performance Standard and Downstream Transport Performance Standards in the Permit. (For purposes of this Attachment 13, “remedy” includes the corrective measures, remedial design and remedial action activities, and operation and maintenance activities undertaken pursuant to the Modification to the RCRA Permit.) In Connecticut, the remedy is intended to meet the standard. Current modeling shows the remedy will achieve attainment in at least 3 of the 4 Connecticut impoundments. However, the results from the Connecticut model are very uncertain due to the empirical, semi-quantitative nature of the analyses. As such, it is not possible to predict with certainty attainment or lack of attainment of the human health criterion based on human consumption of water and organisms of 0.000064 ug/L in Connecticut (Reaches 10-16). Thus, EPA does not believe that there is a basis to waive this criterion at this time.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
				In addition, this concentration (0.000064 ug/L) cannot be reliably measured using available analytical techniques. Until analytical techniques are available to measure to this concentration, the lowest available detection limit will be used to measure progress toward this standard over time throughout the Housatonic River.
State ARARs				
Numeric Massachusetts Water Quality Criteria for PCBs - Massachusetts Surface Water Quality Standards	314 CMR 4.05(5)(e)	Same as federal water quality criteria	Relevant and appropriate	Same as federal standard, see above.
Numeric Connecticut Water Quality Criteria for PCBs	Connecticut Water Quality Standards, Section 22a-462-1 to 22a-462-9	Same as federal water quality criteria	Relevant and appropriate	Same as federal standard, see above.
Connecticut Remediation Standards Regulations, Direct Exposure Criteria for Soil	Conn. Gen. Stat. 22a-133k-1 through k-3 Appendix A	Establishes soil cleanup standards, including those for residential or unrestricted use ("Residential Criteria").	Potentially applicable	Performance Standards based upon unrestricted use or residential use in Connecticut are based upon the Residential Direct Exposure Criteria.
To Be Considered				
Cancer Slope Factors (CSFs)	EPA Integrated Risk Information System	Guidance values used to evaluate the potential carcinogenic hazard caused by exposure to PCBs.	To be considered	CSFs used to compute the individual cancer risk resulting from exposure to carcinogens in site media.
Reference Doses (RfDs)	EPA Integrated Risk Information System	Guidance values used to evaluate the non-cancer hazards associated with exposure to PCBs.	To be considered	RfDs used to characterize human health risks due to non-carcinogens in site media.

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Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
PCBs: Cancer Dose Response Assessment and Application in Environmental Mixtures (EPA, 1996).	EPA/600/P-96/001F (National Center for Environmental Assessment, Office of Research and Development, September 1996)	Guidance describing EPA's reassessment regarding the carcinogenicity of PCBs.	To be considered	The guidance has been used in characterization of site risks.
Guidelines for Carcinogenic Risk Assessment (EPA, 2005)	EPA/630/P-03/001F (EPA Risk Assessment Forum, March 2005)	Framework and guidelines for assessing potential cancer risks from exposure to pollutants and other environmental agents.	To be considered	Guidelines have been used in assessing risks.
Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens	EPA/630/R-03/003F (EPA Risk Assessment Forum, March 2005)	Guidance on issues related to assessing cancer risks associated with early-life exposures, including an adjustment for carcinogens acting through a mutagenic mode of action.	To be considered	Guidance has been used in assessing risks.
Massachusetts Fish Consumption Advisory	Massachusetts Department of Public Health, Freshwater Fish Consumption Advisory List (2007)	Advises that the public should not consume any fish from the Housatonic River from Dalton to Sheffield due to PCBs; also includes frogs and turtles.	To be considered	This advisory will be followed in reference to biota consumption and actions to reduce fish consumption risks, including Institutional Controls.
Massachusetts Waterfowl Consumption Advisory	Massachusetts Department of Public Health, Provisional Waterfowl Consumption Advisory (1999)	Advises that the public should avoid eating all mallards and wood ducks from the Housatonic River and its impoundments from Pittsfield to Rising Pond.	To be considered	This advisory will be followed in reference to waterfowl consumption and actions to reduce waterfowl consumption risks, including Institutional Controls.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Connecticut Fish Consumption Advisory	Connecticut Department of Public Health (CDPH), 2006 Advisory for Eating Fish from Connecticut Water bodies	Establishes advisories on consuming fish from the Housatonic River in Connecticut (above Derby Dam), including Lakes Lillinonah, Zoar and Housatonic, due to PCBs in fish. Advisories vary by species, location and group of consumers, ranging from “do not eat” to “one meal per week.”	To be considered	This advisory will be followed in reference to fish consumption and actions to reduce fish consumption risks, including Institutional Controls.
LOCATION-SPECIFIC ARARs				
Federal ARARs				
Clean Water Act – Section 404 and implementing regulations	33 USC 1344 33 CFR Parts 320-323, 325, 332 (ACOE) 40 CFR Part 230 (EPA)	Under these requirements, no activity that adversely affects a wetland, including vernal pools, shall be permitted if a practicable alternative with less adverse effect on the aquatic ecosystem is available; a discharge cannot cause or contribute to violation of any applicable water quality standard, violate an applicable toxic effluent standard, jeopardize existence of endangered or threatened species; contribute to significant degradation of waters of the U.S. Discharger must take appropriate and practicable steps to minimize potential adverse impacts of the discharge on the aquatic ecosystem. Mitigation/restoration required for unavoidable impacts to resources.	Applicable	Any remedy activities that will alter wetlands, including excavation of contaminated wetland soils and sediments, backfilling and capping, will be conducted in accordance with these standards. (For purposes of this Attachment 13, compliance with ARARs or standards refers to compliance with the substantive requirements, criteria, or limitations of each provision). There is no practicable alternative with lesser effects on the aquatic ecosystem. The remedy will not cause or contribute to violation of any applicable water quality standard, violate an applicable toxic effluent standard, jeopardize existence of endangered or threatened species; contribute to significant degradation of waters of the U.S. Implementation of the remedy will include appropriate and practicable steps to minimize potential adverse impacts of the discharge on the aquatic ecosystem. Mitigation/restoration will be conducted consistent with these regulations.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Floodplain Management and Protection of Wetlands	44 CFR Part 9	Regulation sets forth policy, procedure and responsibilities to implement and enforce Executive Order 11988, Floodplain Management, and Executive Order 11990, Protection of Wetlands.	Applicable	Executive Orders will be implemented and enforced consistent with the policy, procedure and responsibilities stated in these regulations.
Rivers and Harbors Act of 1899, Section 10	33 USC 403	U.S. Army Corps of Engineers approval is generally required to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of the channel of any navigable water in the U.S.	Applicable	The remedy may alter or modify navigable waters as provided under the Act. Any remedy activities subject to this Act will comply with the substantive requirements of this provision. Remedy will be coordinated with the U.S. Army Corps of Engineers.
Fish and Wildlife Coordination Act	16 USC 662(a) 40 CFR 6.302(g)	Any modification to a body of water requires consultation with the U.S. Fish and Wildlife Service and the appropriate state wildlife agency to develop measures to prevent, mitigate, or compensate for losses to fish and wildlife.	Applicable	This remedy may modify a water body as provided under the Act. Any remedy activities subject to this Act will comply with the substantive requirements. These activities will be coordinated with U.S. Fish and Wildlife Service and other federal and state resource agencies.
Resource Conservation and Recovery Act (RCRA) requirements for hazardous waste facilities in floodplains	40 CFR 264.1(j)(7) 40 CFR 264.18(b)	Remediation waste management sites must be designed, constructed, operated and maintained to prevent washout of any hazardous waste by a 100-year flood, unless procedures are in effect to have waste removed safely before flood waters reach the facility or no adverse effects on human health or the environment will result if washout occurs.	Potentially relevant and appropriate	The remedy does not include disposal pursuant to these regulations, but to the extent that these materials are removed from the Area of Contamination and temporary movement of waste (stockpiling) during remediation occurs, measures will be taken to prevent washout.
National Historic Preservation Act and regulations	16 USC 470f 36 CFR Part 800	A federal agency must take into account the project's effect on properties included or eligible for inclusion in the National Register of Historic Places.	Applicable	If this remedy affects historic properties/structures subject to these requirements, activities will be coordinated with the Department of the Interior (DOI) and conducted in accordance with the substantive requirements of these regulations.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Archaeological and Historic Preservation Act	16 USC 469	When a Federal agency finds, or is notified, that its activities in connection with a Federal construction project may cause irreparable loss or destruction of significant scientific, prehistorical, historical, or archeological data, such agency shall notify DOI. Such agency may request DOI to undertake the preservation of such data or it may undertake such activities. If DOI determines that such data is significant and is being or may be irrevocably lost or destroyed, it is to conduct a survey and other investigation of the areas which are or may be affected and recover and preserve such data which are not being, but should be, recovered and preserved in the public interest.	Applicable	If during remedial design or remedial action, it is determined that this remedy may cause irreparable loss or destruction of significant scientific, prehistorical, historical, or archaeological data, EPA will notify DOI and comply with the substantive requirements in this statute.
Executive Order 11988 (Floodplain Management)	Executive Order	Federal agencies are required to avoid impacts associated with the occupancy and modification of a floodplain and avoid support of a floodplain development whenever there is a practicable alternative.	To be considered	In the remedy, activities will be performed in the floodplain. All activities will be conducted to ensure that they do not result in occupancy and modification of the floodplain.
Executive Order 11990 (Protection of Wetlands)	Executive Order	Federal agencies are required to avoid adversely impacting wetlands unless there is no practicable alternative and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use.	To be considered	Activities subject to this Executive Order will be conducted in accordance with the substantive requirements of these standards.
Endangered Species Act and Regulations	16 USC 1536(a)-(d) 40 CFR 6.302(h) 50 CFR Part 402, Subparts A&B	Must identify whether threatened or endangered (T&E) species or critical habitat is affected by proposed action, or take mitigation measures so that action does not affect species/habitat.	Applicable	These provisions will be complied with in regard to federally-listed threatened or endangered species and their critical habitat.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
State ARARs				
Massachusetts Waterways Law and Regulations	MGL Ch. 91 310 CMR 9.00	Regulates construction, placement, excavation, alteration or removal of fill or structures in waterways below the high water mark.	Applicable	This remedy includes construction, placement, excavation, alteration and removal activities in the Housatonic River. Measures undertaken will meet the substantive environmental standards and limit impacts.
Massachusetts Clean Water Act – Water Quality Certification Regulations	314 CMR 9.01-9.08	For discharge of dredged or fill material: (a) no discharge is permitted if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences; (b) no discharge is permitted unless appropriate and practicable steps have been taken which will avoid and minimize potential adverse impacts to bordering or isolated vegetated wetlands or land under water; (c) no discharge to Outstanding Resource Waters, other than specified exceptions; (d) no discharge without a variance to particular Outstanding Resource Waters listed in 9.06(4), including certain vernal pools; (e) stormwater to be controlled with best management practices; (f) no discharge shall be permitted in rare circumstances where the activity will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters.	Applicable	The remedy includes discharge of dredged or fill material and dredging and dredged material management. All activities subject to these requirements will be conducted in accordance with these regulations.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
		For dredging and dredged material management; (a) no dredging is allowed if there is a practicable alternative that would have less impact on the aquatic ecosystem; (b) appropriate and practicable steps must be taken to avoid, minimize or mitigate adverse effects on land under water; (c) dredging must be conducted to meet performance standards designed to minimize impacts on aquatic ecosystem and protect human health; and (d) placement of dredged material in an intermediate facility for sediment management prior to disposal or reuse must meet certain requirements.		
Massachusetts Wetlands Protection Act and Regulations	MGL c. 131, section 40 310 CMR 10.01-10.10, 10.51-10.60	These requirements govern removal, dredging, filling or altering of banks, riverfront areas, inland wetlands, land subject to flooding and other areas, including provisions on limited projects.	Applicable	Any remedy activities that remove, dredge, fill, or alter such areas will be conducted in accordance with these standards.
Massachusetts Dam Safety Standards	302 CMR 10.00	Regulations govern design and construction of new and existing dams, and removal of existing dams, and inspection of dams.	Potentially applicable	To the extent that these regulations are applicable to a Massachusetts dam which is in the area of remedy activity, the remedy will comply with these regulations.
Massachusetts Facility Location Standards	310 CMR 30.700 990 CMR 5.04	Location standards for hazardous waste management facilities in floodplains, including, but not limited to, Land Subject to Flooding and Areas of Critical Environmental Concern.	Potentially applicable or potentially relevant and appropriate	To the extent that non-PCB State hazardous waste is temporarily stockpiled in an area subject to these regulations within the Area of Contamination, the remedy will comply with these requirements. To the extent that the remedy requires activity outside the Area of Contamination in an area subject to these regulations and remaining on-site that requires temporary storage or treatment of hazardous waste, it would be conducted such that it would comply with these requirements.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Massachusetts Site Suitability Criteria	310 CMR 16.40(3)(4)	Site suitability criteria for solid waste facilities	Potentially applicable	To the extent that solid waste is managed outside the Area of Contamination but remaining on-site, the remedy will comply with these requirements.
Massachusetts Historical Commission Act and Regulations	MGL c. 9, section 27C 950 CMR 71.07	If a project has an area of potential impact that could cause a change in the historical, architectural, archaeological, or cultural qualities of a property on the State Register of Historic Places, these provisions establish a process for notification, determination of adverse impact, and evaluation of alternatives to avoid, minimize or mitigate such impacts.	Relevant and appropriate	If such properties are present in the area of remedy activities, the remedy will comply with these requirements.
Massachusetts Endangered Species Act (MESA) and Regulations	MGL c. 131A 321 CMR 10.00, Parts I, II, and V. 321 CMR 10.00, Part IV	A proposed activity in mapped Priority Habitat for a state-listed rare, threatened, endangered species or species of special concern, or other area where such a species has occurred may not result in a "take" of such species, unless it has been authorized for conservation and management purposes that provide a long-term net benefit to the conservation of the affected state-listed species. Projects that will alter a designated Significant Habitat must be reviewed to ensure that they will not reduce the viability of the habitat to sustain an endangered or threatened species.	Applicable	The remedy will take place in priority habitat for one or more state-listed species. In implementing the remedy, impacts to state-listed species and their habitats will be avoided or minimized wherever possible. The processes outlined as part of the remedy for work in Core Habitat areas were developed in consultation with the Commonwealth and will satisfy these requirements. To the extent that unavoidable impacts result in a take of state-listed species, a conservation and management plan providing for a long-term net benefit to the affected state-listed species will be implemented. In a July 31, 2012 letter to EPA, the MA National Heritage and Endangered Species Program identified those state-listed species potentially affected in the project area. Note that since that date, Massachusetts has delisted particular species; in design and implementation of the remedy, EPA, in consultation with MA, will use the then-current listing of State-listed species.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
				There are no designated Significant Habitats in the remedy area. To the extent that a Significant Habitat is designated in the remedy area, this provision will be complied with.
Massachusetts Area of Critical Environmental Concern (ACEC)	301 CMR 12.00	Provides for establishment of Areas of Critical Environmental Concern in the State	Applicable	An ACEC has been established in part of the Rest of River area. The remedy takes this designation into account.
Connecticut Dam Safety Regulations	CGS 22a-401 to 22a-411 Conn. Agencies Regs. Section 22a-409-2.	Regulations govern design and construction of new and existing dams, and removal of existing dams, and inspection of dams.	Potentially applicable	To the extent that these regulations are applicable to a Connecticut dam in the area of remedy activity, the remedy will comply with these regulations.
Connecticut Inland Wetlands and Watercourses Act and regulations	CGS 22a-36 et seq. Conn. Agencies Regs. Sec. 22a-39-4	Permit required for activities that remove material from inland wetlands or watercourses; Connecticut Department of Energy and Environmental Protection (CT DEEP) is allowed to issue general permit for minor activities with minimal environmental impacts, defined to include monitoring and sampling.	Potentially applicable	To the extent that the remedy includes activity in Connecticut that removes material from inland wetlands or watercourses, the remedy will comply with this provision.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Connecticut Endangered Species Act	Conn. Gen. Stat. 26-303 through 26-316	Requires state agency to: (a) ensure that any action authorized or performed by it does not threaten the continued existence of a listed endangered or threatened species or result in destruction or adverse modification of habitat essential to such species, unless an exemption is granted; and (b) take all reasonable measures to mitigate any adverse impacts of the proposed action on such species or habitat. Prohibits "taking" of endangered or threatened species, except where State determines that a proposed action would not appreciably reduce likelihood of survival or recovery of the species.	Potentially applicable	To the extent that any remedy activity takes place in Connecticut that is subject to these regulations, the remedy will comply with these regulations.
To Be Considered				
MassDEP Guidance	Dam Removal and the Wetland Regulations, 2007	Provides guidance on permitting issues and review considerations associated with dam removal projects, especially as it relates to the Massachusetts Wetlands Protection Act.	To be considered	To the extent that this guidance is applicable to a Massachusetts dam that is in the area of remedy activity, the remedy will comply with this guidance.
Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA) Guidance	Dam Removal in Massachusetts: A Basic Guide for Project Proponents, 2007	Provides guidance through the initial conceptualization of a project, the feasibility studies, and the permitting process.	To be considered	To the extent that this guidance is applicable to a Massachusetts dam that is in the area of remedy activity, the remedy will comply with this guidance.
Massachusetts Department of Fish and Game Guidance	Impounded Sediment and Dam Removal in Massachusetts: A Decision-Making Framework Regarding Dam Removal and Sediment Management. 2003	Provides guidance on a decision-making framework regarding dam removal and in-stream management options for impounded sediment.	To be considered	To the extent that this guidance is applicable to a Massachusetts dam in the area of remedy activity, the remedy will comply with this guidance.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
ACTION-SPECIFIC ARARs				
Federal ARARs				
Toxic Substances Control Act (TSCA) Regulations on Cleanup of PCB Remediation Waste	40 CFR 761.50 40 CFR 761.61	General requirements (761.50) and specific options (761.61) for cleanup of PCB Remediation Waste, including PCB-containing sediments and soils. Options include self-implementing provisions (not applicable to sediments) and risk-based approval by EPA. Risk-based approval is pursuant to 40 CFR 761.61(c) and requires demonstration that cleanup method will not pose an unreasonable risk of injury to health or the environment.	Applicable	The remedy will comply with these provisions.
TSCA Regulations on Storage of PCB Remediation Waste	40 CFR 761.50 40 CFR 761.65 40 CFR 761.61(c)	General and specific requirements for storage of PCB Remediation Waste. Regulations include specific provisions for storage of PCB Remediation Waste in piles at the cleanup site or site of generation for up to 180 days (761.65(c)(9)). Also allows for risk-based approval by EPA of alternate storage method (761.61(c)), based on demonstration that it will not pose an unreasonable risk of injury to health or the environment.	Applicable	The remedy will comply with these provisions.
TSCA Regulations on Discharge of PCB-containing Water	40 CFR 761.50(a)(3)	Prohibits discharge of water containing PCBs to navigable waters unless PCB concentration is <3 mg/L or discharge is in accordance with NPDES discharge limits.	Applicable	Any discharge to navigable waters will comply with this provision.
TSCA Regulations on Decontamination	40 CFR 761.79	Establishes decontamination standards and procedures for removing PCBs from water, organic liquids, and various types of surfaces.	Applicable	To the extent the remedy involves decontamination activities, this provision will be complied with.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Clean Water Act and National Pollutant Discharge Elimination System (NPDES) Regulations	33 USC 1342 40 CFR 122 including, but not limited to 122.3(d) and 122.44(a) & (e) 40 CFR 125.1-125.3	These standards include that point source discharge must meet technology-based effluent limitations (including those based on best available technology for toxic and non-conventional pollutants and those based on best conventional technology for conventional pollutants) and effluent limitations and conditions necessary to meet state water quality standards.	Applicable	These standards will be complied with if water from the remedy, such as from dewatering or other processing of sediment and wetland soils, is discharged to surface waters.
Clean Water Act – NPDES Regulations (stormwater discharges)	40 CFR 122.26(c)(1)(ii)(C) 40 CFR 122.44(k)	Best management practices (BMPs) must be employed to control pollutants in stormwater discharges during construction activities.	Applicable	These standards will be complied with during construction activities.
Clean Water Act, National Recommended Water Quality Criteria for PCBs	National Recommended Water Quality Criteria: 2002, EPA-822-R-02-047, USEPA, Office of Water, Office of Science and Technology (Nov. 2002)	Freshwater chronic aquatic life criterion (based on protection of mink): 0.014 ug/L. Human health criterion based on human consumption of water and organisms: 0.000064 ug/L.	Relevant and appropriate	The remedy includes remedial activities within a waterway. All remedial activities will be conducted so as to not contribute to an exceedance of Water Quality Criteria.
RCRA regulations on identification of Hazardous Waste	40 CFR 261	Establishes standards for identifying and listing hazardous waste under RCRA.	Potentially applicable	Under the remedy, testing of wastes subject to removal will take place consistent with these requirements during design/implementation of the remedy.
RCRA regulations for Generators of Hazardous Waste	40 CFR 262.30-33	Pre-transportation requirements for generators of hazardous waste.	Potentially applicable	If RCRA hazardous wastes are identified, and these materials are removed from the Area of Contamination during remedy implementation but remain on-site, the remedy will comply with these requirements.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
RCRA regulations on less-than-90-day Accumulation of Hazardous Waste	40 CFR 262.34	Provides for on-site accumulation of hazardous waste in certain circumstances, provided compliance with other specified requirements.	Potentially applicable	If RCRA hazardous wastes are identified, and these materials are removed from the Area of Contamination during remedy implementation but remain on-site, the remedy will comply with these requirements.
RCRA Hazardous Waste Management Facilities –-General requirements.	40 CFR 264.1(j)	General requirements for hazardous waste management facilities (waste analysis, security, precautions regarding ignition or reaction of wastes, preventing washout of units).	Potentially applicable	If RCRA hazardous wastes are identified, and these materials are removed from the Area of Contamination during remedy implementation but remain on-site, the remedy will comply with these requirements.
State ARARs				
Massachusetts Clean Waters Act – Water Quality Certification Regulations	314 CMR 9.01 -9.08	This includes provisions dealing with discharge of dredged or fill material: (a) no such discharge is allowed if there is a practicable alternative with less adverse impact on aquatic ecosystem; (b) appropriate and practicable steps must be taken to avoid and minimize adverse effects on land under water and on bordering or isolated vegetated wetlands, including 1:1 restoration or replication of such wetlands (unless waived); (c) there must be no discharge that would adversely affect estimated habitat of rare wildlife species under the Wetlands Protection Act or would be to certain designated "Outstanding Resource Waters," including certified vernal pools, unless a variance is obtained; (d) stormwater discharges must be controlled with best management practices (BMPs); and (e) there must be no substantial adverse impacts to physical, chemical, or biological integrity of surface waters.	Applicable	The remedy includes discharge of dredged or fill material and dredging and dredged material management. All activities subject to these requirements will be conducted in accordance with these regulations.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
		For dredging and dredged material management: (a) no dredging is allowed if there is a practicable alternative with less adverse impact on aquatic ecosystem; (b) appropriate and practicable steps must be taken to avoid, minimize, or mitigate adverse effects on land under water; (c) dredging must be conducted to meet performance standards designed to minimize impacts on the aquatic ecosystem and protect human health; and (d) placement of dredged material in an intermediate facility for sediment management (dewatering, processing, etc.) prior to disposal or reuse must meet certain requirements, including requirements governing method of placement/storage of dredged material and siting criteria.		
Massachusetts Clean Water Act and Wetlands Protection Act – stormwater management standards	310 CMR 10.05(6)(k) 314 CMR 9.06(6)(a)	Projects subject to regulation under the Wetlands Protection Act or that involve discharge of dredged or fill material must incorporate stormwater BMPs to attenuate pollutants in stormwater discharges, as well as to provide a setback from receiving waters and wetlands, in accordance with 10 specified stormwater management standards.	Applicable	The remedy will comply with stormwater requirements.
Numeric Massachusetts Water Quality Criteria for PCBs – Massachusetts Surface Water Quality Standards	314 CMR 4.05(5)(e)	Same as federal water quality criteria	Relevant and appropriate	Same as federal action-specific standard; see above.

Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Massachusetts Hazardous Waste Regulations on Identification and Listing of Hazardous Waste	310 CMR 30.100	Establishes criteria and lists for determining whether a waste is a hazardous waste under state law. Wastes that contain PCBs ≥ 50 mg/kg (which are listed wastes) are exempt from the state hazardous waste management regulations so long as they are managed in compliance with EPA's TSCA regulations (40 CFR Part 761) (see 310 CMR 30.501(3)(a)). The state hazardous waste management regulations also exempt dredged material (even if it constitutes non-PCB state hazardous waste) that is temporarily stored at an intermediate facility (pursuant to 314 CMR 9.07(4)) and managed in accordance with a state water quality certification and §404 requirements under the Clean Water Act (see 310 CMR 30.104(3)(f)).	Applicable	Wastes subject to removal will be tested consistent with these requirements during design/implementation of the remedy. Wastes that contain PCBs at levels greater than or equal to 50 mg/kg will be managed in compliance with EPA's TSCA regulations (40 CFR Part 761). Temporary facilities to manage waste materials will be managed in accordance with the substantive state and federal requirements.
Massachusetts hazardous waste regulations for generators	310 CMR 30.321-324	Pre-transport requirements for generators of hazardous waste	Potentially applicable	To the extent that non-PCB hazardous wastes are identified, and these materials are removed from the Area of Contamination during remedy implementation but remain on-site during remedy implementation, the remedy will comply with these pre-transport requirements.

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Statute/Regulation	Citation[a]	Synopsis of Requirements	Status	Action(s) to be Taken to Achieve ARARs
Massachusetts hazardous waste management – general requirements	310 CMR 30.513, 514, 524, 560	General requirements for hazardous waste management facilities	Potentially applicable	To the extent that non-PCB hazardous wastes are identified, and these materials are removed from the Area of Contamination during remedy implementation but remain on-site during remedy implementation, the remedy will comply with these general requirements.
Massachusetts Hazardous Waste regulations - technical requirements for storage	310 CMR 602, 640, 580, 660.	Requirements related to storage of hazardous waste.	Potentially applicable	To the extent that non-PCB hazardous wastes are identified, and are moved out of the Area of Contamination but remain on-site during remedy implementation, the remedy will comply with the substantive requirements of these regulations.
Massachusetts Air Pollution Control Regulations	310 CMR 7.00	These provisions regulate air emissions, dust, odor, and noise, among other things.	Applicable	Remedy will comply with these provisions.
Connecticut Water Quality Standards for PCBs	Connecticut Water Quality Standards, Section 22a-462-1 to 22a-462-9	Criteria and standards for waters in Connecticut.	Relevant and appropriate	To the extent that remedy activities take place in a Connecticut waterway, such remedy activities will be conducted so as to not contribute to an exceedance of Water Quality Criteria. Remedy activities will contribute to the achievement of the State Water Quality Standards.
To Be Considered				
TSCA PCB Spill Cleanup Policy	40 CFR Part 761, Subpart G	Policy used to determine adequacy of cleanup of spills resulting from the release of materials containing PCBs at concentration of 50 mg/kg or greater.	To be considered	To the extent that such a spill occurs in the remedy, this policy will be considered in the response.

[a]The substantive requirements, including environmental performance standards, contained in the statutes, regulations, and other documents referenced in the column captioned “Citation” shall control to determine the requirements that must be met and the actions to achieve such requirements. Other references in the table that summarize the requirements of or action necessary to achieve ARARs are summary in nature, may not be all-inclusive, and are not controlling.

ATTACHMENT 14
SECTION 404 CWA WETLANDS AND FLOODPLAIN ANALYSIS

GE-Pittsfield/Housatonic River Site - Rest of River
Section 404 (Clean Water Act) Wetlands and Floodplain Analysis

I. Introduction

This analysis focuses on the achievement of project purposes and potential adverse impacts to wetlands and floodplains by alternatives evaluated for purposes of the proposed corrective measures for the Rest of River specified in the Draft Modification to the RCRA Permit. This analysis includes an evaluation of how well each sediment/floodplain and treatment/disposal alternative addresses Section 404 of the Clean Water Act and wetlands/floodplain requirements.

A. Section 404/Wetlands Requirements

Under the Clean Water Act (CWA) § 404(b)(1) Guidelines, no discharge of dredged or fill material is permitted if there is a practicable alternative to the proposed discharge that would have less adverse impacts to the aquatic ecosystem so long as the alternative does not have other significant adverse environmental impacts (40 CFR § 230.10(a)). Under the Wetlands Executive Order 11990, adverse impacts to wetlands must be avoided wherever there is a practicable alternative to address contamination at a site. Wetlands requirements focus on avoiding to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative.

Pursuant to 40 C.F.R. Section 230.3, the term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

B. Floodplain Requirements

Under the Floodplain Executive Order 11988, floodplain requirements focus on avoiding to the extent practical the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative.

Before an alternative that is located in or affects a floodplain can be selected, EPA must look at all of the other options for cleanup and make a determination that there is no practicable alternative to taking this action except for the alternative that impacts the floodplain. For the purpose of this floodplain assessment, floodplain areas are defined as the area of water and land inundated during the highest point of the base, or 100-year, flood using maps prepared by the Federal Insurance Administration of the Federal Emergency Management Agency (Flood Insurance Rate Maps or Flood Hazard Boundary Maps). Should floodplains requirements be applicable, EPA would be required to minimize impacts to the floodplain including addressing flood storage impacts consistent with floodplain requirements.

The river bed contains PCB-contaminated sediment throughout the study area, including Reaches 5A through 5C, Backwaters,, Woods Pond (Reach 6), Reach 7, and Rising Pond (Reach 8). The Rest of River area includes over 900 acres of floodplains within the 1 ppm isopleth, which coincides with an area identified as the 10-year flood elevation pursuant to the Flood Hazard Boundary Maps.

II. Sediment and Floodplain Remediation Alternatives

A. Combination Alternative Analysis

The remedy for the Rest of River will necessarily involve both sediment and floodplain components. In order to more easily explain and compare the alternatives, the individual sediment and floodplain alternatives evaluated in the Corrective Measures Study (CMS) and subsequent evaluations by EPA have been combined into nine comprehensive alternatives for all contaminated material (floodplain soil/sediment). The combined alternatives, listed below, were designed to span the full range of remedial actions in terms of removal volumes, methods, and affected areas:

Combination Alternative 1: SED 1/FP 1 (the “no action” alternative)
Combination Alternative 2: SED 2/FP 1
Combination Alternative 3: SED 3/FP 3
Combination Alternative 4: SED 5/FP 4
Combination Alternative 5: SED 6/FP 4
Combination Alternative 6: SED 8/FP 7
Combination Alternative 7: SED 9/FP 8
Combination Alternative 8: SED 10/FP 9
Combination Alternative 9: SED 9 MOD/FP 4 MOD

A full description of these alternatives can be found in GE’s Revised CMS, EPA’s Comparative Analysis of Alternatives and/or the Statement of Basis for the Proposed Remedial Action. The summaries below are provided for ease of reference, but should not be used as a substitute for the information provided in these other documents.

Combination Alternative 1

Combination Alternative 1 is a combination of Sediment Alternative SED 1 and Floodplain Alternative FP 1. This alternative involves no action in either the sediment or the floodplain.

Combination Alternative 2

Combination Alternative 2 is a combination of Sediment Alternative SED 2 and Floodplain Alternative FP 1. This alternative involves monitored natural recovery (MNR) in all River reaches (Reaches 5 through 16) and no action in the floodplain.

Combination Alternative 3

Combination Alternative 3 is a combination of Sediment Alternative SED 3 and Floodplain Alternative FP 3. This alternative involves removal of approximately 2 feet of river bed sediment followed by capping in Reach 5A; bank soil removal and stabilization of Reach 5A and 5B river banks; a combination of thin layer capping (often referred to as enhanced MNR or EMNR) and MNR in Reach 5C; thin layer capping/EMNR in Reach 6 (Woods Pond); and, MNR in all other River reaches (Reach 5B, Reach 5 backwaters, and Reaches 7 through 16).

For the floodplain, Combination Alternative 3 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-4} cancer risk or non-cancer risk (whichever is lower) plus additional cleanup to a depth of 3 feet in certain frequently used areas to achieve a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer risk (whichever is lower). This alternative also includes additional floodplain excavation to achieve the less strict ecological risk-based numerical values.

Combination Alternative 3 involves the excavation of approximately 134,000 cubic yards of sediment, 35,000 cubic yards of bank soil and 74,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 44 acres of floodplain area and also includes the capping of 42 acres of river bed after excavation, and 97 acres of thin-layer capping of sediment. This alternative is expected to take 10 years to implement.

Combination Alternative 4

Combination Alternative 4 is a combination of Sediment Alternative SED 5 and Floodplain Alternative FP 4. This alternative involves removal of approximately 2 feet of river bed sediment followed by capping in Reaches 5A and 5B; bank soil removal and stabilization of Reach 5A and 5B river banks; a combination of 2 foot removal followed by capping (in shallower areas) and capping (in deeper areas) in Reach 5C; a combination of thin layer capping/EMNR and MNR in the Reach 5 backwaters; a combination of 1.5 foot removal with capping in shallow areas and capping (without sediment removal) in deeper areas of Reach 6 (Woods Pond); thin layer capping/EMNR in Reach 8 (Rising Pond) and MNR in all other River reaches (Reach 7 and Reaches 9 through 16).

For the floodplain, Combination Alternative 4 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer risk (whichever is lower). This alternative also includes additional floodplain excavation to achieve the less strict ecological risk-based numerical values.

Combination Alternative 4 involves the excavation of approximately 377,000 cubic yards of sediment, 35,000 cubic yards of bank soil and 121,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 72 acres of floodplain area and also includes the capping of 126 acres of river bed after excavation, 60 additional acres of river bed capping in areas not slated for excavation, and 102 acres of thin-layer capping of sediment. This alternative is expected to take 18 years to implement.

Combination Alternative 5

Combination Alternative 5 is a combination of Sediment Alternative SED 6 and Floodplain Alternative FP 4. This alternative involves removal of approximately 2 feet of river bed sediment followed by capping in Reaches 5A, 5B, and 5C; bank soil removal and stabilization of Reach 5A and 5B river banks; one foot removal followed by capping in areas of the Reach 5 backwaters exceeding 50 mg/kg PCBs; 1.5 foot removal with capping in shallow areas and capping (without sediment removal) in deeper areas of Reach 6 (Woods Pond); thin layer capping/EMNR in the Reach 7 impoundments; a combination of thin layer capping/EMNR in shallow areas and capping in deep areas of Rising Pond (Reach 8); and, MNR in all other River reaches (Reach 7 channel and Reaches 9 through 16).

For the floodplain, Combination Alternative 5 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer risk (whichever is lower). This alternative also includes additional floodplain excavation to achieve the less strict ecological risk-based numerical values.

Combination Alternative 5 involves the excavation of approximately 521,000 cubic yards of sediment, 35,000 cubic yards of bank soil and 121,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 72 acres of floodplain area and also includes the capping of 178 acres of river bed after excavation, 45 additional acres of river bed capping in areas not slated for excavation, and 112 acres of thin-layer capping of sediment. This alternative is expected to take 21 years to implement.

Combination Alternative 6

Combination Alternative 6 is a combination of Sediment Alternative SED 8 and Floodplain Alternative FP 7. This alternative involves removal of river bed sediment in Reaches 5A,5B, and 5C, the Reach 5 backwaters, Woods Pond, the Reach 7 impoundments, and Rising Pond to meet a PCB concentration of 1 mg/kg followed by backfill; bank soil removal and stabilization of Reach 5A and 5B river banks; and, MNR in all other River reaches (Reach 7 channel and Reaches 9 through 16).

For the floodplain, Combination Alternative 6 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-6} cancer risk or non-cancer risk (whichever is lower). This alternative also includes additional floodplain excavation to achieve the more strict ecological risk-based numerical values.

Combination Alternative 6 involves the excavation of approximately 2,252,000 cubic yards of sediment, 35,000 cubic yards of bank soil and 121,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 387 acres of floodplain area and also includes the backfill of 351 acres of river bed after excavation. This alternative is expected to take 52 years to implement.

Combination Alternative 7

Combination Alternative 7 is a combination of Sediment Alternative SED 9 and Floodplain Alternative FP 8. This alternative involves removal of approximately 2 feet of river bed sediment followed by capping in Reaches 5A, 5B, and 5C; bank soil removal and stabilization of Reach 5A and 5B river banks; a combination of one foot removal followed by capping or capping without removal in areas of the Reach 5 backwaters exceeding 1 mg/kg PCBs; one to 3.5 foot removal followed by capping in Reach 6 (Woods Pond); one to 1.5 foot removal followed by capping in the Reach 7 impoundments and Rising Pond (Reach 8); and, MNR in all other River reaches (Reach 7 channel and Reaches 9 through 16). This alternative is similar to Combination 9 and differs from the other sediment removal alternatives in that: (1) all sediment removal and capping work, including in Reaches 5A and 5B, would be performed in the "wet" by equipment operating in the river (either on the river bottom or on barges); and (2) removal of the sediment in the Reach 5 backwaters and Reaches 6, 7, and 8 would be performed concurrently with removal activities in the Reach 5 channel. However, capping in those reaches would be delayed, where necessary, until after all the removal/capping activities in Reach 5 have been completed.

For the floodplain, Combination Alternative 7 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer risk (whichever is lower) and additional removal of soils exceeding 50 mg/kg PCBs. This alternative also includes additional floodplain and vernal pool excavation to achieve the more strict ecological risk-based numerical values.

Combination Alternative 7 involves the excavation of approximately 886,000 cubic yards of sediment, 35,000 cubic yards of bank soil and 177,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 108 acres of floodplain area and also includes the capping of 333 acres of river bed after excavation, and 3 additional acres of river bed capping in areas not slated for excavation. This alternative is expected to take 14 years to implement.

Combination Alternative 8

Combination Alternative 8 is a combination of Sediment Alternative SED 10 and Floodplain Alternative FP 9. This alternative involves removal of approximately 2 feet of river bed sediment followed by capping in select areas of Reach 5A and MNR in the remainder of Reach 5A; bank soil removal and stabilization of Reach 5A and 5B river banks; a combination of 2.5 foot removal in areas with PCB concentrations generally greater than 13 mg/kg in the top 6 inches, without subsequent capping or backfilling, and MNR in other areas of the Pond; and MNR in all other River reaches (Reach 5B, Reach 5C, Reach 5 backwaters, and Reaches 7 through 16).

For the floodplain, Combination Alternative 8 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-4} cancer risk or non-cancer risk (whichever is lower) plus additional cleanup to a depth of 3 feet in certain frequently used areas to achieve a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer risk (whichever is lower).

Combination Alternative 8 involves the excavation of approximately 236,000 cubic yards of sediment, 35,000 cubic yards of bank soil and 26,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 14 acres of floodplain area and also includes the capping of 20 acres of river bed after excavation. This alternative is expected to take 5 years to implement.

<u>Combination Alternative 9:</u>

Combination Alternative 9 is a combination of Sediment Alternative SED 9 MOD and Floodplain Alternative FP 4 MOD. Based on certain cap thickness assumptions, this alternative involves removal of approximately 2 to 2.5 feet of river bed sediment followed by capping in Reaches 5A and 5C; bank soil removal and stabilization of PCB-contaminated erodible Reach 5A river banks; excavation of Reach 5B river bed and bank areas exceeding 50 mg/kg PCBs with EMNR (using activated carbon or other additive) for remaining areas of Reach 5B sediment; a combination of one foot removal followed by capping of the Backwaters exceeding 1 mg/kg PCBs, excluding certain high priority habitat areas; one to seven foot removal followed by capping in Reach 6 (Woods Pond); excavation and/or capping to address Reach 7 impoundments, potentially in coordination with dam removal, and excavation of 1 to 1.5 feet of sediment followed by capping in Rising Pond (Reach 8) in areas exceeding 1 mg/kg PCBs,; and, MNR in all other River reaches (Reach 7 channel and Reaches 9 through 16). This alternative is similar to Combination Alternative 7 and differs from the other sediment removal alternatives in that: (1) all sediment removal and capping work, including in Reaches 5A and 5B, would be performed in the "wet" by equipment operating in the river (either on the river bottom or on barges); and (2) removal of the sediment in the Backwaters and Reaches 6, 7, and 8 would be performed concurrently with removal activities in the Reach 5 channel. However, capping in those reaches would be delayed, where necessary, until after all the removal/capping activities in Reach 5 have been completed. It is important to note that the sediment removal depths outlined above, for the most part, were derived based upon certain assumptions on the required cap thicknesses in the various reaches of the river. Specific cap designs and thicknesses will be determined based upon additional evaluations in the future. Thus, the volume estimates for this alternative outlined below could be reduced should a thinner cap be deemed appropriate.

For the floodplain, Combination Alternative 9 involves the removal of one foot of contaminated soil with subsequent backfilling to meet a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer Hazard Index (HI) = 1 (whichever is more protective) while providing for avoidance, minimization, or mitigation of impacts in priority habitat areas for state-listed species of concern (core areas) by establishing a secondary remediation target to meet a human-health based cleanup target based on 10^{-4} cancer risk or non-cancer HI = 1 (whichever is more protective) in high priority habitat areas. This alternative also includes additional cleanup to a depth of 3 feet in certain frequently used areas to achieve a human-health based cleanup target based on 10^{-5} cancer risk or non-cancer HI = 1 (whichever is more protective). This alternative also includes additional vernal pool excavation to achieve the more stringent ecological risk-based cleanup target for amphibians. For vernal pool remediation, three different approaches would be implemented concurrently in an initial subset of vernal pools. These three approaches are conventional excavation and restoration, testing the effectiveness of an amendment such as activated carbon to reduce the bioavailability of PCBs, and completion of a pilot study of an innovative method to address the risks posed by PCBs. Based on the outcome of the remediation and restoration of this initial set of vernal pools, EPA will determine how and where additional vernal pool remediation will occur. In addition, whether or not a vernal pool is located in a core area will also factor into how and when it will be addressed. These approaches will ensure that significant adverse environmental impacts will be minimized while still addressing the risks posed by PCBs in vernal pools. In addition to the phased approach for vernal pools, this alternative also provides for a phased, adaptive management approach to all remediation activities.

Combination Alternative 9 involves the excavation of approximately 890,000 cubic yards of sediment, 25,000 cubic yards of bank soil and 75,000 cubic yards of floodplain soil. This alternative involves the excavation of approximately 45 acres of floodplain area and also includes the capping of approximately 298 acres of river bed after excavation. Pilot studies, Institutional Controls, long-term operation, monitoring, and maintenance are also components of this alternative. This alternative is estimated to take 13 years to implement.

COMPARISON OF COMBINATION ALTERNATIVES

Combination:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	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[1]
Sediment Removal Volume (cubic yards (cy))	0	0	134,000	377,000	521,000	2,252,000	886,000	235,000	890,000
Bank Soil Removal Volume (cy)	0	0	35,000	35,000	35,000	35,000	35,000	6,700	25,000
Sediment Capping after Removal (acres)	0	0	42	126	178	0	333	20	298
Sediment Backfill after Removal (acres)	0	0	0	0	0	351	0	0	0
Sediment Capping without Removal (acres)	0	0	0	60	45	0	3	0	0
Thin Layer Capping (acres)	0	0	97	102	112	0	0	0	0
Floodplain Soil Removal Volume (cy)	0	0	74,000	121,000	121,000	615,000	177,000	26,000	75,000
Floodplain Acres Excavated (acres)	0	0	44	72	72	377	108	14	45
Total Soil/Sediment Volume Removal (cy)	0	0	243,000	533,000	677,000	2,902,000	1,098,000	267,700	990,000
Estimated PCB Mass Removed (pounds)	0	0	21,700	33,300	37,300	94,100	53,100	13,900	46,970
Time to Implement (years)	0	0	10	18	21	52	14	5	13

Note: Monitored Natural Recovery (MNR) is a component of all Combinations Except Combination Alternative 1. 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.
[1]Combination 9 (EPA's Proposed Remedial Action) sediment removal and capping estimates based upon capping of four Reach 7 impoundments, which is one possible outcome of the cleanup approach proposed for these impoundments.

B. Section 404/Wetlands Analysis for Combination Alternatives

For purposes of the Rest of River, contamination is found at unacceptable levels in wetland areas and the Housatonic River. As identified above, EPA has developed alternatives to address contaminated sediment/soil in the river, floodplains, wetlands and vernal pools. Those alternatives that address sediment and floodplain/vernal pool soil rely on a variety of activities that will have impacts and trigger Section 404 requirements, including but not limited to excavation, backfilling, dewatering, and capping. For those areas of the Rest of River where EPA is proposing to perform work, EPA has determined that there is no practicable alternative to doing work in these areas because this is where the contamination is located and, therefore, there are no practicable alternatives to the discharge of dredged or fill material /impact on wetland areas. As a result, EPA must evaluate alternatives to select the least damaging practicable alternative consistent with Clean Water Act requirements.

Combination Alternatives 1 and 2, which are no action and limited action (monitored natural recovery) are not practicable alternatives because they do not reduce the unacceptable risks to human health and the environment, and do not control sources of releases of PCBs. Combination Alternatives 3 through 9 each use different combinations of activities to address sediment and floodplain soil that trigger Section 404 Clean Water Act/wetlands requirements. Of these alternatives, only Combinations 4, 5, 6, 7, and 9 achieve the project purpose of reducing threats to human health to acceptable levels, as demonstrated by the projected reduction in fish tissue concentrations for each alternative and achievement of risk-based cleanup levels in the floodplain. The other alternatives would result in continued unacceptable risk from contamination remaining in the river, vernal pools or floodplain, from biota consumption, direct contact, and from less control of sources of contamination releases.

The amount of sediment and soil removal and thus the amount of wetland area disturbed during construction and associated construction related impacts increase generally incrementally between individual alternatives in Combinations 3 through 6. Combinations 7 and 9 call for a “wet” excavation instead of dry excavation, which reduces the impacts to the floodplain and any wetland areas, and thus is a less intrusive manner of excavation than Combinations 3 through 6 and Combination 8. Combination 9 is generally similar to Combination 7, except that it includes less removal of sediment in Reach 5B of the River, and more removal of sediment from Woods Pond. Combination 8 requires excavation of somewhat more volume of PCBs than Combination 3, but does not rely on thin-layer capping like Combinations 3, 4, and 5, so overall, less sediment is addressed by Combination 8 than most other alternatives. Combinations 8 and 9 also include specific reference to selecting areas of removal to avoid or minimize ecological harm, and Combination 9 also includes the use of adaptive management techniques for addressing vernal pools and an approach to avoid, minimize, and mitigate potential impacts to core habitat areas for state listed threatened and endangered species, which could further avoid or minimize ecological harm.

Among the alternatives that achieve the project purpose, EPA has determined that the least damaging practicable alternative is Combination Alternative 9 followed by Combination Alternative 7. Combination 9 is the least damaging to wetlands because it (along with Combination 7) uses a less intrusive method of sediment remediation, which would reduce impacts to the riverbanks, floodplain, and surrounding areas which may include wetlands. While both of these alternatives minimize adverse impacts, Combination 9 has less impact on the wetlands than Combination 7 because it involves less PCB removal in Reach 5B, and thus less impact to the environment in that subreach. Combinations 7 and 9 both take a "surgical approach" to remediation of wetland, vernal pool and floodplain soils, but in doing so, Combination 9 impacts fewer acres and calls for the removal of fewer acres and cubic yards of PCB-contaminated soil than Combinations 4, 5, 6, or 7 while being strategic in targeting areas for excavation based on a number of factors, including habitat value. The reduced level of removal and targeted approach in Combination 9 will reduce the environmental impact associated with the cleanup construction. Combination 6 would require disturbance of a much larger area than the other alternatives (over 700 acres of river and floodplain, including approximately 270 acres of wetlands outside of the river (floodplain forest wetlands, shrub and shallow emergent wetlands deep marshes and vernal pools)), in order to construct. Combinations 4 and 5 rely, in part, on thin layer capping in certain portions of the river, which raises concerns of sediment stability and future mobilization downstream or onto wetlands/floodplains adjacent to the river. Combinations 4 and 5 would also likely adversely impact more wetlands than Combination 9 because they do not avoid, or minimize any actions in Core Areas.

C. Floodplain Analysis for Combination Alternatives

The Floodplain Executive Order requires EPA to determine if activities proposed include floodplain development that results in modification and occupancy in a floodplain. At this Site, none of the alternatives include modification and occupancy in the floodplain. All active combination alternatives (Combinations 3-9) will require some limited use of the floodplain in order to conduct remedial activities, including construction of temporary haul roads to access portions of the river and floodplain slated for remediation. Temporary roadway construction as well as excavation followed by backfilling would not constitute modification of the floodplain as roads will be temporary and will be removed and floodplain areas restored to their natural state as construction in each area is completed. In addition, excavation followed by backfilling/capping would result in replacement of an equal amount of fill material than what was excavated and, therefore, would not result in a net increase of fill in the floodplain for any of the alternatives. EPA believes it is likely that none of the activities conducted under all the active combination alternatives (Combinations 3-9) will be subject to the Floodplain Executive Order. All of the active combination alternatives will likely require use of temporary staging areas as well as facilities to prepare soils and sediments for disposal. The location for such facilities has not been selected but the focus will be on selecting an area outside the 100 year floodplain, where practical. However, it is possible that temporary staging areas and other facilities could be located within the 100-year floodplain if there is no practicable location available outside the floodplain. As with the temporary roads discussed above, these features would not constitute modification of the floodplain because they will be temporary and will be removed and floodplain areas restored to their natural state as construction in each area is completed. As a result, all activities proposed meet the requirements of the Floodplain Executive Order.
The activities in Combination 9 that affect the floodplain are not permanent, and would be subject to restoration following remediation. EPA will provide specific requirements to address areas such as floodplain that have been impacted by remediation activities. In addition, the

remedy will be designed to minimize impacts on flood storage capacity from cleanup activities within the 100-year floodplain. For example, the engineered cap proposed in Reach 5 of the River will be designed and placed to not decrease flood storage capacity.

Although the focus of the Floodplain Executive Order is on limiting development in a floodplain with a focus on preventing impacts from flooding, EPA also recognizes that floodplains are an important ecological resource in other ways. Taking this into account, from an environmental standpoint, EPA believes that Combination 9 is the most appropriate combination to address unacceptable risks to human health and the environment of the PCB-contaminated soil, while minimizing floodplain impacts. Combinations 1, 2 3, and 8 do not sufficiently reduce risks to human health and the environment. Combinations 4, 5, 6, 7 and 9 provide excavation and/or capping to sufficiently reduce risks to human health and the environment. However, the temporary impacts to the floodplain from Combinations 4, 5, and 6 would be greater than those for Combinations 7 and 9, because Combinations 4, 5, and 6 use dry excavation techniques for sediment removal, which have greater impacts on associated floodplains. Combination 9 is more appropriate than Combination 7 because Combination 9 includes a more measured approach to floodplain remediation as well as a proposed adaptive management approach for addressing PCB contamination in vernal pools.

III. Treatment/Disposal Alternatives

Pursuant to the revised CMS, five treatment/disposal alternatives have been evaluated.

A. Treatment/Disposal Alternatives Analysis

TD 1 /TD 1 RR - Disposal in an off-site permitted landfill or landfills via truck (TD 1) or rail (TD 1 RR);
TD 2 - Disposition in a local in-water Confined Disposal Facility (CDF) or facilities;
TD 3 - Disposition in a local on-site Upland Disposal Facility or Facilities;
TD 4 - Chemical extraction of PCBs from removed sediment/soil; and
TD 5 – Thermal Desorption of PCBs from removed sediment/soil.

Each of the alternatives would include removal of contaminated sediments and soils, to the extent determined for purposes of the Combination Alternatives.

For TD 1/TD 1RR (off-site disposal), there are no wetlands or floodplains impacts associated solely with this disposal option beyond what would occur under a specific set of sediment/floodplain combination alternatives discussed above. TD 2 (disposal in an in-water CDF) would permanently isolate the hydraulically dredged sediment from Reaches 5C and 6. Construction of this facility would result in the discharge of dredged /fill material and/or have adverse impacts on the wetlands and result in occupancy and modification of the floodplain by having a disposal facility be placed in Woods Pond itself or in the backwaters, resulting in a permanent loss of aquatic habitat in a portion of Woods Pond or the backwaters.
TD 3 (on-site landfill disposal) would provide protection of human health and the environment by permanently isolating the PCB-contaminated soil and sediments. The on-site landfill would

be located outside wetlands and floodplain areas and, therefore, not have wetlands/floodplain impacts.

TD 4 (chemical extraction treatment) would, in conjunction with off-site disposal of treated material, provide protection of human health of the environment. However, the long-term effectiveness of chemical extraction is not demonstrated for Housatonic River PCBs, and it would not negate the need for off-site disposal. The footprint of the chemical extraction facility, and associated facilities and structures, if located in wetlands or floodplain, has the potential for effects on wetlands, and occupancy and modification of the floodplain. Thus, such a facility would need to be sited outside of wetland/floodplain areas.

TD 5 (thermal desorption) would reduce PCB concentrations in sediment and soils, followed by on-site reuse and/or off-site disposal of treated materials, and off-site disposal/destruction of liquids containing condensed PCBs. The footprint of the thermal desorption facility, and associated facilities and structures, if located in the wetlands or floodplain, has the potential for effects on wetlands, and occupancy and modification of the floodplain. Thus, such a facility would need to be sited outside of wetland/floodplain areas.

B. Section 404/Wetlands Impacts

Because there is some question as to whether Alternatives TD 4 and TD 5 treat contamination to safe levels, they may not be practicable alternatives. Alternative TD 2 involves the construction of an in-water CDF, which would trigger Section 404/wetlands impacts. There are other practicable alternatives that avoid these impacts. Alternatives TD 1/TD 1RR and TD 3 have no impacts (unlike TD 2) and clearly meet the project purpose (unlike TD 4 and TD 5) and are, therefore practicable alternatives to conducting work in wetland areas.

C. Floodplain Impacts

The Floodplain Executive Order requires EPA to determine as a first step if there is a practicable alternative to floodplain development (modification and occupancy in a floodplain). Because there is some question as to whether Alternatives TD 4 and TD 5 treat contamination to safe levels, they may not be practicable alternatives. Alternative TD 2 involves the construction of an in-water CDF, which would entail occupancy and modification of the floodplain. There are other practicable alternatives that avoid development in the floodplain. Alternatives TD 1/TD 1 RR, and TD 3 can be conducted outside the floodplain (unlike Alternative TD 2) and clearly meet the project purpose (unlike Alternative TD 4 and TD 5) and are therefore practicable alternatives to floodplain development.